YAYASAN BRATA BHAKTI DAERAH JAWA TIMUR
UNIVERSITAS BHAYANGKARA SURABAYA
LEMBAGA PENELITIAN DAN PENGABDIAN PADA MASYARAKAT
(LPPM)
Kampus : Jl. A. Yani 114 Surabaya Telp. 031 - 8285602, 8291055, Fax. 031 - 8285601

SURAT KETERANGAN

Nomor: Sket/ 11 /I/2023/LPPM/UBHARA

Kepala Lembaga Penelitian dan Pengabdian kepada Masyarakat (LPPM) Universitas Bhayangkara Surabaya menerangkan bahwa:

Nama	: Dr. Amirullah, ST, MT.
NIP	: 197705202005011001
NIDN	: 0020057701
Unit Kerja	: Universitas Bhayangkara Surabaya

Benar telah melakukan kegiatan:

1. Menulis jurnal berjudul Transient Power Quality Performance of Multi Photovoltaics using MPPT P and O/MPPT Fuzzy (Amirullah, Agus Kiswantono, Ontoseno Penangsang, dan Adi Soeprijanto), TELKOMNIKA, Vol.16, No.6, December 2018, pp.2967~2979, ISSN: 1693-6930, Publisher: Universitas Ahmad Dahlan (UAD) in collaboration with Institute of Advanced Engineering and Science (IAES), **Terindeks Scopus Q3.**
2. Telah melakukan korespondensi melalui email dalam proses penerbitan jurnal tersebut. Bukti korespondensi email dan bukti pendukung adalah benar sudah dilakukan oleh yang bersangkutan serta sudah dilampirkan bersama surat ini.

Demikian surat keterangan ini dibuat untuk kepentingan kelengkapan pengusulan Guru Besar.

Surabaya, 20 Januari 2023
Kepala LPPM

Drs. Heru Irianto, M.Si.
NIP. 9000028

Lampiran 1

Bukti Korespondensi Email dengan Editor/Pengelola Jurnal

Kode Makalah 9897 Hasil Review Akhir Makalah ICW Telkomnika 2018

Amirullah Ubhara Surabaya <amirullah@ubhara.ac.id>
Kepada: tole@journal.uad.ac.id
Cc: Amirullah Ubhara Surabaya <amirullah@ubhara.ac.id>
Bcc: Amirullah Amirullah <am9520012003@yahoo.com>

19 Juli 2018 pukul 06.10

Yth. Panitia ICW Telkomnika 2018
di tempat

Mohon info hasil review final makalah saya berjudul Transient Power Quality Performance of Multi Photovoltaics using MPPT P and O/MPPT Fuzzy.

Power/Energy Track Kode Makalah: 9897.

Saya mendaftar makalah melalui web ICW Telkomnika 2018 (bukan EDAS).

Demikian atas jawabannya terima-kasih.

Amirullah
PhD Candidate EE ITS Surabaya
Indonesia

Pada 19 Juli 2018 06.08, Amirullah Ubhara Surabaya <amirullah@ubhara.ac.id> menulis:

> Yth. Panitia ICW Telkomnika 2018
> di tempat
>
> Mohon info hasil review final makalah saya berjudul Transient Power Quality Performance of Multi Photovoltaics using MPPT P and O/MPPT Fuzzy.
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>
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>
> Demikian atas jawabannya terima-kasih.
>
> Amirullah
> PhD Candidate EE ITS Surabaya
> Indonesia

Ubhara Surabaya

Amirullah Ubhara Surabaya <amirullah@ubhara.ac.id>

Kode Makalah 9897 Hasil Review Akhir Makalah ICW Telkomnika 2018

Tole Sutikno <tole@journal.uad.ac.id> 4 Agustus 2018 pukul 20.07
Kepada: Amirullah Ubhara Surabaya <amirullah@ubhara.ac.id>, icw.telkomnika@journal.uad.ac.id

Editor
2018-07-22 05:46 AM

Subject: [TELKOMNIKA] Editor Decision
Dear Prof/Dr/Mr/Mrs: Amirullah Amirullah:

We have reached a decision regarding your submission entitled "Transient Power Quality Performance of Multi Photovoltaics using MPPT P and O/MPPT Fuzzy" to International Conference and Workshop on TELKOMNIKA (Telecommunication Computing Electronics and Control) 2018 (ICW TELKOMNIKA 2018).

Our decision is to ACCEPT with minor revisions.
We invite you to present your paper in the ICW TELKOMNIKA 2018 on Sep 18-20, 2018 in Yogyakarta, Indonesia. All presented papers (after revisions based upon feedback at the conference & workshop, if necessary) will be published in the TELKOMNIKA Telecommunication Computing Electronics and Control (a Scopus indexed journal, SCImago Journal Rank (SJR) Q3) as REGULAR issue. All presented papers will be prioritized for publication in our journal, but all submitted papers still will be processed for possible publication if the papers are suitable.

In preparing your final camera ready paper for conference, you should pay attention to:

1. Authors should have made substantial contributions to:

(a) the conception and design of the study, or acquisition of data, or analysis and interpretation of data
(b) drafting the article or revising it critically for important intellectual content

2. Introduction section

Explain the context of the study and state the precise objective
An Introduction should contain the following three parts:
- Background: Authors have to make clear what the context is. Ideally, authors should give an idea of the state-of-the art of the field the report is about.
- The Problem: If there was no problem, there would be no reason for writing a manuscript, and definitely no reason for reading it.
So, please tell readers why they should proceed reading. Experience shows that for this part a few lines are often sufficient.
- The Proposed Solution: Now and only now! - authors may outline the contribution of the manuscript. Here authors have to make sure readers point out what are the novel aspects of authors work. Authors should place the paper in proper context by citing relevant papers. At least, 5 references (recently journal articles) are used in this section.

3. Results and Discussion

The presentation of results should be simple and straightforward in style. This section reports the most important findings, including results analyses as appropriate and comparisons to other research results. This section should be supported suitable references.

4. Conclusion

Your conclusion should make your readers glad they read your paper. Summarize sentences the primary outcomes of the study in a paragraph (NOT in numbering).

5. References and Citations

We usually expect a minimum of 25 and 40 references primarily to recent journal papers for research/original paper and review paper, respectively. Each citation should be written in the order of appearance in the text [1], [2], [3], [4], ... (Sequential order!!)
URGENT: SELF CITATION from same author or group authors is MAX 10%.

6. Paragraph

A paragraph is a sentence or group of sentences that support one main idea. Many authors have presented paragraphs in very long terms. Author should use simple sentences which are grammatically correct, but too many can make your writing less interesting.
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IMPORTANT:

Please register & submit your final camera paper in MS Word file format (or LATEX source files; ZIP your files if you present your final paper in LATEX) through https://s.id/icwtelkomnika2018 within 4 weeks.
Registration fee please refer to https://s.id/22o5m
This fee covers conference, gala dinner, seminar kit, workshop & publication fees on the TELKOMNIKA, but excludes hotel room, transportation & tour.

Payment is by T/T transfer:

Bank Account name (please be exact)/Beneficiary: TOLE SUTIKNO
Bank Name: Bank Central Asia (BCA)
Branch Office: Kusumanegara
City: Yogyakarta
Country :Indonesia
Bank Account #: 8465122249
SWIFT Code: CENAIDJAXXX

I look forward for hearing from you

Thank you

Best Regards,
Assoc. Prof. Dr. Tole Sutikno
General Chair, ICW TELKOMNIKA 2018
Editor-in-Chief, TELKOMNIKA, Scimago Journal Rank (SJR): Q3
email: tole@journal.uad.ac.id

Tentative agenda of the ICW TELKOMNIKA:
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* Sep 18, 2018 (08.00-21.00): International Conference-Keynote Speeches and Parallel Sessions
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____
TELKOMNIKA (Telecommunication Computing Electronics and Control)
http://www.journal.uad.ac.id/index.php/TELKOMNIKA

Editor
2018-07-27 06:25 AM

Subject: [TELKOMNIKA] Editor Decision - (Link for Registration) --> bit.ly/icw-telkomnika2018
--- International Conference and Workshop on TELKOMNIKA (Telecommunication Computing Electronics and Control) 2018
--- September 18-21, 2018 at ROYAL AMBARRUKMO Yogyakarta
--- Jl. Laksda Adisucipto No.81, Ambarukmo, Caturtunggal, Depok, Sleman
--- Yogyakarta 55281, Indonesia

Dear Prof/Dr/Mr/Mrs: Amirullah Amirullah:

We have reached a decision regarding your submission entitled "Transient Power Quality Performance of Multi Photovoltaics using MPPT P and O/MPPT Fuzzy" to International Conference and Workshop on TELKOMNIKA (Telecommunication Computing Electronics and Control) 2018 (ICW TELKOMNIKA 2018).

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IMPORTANT:

Please register & submit your final camera paper in MS Word file format (or LATEX source files; ZIP your files if you present your final paper in LATEX) through bit.ly/icw-telkomnika2018 (registration form) or goo.gl/q7Hjx3 (registration form) as soon.

Conference fee please refer to bit.ly/icw-poster or goo.gl/3WJWFp
Batch I (for latest papers submission: May 1, 2018)
- Early Bird deadline: Jul 30, 2018
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Payment is by T/T transfer:

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Bank Name: Bank Central Asia (BCA)
Branch Office: Kusumanegara
City: Yogyakarta
Country :Indonesia
Bank Account #: 8465122249
SWIFT Code: CENAIDJAXXX

I look forward for hearing from you

Thank you

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General Chair, ICW TELKOMNIKA 2018
Editor-in-Chief, TELKOMNIKA, Scimago Journal Rank (SJR): Q3
email: tole@journal.uad.ac.id

Tentative agenda of the ICW TELKOMNIKA:

--- September 18-21, 2018 at Royal Ambarrukmo Yogyakarta
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TELKOMNIKA (Telecommunication Computing Electronics and Control)
http://www.journal.uad.ac.id/index.php/TELKOMNIKA

2018-07-19 6:10 GMT+07:00 Amirullah Ubhara Surabaya <amirullah@ubhara.ac.id>:

> Yth. Panitia ICW Telkomnika 2018
> di tempat
>
> Mohon info hasil review final makalah saya berjudul Transient Power Quality Performance of Multi Photovoltaics using MPPT P and O/MPPT Fuzzy.
>
> Power/Energy Track Kode Makalah: 9897.
>
> Saya mendaftar makalah melalui web ICW Telkomnika 2018 (bukan EDAS).
>
> Demikian atas jawabannya terima-kasih.
>
> Amirullah
> PhD Candidate EE ITS Surabaya
> Indonesia
>
> Pada 19 Juli 2018 06.08, Amirullah Ubhara Surabaya <amirullah@ubhara.ac.id> menulis:
>
>> Yth. Panitia ICW Telkomnika 2018
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Demikian atas jawabannya terima-kasih.

Amirullah
PhD Candidate EE ITS Surabaya
Indonesia

Ubhara Surabaya

Amirullah Ubhara Surabaya <amirullah@ubhara.ac.id>

[TELKOMNIKA] Editor Decision - (Link for Registration) --> bit.ly/icw-telkomnika2018

icw.telkomnika@journal.uad.ac.id <icw.telkomnika@journal.uad.ac.id> 6 Agustus 2018 pukul 15.11
Kepada: amirullah@ubhara.ac.id

--- International Conference and Workshop on TELKOMNIKA (Telecommunication Computing Electronics and Control) 2018
--- September 18-21, 2018 at ROYAL AMBARRUKMO Yogyakarta
--- Jl. Laksda Adisucipto No.81, Ambarukmo, Caturtunggal, Depok, Sleman
--- Yogyakarta 55281, Indonesia

Dear Prof/Dr/Mr/Mrs Authors:

We have reached a decision regarding your submission entitled **"Transient Power Quality Performance of Multi Photovoltaics using MPPT P and O/MPPT Fuzzy" Paper ID # 9897** to International Conference and Workshop on TELKOMNIKA (Telecommunication Computing Electronics and Control) 2018 (ICW TELKOMNIKA 2018).

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I look forward for hearing from you

Thank you

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Ignore this email, if your paper is mentioned to b accepted by previous notification and you have register to Google Form

Confirmation of ICW TELKOMNIKA Registration

Int. Conf. - ICW TELKOMNIKA <icw.telkomnika@journal.uad.ac.id>
Kepada: amirullah@ubhara.ac.id

11 Agustus 2018 pukul 13.04

Dear Mr/Mrs Amirullah,

Thank you for registering for **International Conference and Workshop on Telecommunication, Computing, Electronics and Control (ICW-TELKOMNIKA) 2018**. We are pleased to confirm with appreciation the acceptance of your article **#9897 Transient Power Quality Performance of Multi Photovoltaics using MPPT P and O/MPPT Fuzzy**. Within this email is attached your payment receipt. Parallel session and workshop schedule will be informed later by email and also uploaded to TELKOMNIKA website.

If you need a Letter of Acceptance, send us an email for Letter of Acceptance inquiry by using email subject "ICW Telkomnika LOA inquiry" and mentioning author(s), title and article ID.

Best regards,
ICW TELKOMNIKA Committee

---

p60 amirullah.pdf
136K

Ubhara Surabaya

Amirullah Ubhara Surabaya <amirullah@ubhara.ac.id>

9897_ICW Telkomnika LOA inquiry_Amirullah

Int. Conf. - ICW TELKOMNIKA <icw.telkomnika@journal.uad.ac.id> 15 Agustus 2018 pukul 14.16
Kepada: Amirullah Ubhara Surabaya <amirullah@ubhara.ac.id>

Dear Sir/Madam,

Letter of Acceptance of your paper attached in this email.
Thank you

Best regards,
ICW TELKOMNIKA Committee

On Sat, Aug 11, 2018 at 1:40 PM, Amirullah Ubhara Surabaya <amirullah@ubhara.ac.id> wrote:

> Dear Tole Sutikno, PhD
> ICW TELKOMNIKA Committee
>
> I would like to request Letter of Acceptance (LoA) for my paper
> #9897 (Paper ID) Transient Power Quality Performance of Multi Photovoltaics using MPPT P and O/MPPT Fuzzy (Amirullah, Agus Kiswantono, Ontoseno Penangsang, Adi Soeprijanto).
>
> This is my email and thanks a lot for your response.
>
> Amirullah
> PhD Candidate in EE
> ITS Surabaya

---

037 Amirullah Amirullah.pdf
179K

Ubhara Surabaya

Amirullah Ubhara Surabaya <amirullah@ubhara.ac.id>

Revision Required - ICW TELKOMNIKA 2018

Int. Conf. - ICW TELKOMNIKA <icw.telkomnika@journal.uad.ac.id> 29 Agustus 2018 pukul 08.18
Kepada: Amirullah Ubhara Surabaya <amirullah@ubhara.ac.id>

International Conference and Workshop on TELKOMNIKA (Telecommunication Computing Electronics and Control) 2018

September 18-21, 2018 at ROYAL AMBARRUKMO Yogyakarta
Jl. Laksda Adisucipto No.81, Ambarukmo, Caturtunggal, Depok, Sleman
Yogyakarta 55281, Indonesia

Dear Prof/Dr/Mr/Mrs**,**

After doing in depth analysis of your article,we found some mistakes in the writing of the paper that you submitted for conference, entitled **"Transient Power Quality Performance of Multi Photovoltaics using MPPT P and O/MPPT Fuzzy" ID #9897**. We have addressed the errors in the attached file.

We are also informing some TELKOMNIKA POLICY that you have to pay attention, there are :

1. TELKOMNIKA not accepting single author paper. If your article is written by single author you need to add additional author during the revision.

2. Maximum allowed articles pages are 8 pages. Exceeding the 8 pages will be charged US$50 for each page.

3. Please revised exactly based on the TELKOMNIKA TEMPLATE. You can download the template in **bit.ly/telkomnika.**

You can send your revised paper by reply this email. Please immediately repair and send the paper **before August 31, 2018**. You should pay attention to:

1. Authors should have made substantial contributions to:

(a) The conception and design of the study, or acquisition of data, or analysis and interpretation of data

(b) Drafting the article or revising it critically for important intellectual content

2. Introduction section

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- Coherent: The sentences should be arranged in a logical manner and should follow a definite plan for development.

- Well-developed: Every idea discussed in the paragraph should be adequately explained and supported through evidence and details that work together to explain the paragraph’s controlling idea.

For more information, please contact email icw.telkomnika@journal.uad.ac.id.

We are expecting your response soon. Thank you.

Regards,
ICW-Telkomnika 2018 Committee

#9897 8.9.2018.docx
1418K

Ubhara Surabaya

Amirullah Ubhara Surabaya <amirullah@ubhara.ac.id>

Revision Required - ICW TELKOMNIKA 2018

Amirullah Ubhara Surabaya <amirullah@ubhara.ac.id> 29 Agustus 2018 pukul 22.44
Kepada: "Int. Conf. - ICW TELKOMNIKA" <icw.telkomnika@journal.uad.ac.id>
Bcc: Amirullah Ubhara Surabaya <amirullah@ubhara.ac.id>, amirullah14@mhs.ee.its.ac.id

Dear ICW-Telkomnika 2018 Committee

Here I send you final revised paper entitled "**Transient Power Quality Performance of Multi Photovoltaics using MPPT P and O/MPPT Fuzzy**" **ID #9897**.

depend on template Telkomnika Feb 2019. I also have reduce page number of this paper from 12 into 10 pages and its consequences I have to pay 2 extra pages (100 USD).

It is difficult to reduce number of page into 8 pages because I'm worried about changing the purpose and substance of my paper.

This is my email and revised paper.

Thanks a lot of for your information.

Amirullah
PhD Candidate in EE
ITS Surabaya Indonesia

[Kutipan teks disembunyikan]

9897-24089-1-RV_Author_Amirullah_Revisi Final_10 Hal_Temp 2019_29 Agustus 2018.docx
1441K

Amirullah Ubhara Surabaya <amirullah@ubhara.ac.id>

Revision Required - ICW TELKOMNIKA 2018

Amirullah Ubhara Surabaya <amirullah@ubhara.ac.id> 30 Agustus 2018 pukul 04.59
Kepada: "Int. Conf. - ICW TELKOMNIKA" <icw.telkomnika@journal.uad.ac.id>
Bcc: Amirullah Ubhara Surabaya <amirullah@ubhara.ac.id>, amirullah14@mhs.ee.its.ac.id

Dear ICW-Telkomnika 2018 Committee

Here I send you final revised paper entitled "**Transient Power Quality Performance of Multi Photovoltaics using MPPT P and O/MPPT Fuzzy**" **ID #9897**.

There is a little revision on page 7 (sentence before Table 3) from....

Table 3 shows unbalanced **current**, THD grid **current**, and average THD of grid **current** of multi PV connected on a three phase low voltage grid using MPPT P and O/ MPPT Fuzzy.

Into....

Table 3 shows unbalanced **voltage**, THD grid **voltage**, and average THD of grid **voltage** of multi PV connected on a three phase low voltage grid using MPPT P and O/ MPPT Fuzzy.

Amirullah
PhD Candidate in EE
ITS Surabaya

[Kutipan teks disembunyikan]

9897-24089-1-RV_Author_Amirullah_Revisi Final_10 Hal_Temp 2019_29 Agustus 2018.docx
1441K

Ubhara Surabaya

[ICW-Telkomnika] Invitation letter and Event Schedule, Royal Ambarukmo Hotel, September 18-20 September 2018

Amirullah Ubhara Surabaya <amirullah@ubhara.ac.id> 10 September 2018 pukul 19.20
Kepada: "Int. Conf. - ICW TELKOMNIKA" <icw.telkomnika@journal.uad.ac.id>
Cc: Zenno_379@yahoo.com
Bcc: adisup@ee.its.ac.id, kiswantono@gmail.com, amirullah14@mhs.ee.its.ac.id, Amirullah Ubhara Surabaya <amirullah@ubhara.ac.id>

Dear ICW Telkomnika Committee

Thanks a lot for your schedule and invitation to attend ICW Telkomnika 2018 which it will be held on September 18-20, 2018 at Royal Ambarukmo Hotel Yogyakarta, Indonesia.

Regards,

PhD Candidate in EE
ITS Surabaya Indonesia

2018-09-10 15:48 GMT+07:00 <icw.telkomnika@journal.uad.ac.id>:

> Dear ICW TELKOMNIKA Presenters,
>
> We are pleased to announce about the event schedule for 1st International Conference and Workshop on Telecommunication Computing Electronics and Control 2018. The event will be held on September 18-20, 2018 at Royal Ambarukmo Hotel Yogyakarta, Indonesia.
>
> September 18-19 will be scheduled for Keynote speakers and Parallel presentations and the September 20 will be scheduled for Workshop and mentoring session. Detail of the invitation letter, event schedule, and Parallel presentation schedules for each presenter can be downloaded on this link http://bit.ly/icwtelkomnika18. Please recheck that names of authors/ presenters are correct. ICW-TELKOMNIKA 2018 certificates will refer to the list. Reply this email in case your name is not correct.
>
> Each presenter required to bring 2 hardcopies of your article(s) for the workshop and mentoring session, and Laptop/netbook to do revision during the workshop and mentoring session. Committee do not provide printing service in the place.
>
> See you in Yogyakarta
>
> Regards,
> ICW Telkomnika Committee

Ubhara Surabaya

Amirullah Ubhara Surabaya <amirullah@ubhara.ac.id>

Amirullah PPT in English Version Paper ID 9897

Amirullah Ubhara Surabaya <amirullah@ubhara.ac.id> 17 September 2018 pukul 11.50
Kepada: "Int. Conf. - ICW TELKOMNIKA" <icw.telkomnika@journal.uad.ac.id>
Cc: Amirullah Ubhara Surabaya <amirullah@ubhara.ac.id>
Bcc: amirullah14@mhs.ee.its.ac.id, Amirullah Amirullah <amirullah.ubhara.surabaya@gmail.com>, Amirullah Amirullah <am9520012003@yahoo.com>, Zenno_379@yahoo.com, adisup@ee.its.ac.id, Agus Kiswantono <kiswantono@gmail.com>

Dear ICW Telkomnika Committee,

Here I send you PPT in **English Version** Paper ID 9897 entitled Transient Power Quality Performance of Multi Photovoltaics using MPPT P and O/MPPT Fuzzy (Amirullah, Agus Kiswantono, Ontoseno Penangsang, Adi Soeprijanto) which it would be presented in ICW Telkomnika 2018 (Tuesday 18 Sep 2018, 19-00-19.15 WIB, Pamandengan 2, ID Section POW10).

The file is used to replace PPT in **Indonesian Version** which I had submitted at Thursday 9 August 2018 to google online conference submission (bit.ly).

This is my email and thanks a lot for your helping.

Amirullah

PhD Candidate in EE
ITS Surabaya-Indonesia

PPT Seminar ICW Telkomnika 18-19 September 2018_English.pptx
3764K

Ubhara Surabaya

Amirullah Ubhara Surabaya <amirullah@ubhara.ac.id>

[ICW-Telkomnika] INFORMATION ABOUT UPDATE LIST COACHING PAPER

1 pesan

icw.telkomnika@journal.uad.ac.id <icw.telkomnika@journal.uad.ac.id> 19 September 2018 pukul 21.36
Kepada: amirullah@ubhara.ac.id

Dear ICW TELKOMNIKA Presenters,

Tomorrow, on September 20, 2018 will be held **Manuscript Mentoring and Coaching**. You can check your mentor and room in **bit.ly/icwtelkomnika18**, file **UPDATE LIST COACHING PAPER**. Please check it again, because we have little change about the list. Thank you.

Best regards,
ICW TELKOMNIKA Committee

[ICW-TELKOMNIKA 2018]: Preparing final camera ready paper for publication on the TELKOMNIKA (a Scopus indexed journal, SJR Q3)

Amirullah Ubhara Surabaya <amirullah@ubhara.ac.id> 26 Oktober 2018 pukul 15.57
Kepada: "Int. Conf. - ICW TELKOMNIKA" <icw.telkomnika@journal.uad.ac.id>
Cc: tole@journal.uad.ac.id
Bcc: Amirullah Ubhara Surabaya <amirullah@ubhara.ac.id>

Dear Tole Sutikno, PhD

Here I send you again final revision paper in ICW Telkomnika submitted to Telkomnika Journal.
1. Final revised paper-no yellow mark.
2. Final revised paper with yellow mark showing revised points.
3. File 9897 comments.
4. File Response to Mentor(s) Comments.

I already have send this email on 6 Oct 2018 to **icw.telkomnika@journal.uad.ac.id** but I forgot to sent to **tole@journal.uad.ac.id**.

I am sorry for this and thanks a lot for your cooperation.

Amirullah
PhD Candidate ITS Surabaya
Lecturer Ubhara Surabaya

---------- Forwarded message ---------
From: **Amirullah Ubhara Surabaya** <amirullah@ubhara.ac.id>
Date: Sab, 6 Okt 2018 pukul 15.51
Subject: Fwd: [ICW-TELKOMNIKA 2018]: Preparing final camera ready paper for publication on the TELKOMNIKA (a Scopus indexed journal, SJR Q3)
To: Int. Conf. - ICW TELKOMNIKA <icw.telkomnika@journal.uad.ac.id>
Cc: Amirullah Ubhara Surabaya <amirullah@ubhara.ac.id>

Yth. ICW Telkomnika Commitee 2018

Here I sent you again final revised paper entitled Transient Power Quality Performance of Multi Photovoltaics using MPPT P and O/MPPT Fuzzy (Amirullah, Agus Kiswantono, Ontoseno Penangsang, Adi Soeprijanto) ID Paper 9897 with attachment file of:
1. Final revised paper-no yellow mark.
2. Final revised paper with yellow mark showing revised points.
3. File 9897 comments.
4. File Response to Mentor(s) Comments.

This is my email and thanks a lot for your cooperation.

Amirullah
PhD Candidate Elect Eng ITS Surabaya
Indonesia

---------- Forwarded message ---------
From: **Amirullah Ubhara Surabaya** <amirullah@ubhara.ac.id>
Date: Sab, 6 Okt 2018 pukul 15.27
Subject: Fwd: [ICW-TELKOMNIKA 2018]: Preparing final camera ready paper for publication on the TELKOMNIKA (a Scopus indexed journal, SJR Q3)
To: Int. Conf. - ICW TELKOMNIKA <icw.telkomnika@journal.uad.ac.id>
Cc: Amirullah Ubhara Surabaya <amirullah@ubhara.ac.id>

Yth. ICW Telkomnika Commitee 2018

Here I sent you final revised paper entitled Transient Power Quality Performance of Multi Photovoltaics using MPPT P and O/MPPT Fuzzy (Amirullah, Agus Kiswantono, Ontoseno Penangsang, Adi Soeprijanto) ID Paper 9897 with attachment file of:
1. Final revised paper-no yellow mark.
2. Final revised paper with yellow mark showing revised points.
3. File 9897 comments.
4. File Response to Mentor(s) Comments.

This is my email and thanks a lot for your cooperation.

Amirullah
PhD Candidate Elect Eng ITS Surabaya
Indonesia

---------- Forwarded message ---------
From: **Int. Conf. - ICW TELKOMNIKA** <icw.telkomnika@journal.uad.ac.id>
Date: Rab, 26 Sep 2018 pukul 14.16
Subject: [ICW-TELKOMNIKA 2018]: Preparing final camera ready paper for publication on the TELKOMNIKA (a Scopus indexed journal, SJR Q3)
To: Amirullah Ubhara Surabaya <amirullah@ubhara.ac.id>
Cc: Assoc. Prof. Dr. Tole Sutikno <tole@journal.uad.ac.id>

Guideline to extend your paper of the 2018 1st International Conference and Workshop on Telecommunication, Computing, Electrical, Electronics and Control (2018 ICW-TELKOMNIKA) to be published on the TELKOMNIKA, a Scopus indexed journal, SJR Q3

****Please pay attention to the details of this email****

#9897 entitled "Transient Power Quality Performance of Multi Photovoltaics using MPPT P and O/MPPT Fuzzy"

Dear Prof/Dr/Mr/Mrs Amirullah

TELKOMNIKA Telecommunication, Computing, Electronics and Control is a Scopus indexed journal, SJR Q3, and ONLY publishes high quality papers. A high quality paper has:
(1) a clear statement of the problem the paper is addressing;
(2) the proposed solution(s); and
(3) results achieved. It describes clearly what has been done before on the problem, and what is new. The goal of your revised paper is to describe novel technical results.

There are four types of technical results:
1. An algorithm;
2. A system construct: such as hardware design, software system, protocol, etc.; The main goal of your revised paper is to ensure that the next person who designs a system like yours doesn't make the same mistakes and takes advantage of some of your best solutions. So make sure that the hard problems (and their solutions) are discussed and the non-obvious mistakes (and how to avoid them) are discussed.
3. A performance evaluation: obtained through analyses, simulation or measurements;
4. A theory: consisting of a collection of theorems.

Your revised paper should focus on:
1. Describing the results in sufficient details to establish their validity;
2. Identifying the novel aspects of the results, i.e., what new knowledge is reported and what makes it non-obvious;
3. Identifying the significance of the results: what improvements and impact do they suggest.

Second, change title of your paper. The title summarizes the main idea or ideas of your study. A good title contains the fewest possible words needed to adequately describe the content and/or purpose of your research paper. Rarely use abbreviations or acronyms unless they are commonly known. Find the below guide, how to update your paper title.

You have **4 weeks, until October 24, 2018** to revised your paper. Please submit your revised paper by reply this email (icw.telkomnika@journal.uad.ac.id), cc: tole@journal.uad.ac.id. Attach:
1. File Response to Mentor(s) Comments
2. File of your revised paper

When your revised paper reached us, it will be re-checked & reviewed by Editor(s) and Mentor(s) based on your response to Mentor & Coach comments and the following criteria: Relevance, Significance, Novelty, Technical correctness, Experimental/evidential support, Clarity of presentation and Reference to prior work and publications.

I am looking forward to receiving your revised paper.

Your cooperation is very appreciated.

Thank you,

Sincerely yours,

Tole Sutikno, Ph.D.
General Chair, 2018 ICW-TELKOMNIKA
Editor-in-Chief, TELKOMNIKA Telecommunication, Computing, Electronics and Control (Scopus indexed journal, Q3)
email: tole@journal.uad.ac.id

Guideline for preparing your paper title:

A good research paper title: (1) Condenses the paper's content in a few words & Use words that create a positive impression and stimulate reader interest; (2) Captures the readers' attention; (3) Indicate accurately the subject and scope of the study and Differentiates the paper from other papers of the same subject area. Five (5) Simple steps to write a good research paper title:

STEP 1: Ask yourself these questions and make note of the answers:
What is my paper about?
What techniques/ designs were used?
Who/what is studied?
What were the results?

STEP 2: Use your answers to list key words.

STEP 3: Create a sentence that includes the key words you listed

STEP 4: Delete all unnecessary/ repetitive words and link the remaining.

STEP 5: Delete non-essential information and reword the title.

Mentor & Coach Comments:

Attached file and/or as Mentor comments in the 2018 ICW TELKOMNIKA workshop

General Guidelines:

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1. Please re-read our instructions (at: http://journal.uad.ac.id/index.php/TELKOMNIKA/about/editorialPolicies#custom-1) carefully and follow the checklist strictly, as any spelling mistakes and errors may be translated into the typeset version.

2. The "result and discussion" section reports the most important findings, including analysing results as appropriate. It is very important to prove that your manuscript has a significant value and not trivial.

3. Please re-check that all references are already cited in your article, and order of your citation is SEQUENTIAL

example in a paper:

—> [1-4], [2], [5-6], [7-9], [8], [4-5], [9], [10-14], [12], [15] ...... (SEQUENTIAL) — correct

—> [1], [2], [3], [4-6], [7], [8-10], [4-5], [11-16], [13], [17] ...... (SEQUENTIAL) — correct

—> [2], [3], [6], [1], [4-5], [7], [11-16], [8-10], [13], [17] ...... (NOT SEQUENTIAL) — INCORRECT

—> [4-5], [7], [2], [3], [17], [6], [1], [11-16], [8-10], [13] ...... (NOT SEQUENTIAL) — INCORRECT

4. If your need references to improve your paper, please get take a look at:
- http://iaescore.com/journals/index.php/ijece
- http://iaescore.com/journals/index.php/ijeecs
- http://iaescore.com/journals/index.php/ijpeds
- http://journal.uad.ac.id/index.php/TELKOMNIKA
- http://journal.portalgaruda.org/index.php/EEI

Please use "Search" at menu "Journal Content" in right side of the site.

P.S.
For Keynote Speech and Documentation of 1st ICW 2018, you can visit this link **bit.ly/icwtelkomnika18**

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4 lampiran

9897-24089-1-RV_Author_Amirullah_Revisi Final_10 Hal_Temp 2019_6 Okt 2018.docx
1485K

9897 Comment_Amirullah.docx
18K

9897-24089-1-RV_Author_Amirullah_Revisi Final_10 Hal_Temp 2019_6 Okt 2018_Yellow Mark.docx
1486K

FORM COMMENT REVIEW_Amirullah_9897.docx
22K

Ubhara Surabaya

Amirullah Ubhara Surabaya <amirullah@ubhara.ac.id>

Revise Keyword Paper ID 9897

3 pesan

Amirullah Ubhara Surabaya <amirullah@ubhara.ac.id> 30 Oktober 2018 pukul 10.54
Kepada: tole@journal.uad.ac.id
Cc: "Int. Conf. - ICW TELKOMNIKA" <icw.telkomnika@journal.uad.ac.id>
Bcc: Amirullah Ubhara Surabaya <amirullah@ubhara.ac.id>, amirullah14@mhs.ee.its.ac.id

Dear Dr Tole Sutikno,

My paper entitled Transient Power Quality Performance of Multi Photovoltaics using MPPT P and O/MPPT Fuzzy (Amirullah, Agus Kiswantono, Ontoseno Penangsang, Adi Soeprijanto) ID Paper 9897 has been avialable online in Telkomnika Journal Vol 16 No 6 Dec 2018.

But there is a mistake in abstract keyword the correct keyword are:
MPPT Fuzzy, MPPT P and O, Multi Photovoltaics, Power Quality, Short Circuit, Transient

This revision base on editor comment to my paper on ICW Telkomnika Clinic 20 Sep 2018 in Ambarukmo Hotel (Dr. Moh Facta).

This is my email and thanks a lot for your cooperation.

Amirullah
PhD in EE Candidate ITS Surabaya
Ubhara Lecturer

9897-24089-1-RV_Author_Amirullah_Revisi Final_10 Hal_Temp 2019_6 Okt 2018.docx
1485K

Tole Sutikno <tole@journal.uad.ac.id> 30 Oktober 2018 pukul 11.05
Kepada: amirullah@ubhara.ac.id

Dear Sir/Madam,

Your email has reached my queues safely, so i will get back in touch with you there as soon as i can. Just a heads up i might not get back to you straight away, as i answer all emails in order to keep things fair.

How to submit your manuscript
To make a submission, you must have a user account and be enrolled as an Author. User accounts can either be created by the Journal Manager or you can register yourself (this journal policy allow you create user account by your self as a Reader, an Author and/or a Reviewer). All fields with an asterisk beside them (Username; Password; Repeat Password; First Name; Last Name; Email) are mandatory. Your username and your email address must be unique; furthermore, while you can change your email address at a later date, you will be unable to change your username. If you want to register in another role within the same journal (for example, if you are already a Reader, but also want to become an Author) you can log in; go to Edit My Profile (under My Account on your User Home page); and check off the checkboxes next to any available roles, near the bottom of the page. Once you have an account, log in to the journal site and select the role of Author. The Author is asked to upload a submission file and to provide metadata or indexing information. (The metadata improves the search capacity for research online and for the journal.) The Author can upload Supplementary Files, in the form of data sets, research instruments, or source texts that will enrich the item, as well as contribute to more open and robust forms of research and scholarship.

Your paper ID?
Please ALWAYS put your paper ID number in the subject line of email communication when making inquiries. For example, if your submitted manuscript URL: http://journal.uad.ac.id/index.php/TELKOMNIKA/author/submission/1234, your paper ID number is 1234.

Your cooperation is very appreciated.

Thank you

Best Regards,
Tole Sutikno
Editor:
TELKOMNIKA TCEC, http://journal.uad.ac.id/index.php/TELKOMNIKA

Journal Form for Hardcopy Order

Please download "Journal form for Hardcopy order" and contact us if further information is needed:

1. Mr. Sulchan Hidayat: sulchan.hidayat@gmail.com, +62 81328731075
2. Mr. Son Ali Akbar: sonjannah@gmail.com, Phone: +62 85643888512
3. Dr. Anton Yudhana, eyudhana@yahoo.com, +62 85746722592

Our events:

International Conference and Workshop on Telecommunication, Computing, Electronics and Control (ICW-TELKOMNIKA), September 18-21, 2018 in Yogyakarta, Indonesia
http://journal.uad.ac.id/index.php/TELKOMNIKA/pages/view/conference
----
2018 5th International Conference on Electrical Engineering, Computer Science and Informatics (EECSI 2018), October 16-18, 2018 in Malang, Indonesia.
http://eecsi.org/2018

Int. Conf. - ICW TELKOMNIKA <icw.telkomnika@journal.uad.ac.id> 30 Oktober 2018 pukul 13.37
Kepada: Amirullah Ubhara Surabaya <amirullah@ubhara.ac.id>
Cc: "Assoc. Prof. Dr. Tole Sutikno" <tole@journal.uad.ac.id>

Dear Sir,

Received, thank you.

Best regards,
ICW TELKOMNIKA Committee

On Tue, Oct 30, 2018 at 10:54 AM Amirullah Ubhara Surabaya <amirullah@ubhara.ac.id> wrote:

> Dear Dr Tole Sutikno,
>
> My paper entitled Transient Power Quality Performance of Multi Photovoltaics using MPPT P and O/MPPT Fuzzy (Amirullah, Agus Kiswantono, Ontoseno Penangsang, Adi Soeprijanto) ID Paper 9897 has been avialable online in Telkomnika Journal Vol 16 No 6 Dec 2018.
>
> But there is a mistake in abstract keyword the correct keyword are:
> *MPPT Fuzzy, MPPT P and O, Multi Photovoltaics, Power Quality, Short Circuit, Transient*
>
> This revision base on editor comment to my paper on ICW Telkomnika Clinic 20 Sep 2018 in Ambarukmo Hotel (Dr. Moh Facta).
>
> This is my email and thanks a lot for your cooperation.
>
> Amirullah
> PhD in EE Candidate ITS Surabaya
> Ubhara Lecturer

Ubhara Surabaya

Amirullah Ubhara Surabaya <amirullah@ubhara.ac.id>

[TELKOMNIKA] Please Revise Your Paper

7 pesan

Int. Conf. - ICW TELKOMNIKA <icw.telkomnika@journal.uad.ac.id> 13 November 2018 pukul 14.24
Kepada: Amirullah Ubhara Surabaya <amirullah@ubhara.ac.id>
Cc: Agus Kiswantono <kiswantono@gmail.com>, ontosenop@ee.its.ac.id, adisup@ee.its.ac.id

Dear Sir/Madam,

Please revised again your paper based on the comment on the paper. **You have 2 days to revise your paper until November 15, 2018**. Thank you.

Best regards,
TELKOMNIKA Staff

9897 (2018-10-30).docx
1488K

Amirullah Ubhara Surabaya <amirullah@ubhara.ac.id> 13 November 2018 pukul 20.14
Kepada: "Int. Conf. - ICW TELKOMNIKA" <icw.telkomnika@journal.uad.ac.id>
Cc: Amirullah Ubhara Surabaya <amirullah@ubhara.ac.id>
Bcc: amirullah14@mhs.ee.its.ac.id, Agus Kiswantono <kiswantono@gmail.com>, ontosenop@ee.its.ac.id, adisup@ee.its.ac.id

Dear Telkomnika Staff

Here I send you Telkomnika revised paper ID 9897 base on your file (doc) and comment on the paper.

This is my email and thanks a lot for your cooperation.

Amirullah
PhD Candidate EE ITS Surabaya
Lecturer Ubhara Surabaya

Pada tanggal Sel, 13 Nov 2018 pukul 14.24 Int. Conf. - ICW TELKOMNIKA <icw.telkomnika@journal.uad.ac.id> menulis:

> Dear Sir/Madam,
>
> Please revised again your paper based on the comment on the paper. **You have 2 days to revise your paper until November 15, 2018**. Thank you.
>
> Best regards,
> TELKOMNIKA Staff

9897 (2018-10-30)_Revisi_13 Nop 2018.docx
1486K

Int. Conf. - ICW TELKOMNIKA <icw.telkomnika@journal.uad.ac.id> 14 November 2018 pukul 11.30
Kepada: Amirullah Ubhara Surabaya <amirullah@ubhara.ac.id>

Dear Sir,

Please send your figure 5, 6, 7, 8, 9. 10 with a high-quality image. Because the figure in your paper is not clear enough. We hope you can send us the image before November 15, 2018. Thank you

Best regards,

TELKOMNIKA Staff

On Tue, Nov 13, 2018 at 8:14 PM Amirullah Ubhara Surabaya <amirullah@ubhara.ac.id> wrote:

> Dear Telkomnika Staff
>
> Here I send you Telkomnika revised paper ID 9897 base on your file (doc) and comment on the paper.
>
> This is my email and thanks a lot for your cooperation.
>
> Amirullah
> PhD Candidate EE ITS Surabaya
> Lecturer Ubhara Surabaya
>
> Pada tanggal Sel, 13 Nov 2018 pukul 14.24 Int. Conf. - ICW TELKOMNIKA <icw.telkomnika@journal.uad.ac.id> menulis:
>
>> Dear Sir/Madam,
>>
>> Please revised again your paper based on the comment on the paper. **You have 2 days to revise your paper until November 15, 2018**. Thank you.
>>
>> Best regards,
>> TELKOMNIKA Staff

Amirullah Ubhara Surabaya <amirullah@ubhara.ac.id> 16 November 2018 pukul 07.48
Kepada: "Int. Conf. - ICW TELKOMNIKA" <icw.telkomnika@journal.uad.ac.id>
Cc: Amirullah Ubhara Surabaya <amirullah@ubhara.ac.id>
Bcc: amirullah14@mhs.ee.its.ac.id

Dear Telkomnika Staff

I am apologize you because just have read your email.

It is okay I would like send you those figure soon please wait it at least in an hour.

Amirullah

Pada tanggal Rab, 14 Nov 2018 pukul 11.30 Int. Conf. - ICW TELKOMNIKA <icw.telkomnika@journal.uad.ac.id> menulis:

> Dear Sir,
>
> Please send your figure 5, 6, 7, 8, 9. 10 with a high-quality image. Because the figure in your paper is not clear enough. We hope you can send us the image before November 15, 2018. Thank you
>
> Best regards,
> TELKOMNIKA Staff
>
> On Tue, Nov 13, 2018 at 8:14 PM Amirullah Ubhara Surabaya <amirullah@ubhara.ac.id> wrote:
>
>> Dear Telkomnika Staff
>>
>> Here I send you Telkomnika revised paper ID 9897 base on your file (doc) and comment on the paper.
>>
>> This is my email and thanks a lot for your cooperation.
>>
>> Amirullah
>> PhD Candidate EE ITS Surabaya
>> Lecturer Ubhara Surabaya
>>
>> Pada tanggal Sel, 13 Nov 2018 pukul 14.24 Int. Conf. - ICW TELKOMNIKA <icw.telkomnika@journal.uad.ac.id> menulis:
>>
>>> Dear Sir/Madam,
>>>
>>> Please revised again your paper based on the comment on the paper. **You have 2 days to revise your paper until November 15, 2018**. Thank you.

> > > Best regards,
> > > TELKOMNIKA Staff

Amirullah Ubhara Surabaya <amirullah@ubhara.ac.id> 16 November 2018 pukul 08.23
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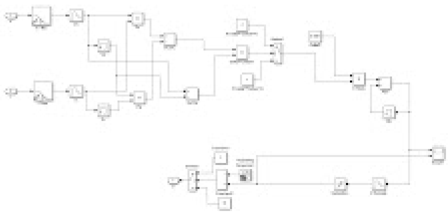

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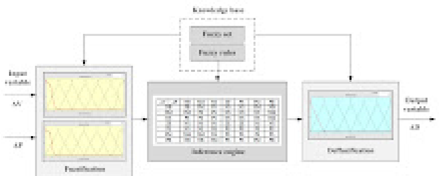

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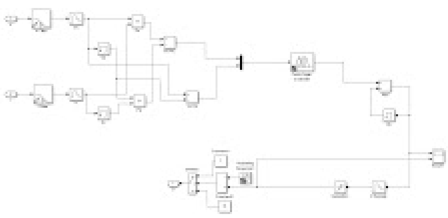

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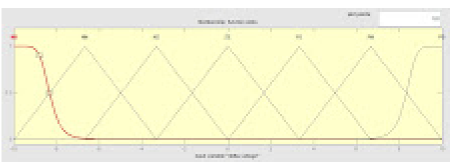

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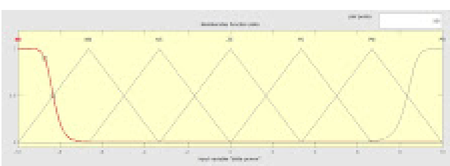

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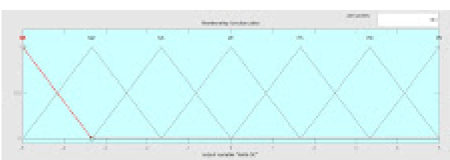

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Lampiran 2

Bukti Pendukung

Lampiran 2.1

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Yokyakarta

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Transient Power Quality Performance of Multi Photovoltaics using MPPT P and O/MPPT Fuzzy

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Abstract

Short-circuit fault can cause rise of current and voltage drop in certain phases depend on fault types, so able to generate unbalance voltage and current on low voltage distribution network (grid). Photovoltaic (PV) beside being able to generate power, it also results harmonics due to inverter as a medium to convert DC into AC voltage so capable to decrease power quality. This paper presents comparative performance of power quality due to multi PV integration at both fixed temperature and solar irradiation levels connected to 380 kV and 50 Hz distribution network using maximum power point tracking (MPPT) Perturb and Observer (P and O)/MPPT Fuzzy. This research is performed during transient disturbances of short-circuit fault on point common coupling (PCC) bus based on a five short circuit faults. An artificial intelligence method with fuzzy logic controller (FLC) is used to set duty cycle (D) with step variable to control DC/DC boost converter, generate quick convergence calculation to determine MPPT value for controlling of PV output voltage and then its result is compared with MPPT P and O method. During transient phase, non-symmetrical faults (2Ph-N, 2Ph, and 1Ph-N) are capable of generate unbalance current/voltage greater than symmetrical faults (3Ph-N and 3Ph). On symmetrical faults, MPPT Fuzzy produces average THD voltage smaller than MPPT P and O method. Otherwise on non-symmetrical faults, MPPT P and O method gives average total harmonics distortion (THD) voltage slightly smaller than MPPT Fuzzy. On symmetrical faults, MPPT Fuzzy and MPPT P and O method produce same average with THD current. Whereas in the case of non-symmetrical faults, MPPT P and O method resulted in average THD current slightly smaller than MPPT Fuzzy. Both of MPPT P and O and MPPT Fuzzy method on all short circuit faults during transient phase result significantly smaller current average THD current depend on average THD voltage. Futhermore the nominal of average THD current using both methods also meets THD limit prescribed in IEEE 519.

Keywords: *Short Circuit, Transient, Power Quality, Multi PV, MPPT P and O, MPPT Fuzzy*

1. Introduction

The PV beside being able to generate power, it also results harmonics due to inverter as a medium to convert DC into AC voltage so capable to decrease power quality. The short circuit fault can cause rise of current and voltage drop in certain phases depend on fault types, so able to generate unbalance voltage and current on low voltage distribution network (grid). The research on power quality of PV connected grid to power system using LCL filter has been done Kon Keng Weng et. al. A number of power quality problems i.e. over voltage, less voltage, power fluctuations, inrush currents, low power factor, and current harmonics or THD will appear on microgrid power system. This research is conducted only on constant solar irradiance and temperature condition (1000 W/m^2 and 25^0 C) as environmental input parameters for PV systems [1]. The study on effect of solar radiation on grid connected to PV generator to power quality i.e. voltage/current hamonics, active/reactive power, and power factor correction has been investigated by Minas Patsalides, et.al. It considers two different scenarios of average and low radiation. The shortcoming of paper is not to consider effect of temperature as an input variable for PV generator [2]. Investigation of grid connected a single phase PV generator

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inverter using a current proportional resonant, proportional resonant integral, and genetic algorithm using an active filter to reduce current harmonics of inverter output has been studied by Renu et. al. The laxity of research is only done on a single phase PV as well as certain solar irradiance and temperature [3]. The dynamic analysis of power quality due to high penetration effect of distribution network connected to PV system under variable solar irradiance has been studied by Massoud Farhoodnea, et. al. It was performed on a 16 bus model and the result showed that high level penetration of grid connected PV will cause a number of power quality problems i.e. swell/flicker voltage, loss power factor and current harmonics. The system is only analyzed on voltage harmonics and did not consider the ambient temperature condition [4].

Power quality characteristics in a number of three phase PV inverters at top roof PV i.e. harmonics distortion, voltage fluctuation, reactive power and power factor has been performed by K.P. Kontogianis, et. al [5]. A comparative study of MPPT between FLC and conventional PI controller has been presented for interfacing PV array with utility grid through a three-phase line-commutated inverter by Omid Zhoulai Bakhoda, et.al. FLC was dominating PI controller in many important aspects like i.e., provided active power for grid, output current shape of inverter, grid current and current THD [6]. A grid interfaced solar PV (SPV) power generating system in a three-phase four-wire (3P4W) distribution system has been proposed by Arun Kumar Verma, et.al. It consists of a SPV, a boost converter, a three leg VSC and a transformer connected at AC mains with power quality improvement. A FLC is utilized to extract MPP of a SPV system through control of an Insulated Gate Bipolar Transistor (IGBT) switch of the boost converter. This system is used for compensation of neutral current, harmonic currents, reactive power and to provide load balancing [7]. However, both of power quality analysis in both papers was only performed by using single PV.

The method for balancing line current and voltage, due to the presence of distributed generations (DGs) i.e. a number of single phase PV generation units in homes has been presented by Amirullah, et.al. The single phase PV generator is installed randomly on a 220 kV and 50 Hz three phase four wire distribution network using battery energy storage (BES) and three single phase bidirectional inverter circuits. The result shows that the combination of BES and three single phase bidirectional inverter able to reduce unbalanced line current/voltage. Otherwise, the combination of both circuit able to inreases current/voltage harmonics [8]. Power quality enhancement on low voltage of three phase grid caused by different level of PV generator integration using MPPT Fuzzy under variabel solar irradiance level on constant temperature and load has been investigated by Amirullah, et.al.. The application of MPPT Fuzzy was able to enhance profile of grid voltage and current THD due to different level of integration of PV generator to three phase grid corresponding with IEEE Standard 519-1992. MPPT Fuzzy was also capable to improve input power factor better than MPPT P and O. Analysis of this paper was only done in normal condition [9].

This paper presents comparative performance of power quality due to the multi PV integration at both fixed temperature and solar irradiation levels connected to 380 kV and 50 Hz distribution network using MPPT P and O/MPPT Fuzzy controller. The research is performed during transient disturbances of short-circuit fault on PCC bus based on five of short circuit faults. An artificial intelligence method with FLC is used to set duty cycle (D) with step variable to control DC/DC boost converter, generate quick convergence calculation to determine MPPT value for controlling of PV generator output voltage, and then its result is compared with MPPT P and O method. The parameters are voltage/current unbalanced, voltage/current THD on each phase, and voltage/current average THD on PCC bus of three phase grid.

This paper is organized as follow. Section 2 presents proposed method i.e. proposed model of single PV generator using MPPT Fuzzy, model multi PV generator connected three phase grid under short circuit fault, simulation parameters, equivalent circuit, mathematical, and characteristic curve of PV model, MPPT P and O method, MPPT Fuzzy method, voltage and current harmonics, voltage and current unbalance. Section 3 describes comparative performance of multi PV connected grid under short circuit fault during transient phase to current/voltage unbalance and current/voltage THD of three phase grid using MPPT P and O/MPPT Fuzzy method. In this section, example cases studied are presented and the results are verified with those of Matlab/Simulink. Finally, the paper in concluded in Section 4.

2. Research Method

2.1. Proposed Model

Figure 1 shows model of a single PV generator system connected to a three phase grid. The DC/DC converter circuit consists of a boost converter circuit that serves to raise the DC output voltage from the PV generator. The DC output voltage of the boost converter circuit is then changed by a three phase DC/AC inverter into an AC voltage to three phase grid. The single PV generator model is then used as a reference to construct multiple (multi) PV models connected to grid through a three phase phase distribution transformer showed in Figure 2. This research uses three model group of PV generators with an active power of 100 kW each. Besides connected three phase grid, multi PV is also connected to three group of three phase loads with 20 kW of active power each. The aim of research is to compare performance of power quality due to the multi PV integration at both fixed temperature and solar irradiation levels connected to distribution network using MPPT P and O/MPPT Fuzzy. The research analysis includes transient disturbances of short-circuit fault on PCC bus based on a number of short circuit faults. An artificial intelligence method with FLC is used to set duty cycle (D) with step variable to control DC/DC boost converter, generate quick convergence calculation to determine MPPT value for controlling of PV output voltage, and then its result is compared with MPPT P and O method. The DC/DC converter produces a constant DC voltage as an input for DC/AC inverter using pulse with modulation (PWM).

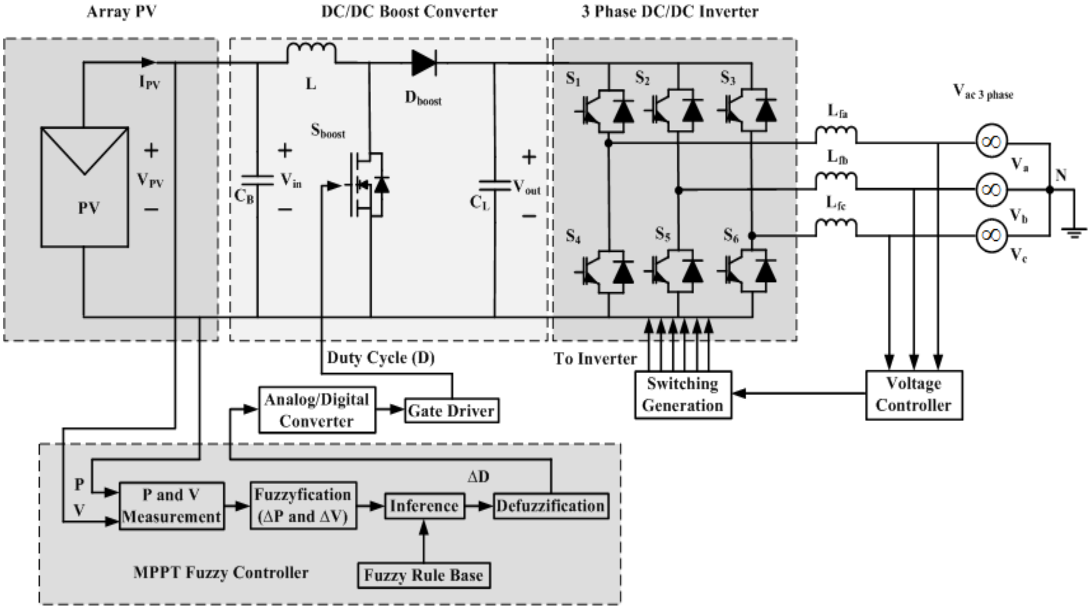


Figure 1. Proposed model of single PV using MPPT Fuzzy

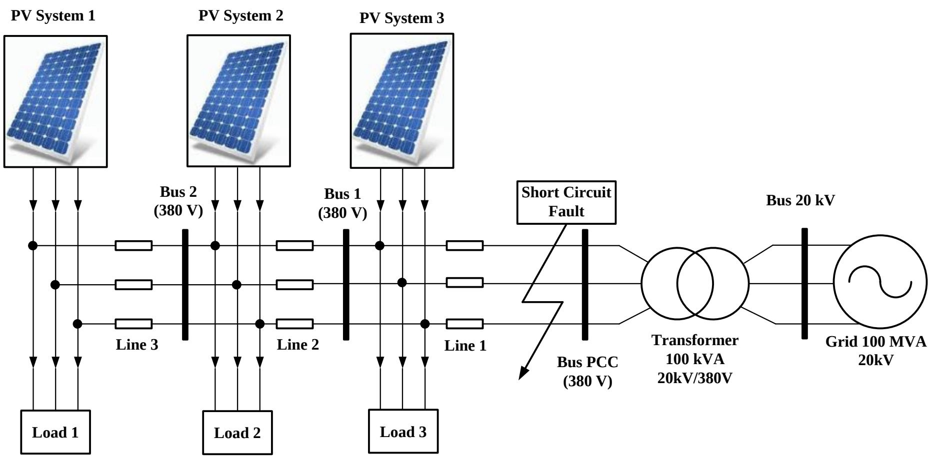


Figure 2. Proposed model of multi PV connected three phase grid under short circuit fault

There are two scenarios of multi PV connected three phase grids under fixed temperature and solar irradiation of 25^0 C and 400 W/m^2, i.e. using MPPT P and O and MPPT Fuzzy methods respectively. The transient state in each of MPPT controllers are indicated by five short-circuit faults, resulting in a total of ten fault scenarios i.e. three phases to ground (3Ph-N), three phases (3Ph), two phases to ground (2Ph-N), two phases (2 Ph), and single phase to ground (1Ph-N). Futhermore is to determine voltage/current unbalanced, voltage/current harmonics (THD) on each phase, and voltage/current average harmonics on PCC bus of three-phase low voltage grid. The final step is to validate the results referring to the ANSI/IEEE 241-1990 standard (unbalanced voltage and current) and IEEE Standard 519-1992 (average grid voltage and current harmonics). Simulation and analysis of this research use Matlab/Simulink. The simulation parameter values of proposed model are shown in Appendix Section.

2.2. Modelling of PV Array

Figure 3 shows the equivalent circuit of a solar panel. A solar panel is composed of several PV cells that have series, parallel, or series-parallel external connections [10].

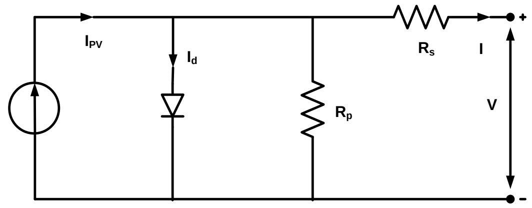


Figure 3. Equivalent circuit of solar panel

The V-I characteristic of a solar panel is showed in (1):

$$I = I_{PV} - I_o\left[\exp\left(\frac{V + R_S I}{aV_t}\right) - 1\right] - \frac{V + R_S I}{R_P} \tag{1}$$

where I_{PV} is the photovoltaic current, I_o is saturated reverse current, 'a' is the ideal diode constant, $V_t = N_S K T q^{-1}$ is the thermal voltage, N_S is the number of series cells, q is the electron charge, K is the Boltzmann constant, T is the temperature of p–n junction, R_S and R_P are series and parallel equivalent resistance of the solar panels. I_{PV} has a linear relation with light intensity and also varies with temperature variations. I_o is dependent on temperature variations. The values of I_{pv} and I_o are calculated as following (2) and (3):

$$I_{PV} = (I_{PV,n} + K_1 \Delta T)\frac{G}{G_n} I \tag{2}$$

$$I_o = \frac{I_{SC,n} + K_I \Delta T}{\exp(V_{OC,n} + K_V \Delta T)/aV_t - 1} \tag{3}$$

In which $I_{PV,n}$, $I_{SC,n}$ and $V_{OC,n}$ are photovoltaic current, short circuit current and open circuit voltage in standard conditions (T_n = 25 C and G_n = 1000 Wm^{-2}) respectively. K_I is the coefficient of short circuit current to temperature, $\Delta T = T - T_n$ is the temperature deviation from standard temperature, G is the light intensity and K_V is the ratio coefficient of open circuit voltage to temperature. Open circuit voltage, short circuit current and voltage-current corresponding to the maximum power are three important points of I-V characteristic of solar panel. These points are changed by variations of atmospheric conditions. By using (4) and (5) which are derived from PV model equations, short circuit current and open circuit voltage can be calculated in different atmospheric conditions.

$$I_{SC} = (I_{SC} + K_1 \Delta T)\frac{G}{G_n} \tag{4}$$

$$V_{OC} = V_{OC} + K_V \Delta T \tag{5}$$

2.3. MPPT P and O and MPPT Fuzzy

The initial research is to determine value of duty cycle (D) with a variable step to control DC/DC boost converter circuit with MPPT P and O. For PV converter, maximum power available is determined by PV cell characteristics, but this value often mismatches with the maximum power point (MPP) of the load. By implementing MPPT in PV systems, MPP can be maintained so that the number and size of PV panels can be reduced or energy yield can be optimized [9].

Due to moving of sun, which leads to change in irradiance, PV panels angle and variation of irradiance reaching the panels, energy generated from PV panels are absorbed does not constant over time. When this condition occurs, VI characteristics changes and MPP will move. If the system was previously operating at MPP, there will most probably a power loss with the same operating point and new condition. To overcome these problems, MPPT has been developed. The system includes no moving parts (where the modules are moved to track the sun). MPPT search for the maximum power independent based on environmental conditions (following changes in solar radiation and temperature) and maintain the PV terminal voltage remains constant at maximum value. The most used method of MPPT is P and O that algorithm is shown in Figure 4 [11] and its Matlab/Simulink model is presented in Figure 5.

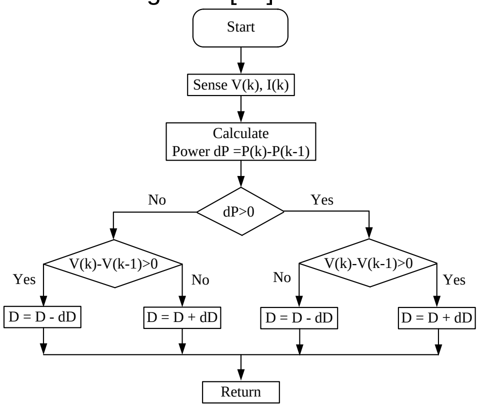


Figure 4. MPPT using P and O algorithm

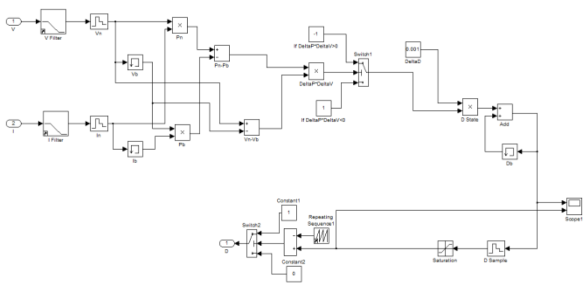


Figure 5. Matlab/Simulink for MPPT P and O

The same procedure for determining MPPT is using FLC. This method have been widely used in industrial process in the recent years due to their heuristic nature associated with simplicity, effectiveness and its multi rule based variable's consideration for both linear and non-linear parameter variation of the system. Fuzzy system is composed of knowledge based rules system. The main part of fuzzy is knowledge of base consisting of the If-Then rules. Fuzzy set theory is a new method of controlling the MPPT in obtaining the peak power point. The MPPT is implemented to obtain MPP operation voltage point faster with less overshoot and also it can minimize voltage fluctuation after MPP has been recognized. It also is capable to enhance power quality problem unbalance current/voltage and current/voltage harmonics. The control objective is to track maximum power will lead consequently to effective operation of the PV panel. To design the FLC, variables which represent the dynamic performance of the system should be chosen as the input to controller. Typical fuzzy based MPPT controller reffered to MPPT Fuzzy includes three basic components i.e. fuzzification, inference engine, and defuzzification block as shown in Figure 6 and its Matlab/Simulink model presented in Figure 7.

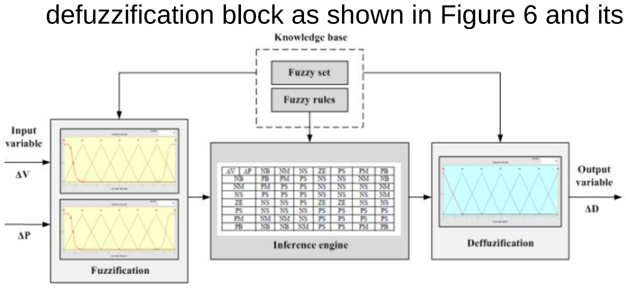


Figure 6. Structure of FLC

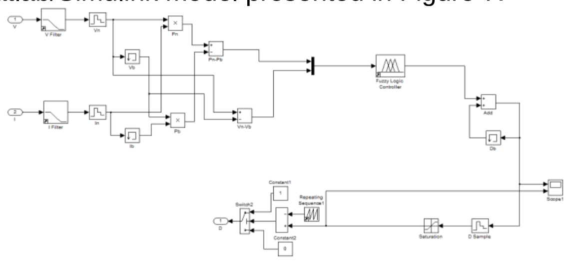


Figure 7. Matlab/Simulink for MPPT Fuzzy

Due account MPPT Fuzzy method is in terms of intelligence and speed. Fuzzy MPPT method is done by determining input variables, namely fuzzy control output power (ΔP) and output voltage (ΔV) PV generator, seven linguistic variables fuzzy sets, fuzzy operating system block (fuzzification, fuzzy rules, and defuzzification), Function ΔP and Δ V during fuzzification, a table fuzzy rule base, crisp values to determine duty cycle (D) in defuzzification phase with variable step to control DC /DC boost converter. Figure 8 shows Matlab/Simulink model for MPPT Fuzzy. During fuzzification phase shown in Figure 7, a number of input variables is calculated and converted into a linguistic variable based on the subset called membership function (MF). To translate value of voltage change and power change in, input fuzzy "change of voltage" and "change of power" is designed to use seven fuzzy variable called PB (Positive Big), PM (Positive Medium), NS (Negative Small), PS (Positive Small) ZE (Zero), NM (Negative Medium), and Negative Big (NB). voltage change (ΔV) and power changes (ΔP) is a proposed system input variables and output variable FLC is duty cycle change (ΔD). The membership functions i.e. voltage changes, power changes, and duty cycle change, each are shown in Figure 8 into Figure 10. Limit of input and output membership functions applied, determined by prior knowledge of parameter variation.

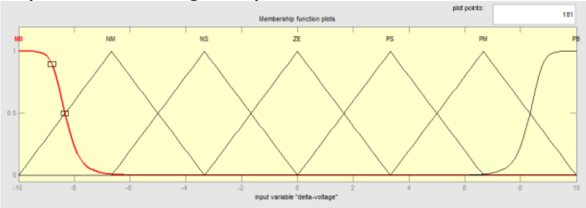


Figure 8. Input voltage change (delta voltage)

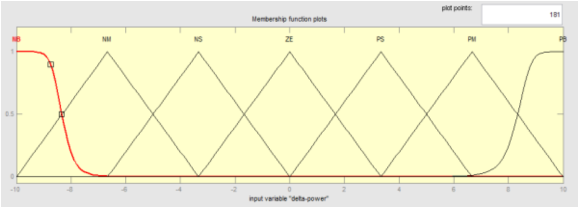


Figure 9. Input power change (delta power)

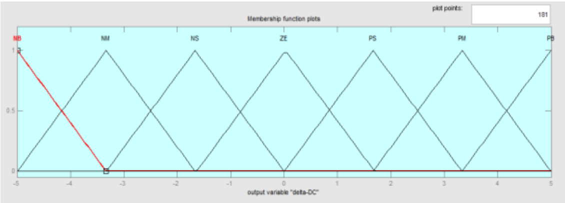


Figure 10. Output duty cycle change (delta D)

The fuzzy rule algorithm collects a number of fuzzy control rules in a specific order. This rule is used to control system to meet desired performance requirements, and they are designed from a knowledge of intelligent control systems. The fuzzy inference using a method that relates to a composition Mamdani Max-Min. Fuzzy inference system consists of three parts, namely rule base, database, and reasoning mechanism. Rule base consists of a number of If-Then rule for proper operation of controller. The If side of rule is called antecedent and Then side is called consequence. These rules may be regarded as similar response made by human thought processes and controllers using linguistic input variables, obtained after fuzzification for operation of these rules. The database consists of all user-defined membership function to be used in a number of these rules. Reasoning mechanism basically given processing rules based on specific rules and given conditions required result.

After determining ΔV and ΔP, these value are then converted into linguistic variables and use them as input functions for FLC. The output value is ΔD is generated using block inference and fuzzy rules as shown in Table 1. Finally defuzzification block operates to change value of ΔD is raised from linguistic variables into numeric variables back. Numeric variables that become inputs signal for the IGBT switch of DC/DC boost converter to be able to determine MPPT value for each generation PV accurately at the same time also improve power quality as a result of integration of multi PV to low voltage three phase grid under short circuit fault.

Table 1. Fuzzy Rules

ΔV ΔP	NB	NM	NS	ZE	PS	PM	PB
NB	PB	PM	PS	NS	NS	NM	NB
NM	PM	PS	PS	NS	NS	NS	NM
NS	PS	PS	PS	NS	NS	NS	NM
ZE	NS	NS	PS	ZE	ZE	NS	NS
PS	NS	NS	NS	PS	PS	PS	PS
PM	NM	NM	NS	PS	PS	PS	PS
PB	NB	NB	NM	PS	PS	PM	PB

2.4. Voltage and Current Harmonics

Power quality means quality of voltage and current. Power quality is determined based on the voltage and current value or the tolerance limit of equipment used. In general, current and voltage waveform of pure sinusoidal waves. One problem that occurs is non sinusoida or distorted current and voltage waves generated by harmonics in the power system [9]. Harmonic is distorted periodic steady state wave caused by the interaction between the shape of a sine wave at the fundamental frequency system with another wave component which is an integer multiples frequency of fundamental frequency. The most common harmonic index, which relates to the voltage waveform is THD (6), which is defined as the root mean square (rms) of the harmonics expressed as a percentage of the fundamental component as showed in [12]. For most applications, it is sufficient to consider the harmonic range from the 2nd to 25th, but most standards specify up to the 50th. Second harmonic index is current THD means the ratio of rms harmonic current value to rms fundamental current which expressed in (7) [9].

$$THD_V = \frac{\sqrt{\sum_{n=2}^{N} V_n^2}}{V_1} \times 100\,\% \quad (6) \qquad THD_I = \frac{\sqrt{\sum_{n=2}^{N} I_n^2}}{I_1} \times 100\,\% \quad (7)$$

Where V_n and I_n (the rms voltage and current at harmonic n), V_1 and I_1 (the fundamental rms voltage and current), N (the maximum harmonic order to be considered). The allowable maximum THD value for each country is different depending on the standard used. THD standards most often used in electric power system is IEEE 519-1992. There are two criteria used in analysis of harmonics distortion i.e. voltage distortion and current distortion limit [13].

2.5. Voltage and Current Unbalance

There are several standards that can be used to determine level of voltage unbalance in three phase systems, e.g. IEC, NEMA, and IEEE. In this study, value of unbalance voltage use (8) is based ANSI/IEEE 241-1990 Standard [14] as follows:

$$V(\%) = \frac{\left| V_{avarage} - V_{a,b,c\,\min\,or\,\max} \right|}{V_{avarage}} \times 100\% \quad (8)$$

By using (8), value of unbalance voltage expressed in percent (%) and is defined as follows; $V_{avarage}$ is the average value of maximum voltage on phase a, b, c, (volt), $V_{a,b,c\ min}$ is minimum voltage on phase a, b, c, (volt), $V_{a,b,c\ max}$ is maximum voltage on phase a, b, c (volt). By using the same equation, then percentage of unbalance current can be calculated by replacing voltage magnitude into current magnitude.

3. Results and Discussions

This research is started by determining the maximum and minimum of grid current in each phase, unbalanced current using (8), current THD on each phase using (7), and average THD of three phase current grids on PCC bus using MPPT P and O/MPPT Fuzzy method. By using the same procedure then obtained unbalanced voltage, voltage THD on each phase, and average voltage THD. Table 2 shows unbalanced current value, THD grid current, and average THD of grid current, multi PV connected on a three phase low voltage distribution network using MPPT P and O/MPPT Fuzzy method. There are five short-circuit faults i.e. 3Ph-N, 3Ph, 2Ph-N, 2Ph, and 1Ph-N. So there are three fault durations i.e. before fault, during fault (transient), and after fault phase with time durations are 0-0.02 sec, 0.02-0.04 sec, and 0.04-0.06 sec respectivelty. The simulation result of unbalanced current/voltage and average THD current/voltage is also presented as verification under five short circuit faults. The results analysis is conducted only on short circuit fault during transient phase.

Table 2. Unbalance Current and Average Current Harmonics

No.	Fault Type	Fault Phase	Phase Current (V) A	B	C	Unba Current (%)	THD$_I$ (%) A	B	C	Avg THD$_I$ (%)
					MPPT P and O Method					
1	Normal	Before	10.51	10.67	10.52	0.978	2.34	1.65	1.87	1.954
		Transient	**10.61**	**10.74**	**10.69**	**0.562**	**2.65**	**3.22**	**3.40**	**3,090**
		After	10.85	10.97	10.90	0.581	4.11	4.34	3.63	4.020
2	3Ph-N	Before	10.51	10.66	10.52	0.916	2.35	1.62	1.86	1.944
		Transient	**1331**	**1359**	**1296**	**2.283**	**4.41**	**2.05**	**2.38**	**2.947**
		After	38.91	11.57	326.1	159.786	165	92.55	71.13	109.560
3	3Ph	Before	10.51	10.67	10.52	0.978	2.36	1.64	1.88	1.960
		Transient	**1331**	**1359**	**1296**	**2.283**	**4.41**	**2.05**	**2.38**	**2.947**
		After	103	11.98	102.3	42.213	110.84	90.27	110.05	103.720
4	2Ph-N	Before	10.51	10.66	10.52	0.915	2.34	1.62	1.86	1.947
		Transient	**1336**	**1350**	**7.671**	**50.353**	**4.70**	**1.76**	**3.91**	**3.457**
		After	41.92	11.69	10.98	94.705	164.26	73.46	4.47	80.730
5	2Ph	Before	10.51	10.66	10.52	0.915	2.35	1.63	1.88	1.954

		Transient	**1179**	**1179**	**10.32**	**49.347**	**3.67**	**3.67**	**3.33**	**3.557**
		After	17.71	15.06	10.98	21.440	154.01	180.83	4.96	113.267
6	1Ph-N	Before	10.51	10.66	10.58	0.725	2.34	1.62	1.86	1.940
		Transient	**1132**	**9.451**	**9.482**	**195.065**	**4.96**	**3.27**	**4.06**	**4.097**
		After	44.29	11.02	10.93	100.589	164.75	5.60	3.57	57.974
				MPPT Fuzzy Method						
1	Normal	Before	10.48	10.63	10.52	0.822	2.04	1.24	1.69	1.657
		Transient	**10.72**	**10.76**	**10.80**	**0.372**	**3.32**	**3.76**	**4.28**	**3.787**
		After	11.01	11.13	11.05	0.603	4.98	5.45	5.01	5.147
2	3Phasa-N	Before	10.48	10.63	10.52	0.822	2.04	1.25	1.69	1.660
		Transient	**1331**	**1359**	**1296**	**2.283**	**4.41**	**2.05**	**2.38**	**2.947**
		After	38.99	11.61	326.5	159.746	165.09	92.62	71.07	109.594
3	3Phasa	Before	10.48	10.63	10.52	0.822	2.04	1.24	1.69	1.657
		Transient	**1331**	**1359**	**1296**	**2.283**	**4.41**	**2.05**	**2.38**	**2.947**
		After	103	11.98	103.6	42.191	110.89	90.73	109.79	103.804
4	2Phasa-N	Before	10.48	10.63	10.52	0.822	2.05	1.25	1.69	1.664
		Transient	**1336**	**1350**	**7.475**	**50.364**	**4.70**	**1.76**	**6.0**	**4.154**
		After	42.16	11.98	11.18	93.631	163.75	72.36	6.61	80.907
5	2Phasa	Before	10.48	10.63	10.52	0.822	2.04	1.24	1.69	1.657
		Transient	**1179**	**1179**	**10.09**	**49.361**	**3.69**	**3.66**	**5.10**	**4.150**
		After	18.05	15.3	11.26	18.560	152.15	178.90	4.55	111.867
6	1Phase-N	Before	10.48	10.63	10.52	0.822	2.04	1.25	1.69	1.660
		Transient	**1332**	**9.203**	**9.319**	**195.886**	**4.97**	**4.88**	**5.28**	**5.044**
		After	44.42	11.30	11.40	98.540	164.46	7.64	6.75	59.617

Table 3 shows unbalanced current value, THD grid current, and average THD of grid current, multi PV connected on a three phase low voltage distribution network using MPPT P and O/ MPPT Fuzzy method.

Table 3. Unbalance Voltage and Average Voltage Harmonics

No.	Fault Type	Fault Phase	Phase Voltage (V)			Unba Voltage (%)	THD_V (%)			Avg THD_V (%)
			A	B	C		A	B	C	
				MPPT P and O Method						
1	Normal	Before	307.8	307.7	307.8	0	4.08	4.00	3.96	4.014
		Transient	**308.8**	**308.7**	**307.8**	**0**	**6.74**	**7.06**	**7.14**	**6.980**
		After	307.8	307.8	307.8	0	10.38	11.41	11.41	11.067
2	3 Ph-N	Before	307.7	307.7	307.7	0	4.12	4.05	3.96	4.044
		Transient	**1.332**	**1.350**	**1.307**	**1.523**	**6.50**	**179.32**	**189.46**	**125.094**
		After	301.7	300.4	241.9	7.240	16.94	20.0	53.83	31.924
3	3 Ph	Before	307.7	307.7	307.7	0	4.07	4.02	3.96	4.017
		Transient	**1.347**	**1.325**	**1.318**	**1.279**	**275.94**	**336.34**	**341.31**	**317.864**
		After	289.3	300.5	296.2	4.948	22.43	20.25	27.30	23.327
4	2 Ph-N	Before	307.7	307.8	307.7	0	4.07	4.03	3.98	4.027
		Transient	**2.242**	**2.268**	**308.4**	**195.677**	**5.36**	**106.86**	**7.83**	**39.017**
		After	301	301.5	307.7	1.418	18.51	20.16	10.94	16.537
5	2 Ph	Before	307.7	307.7	307.8	0	4.04	4.07	3.98	4.030
		Transient	**155.0**	**152.7**	**307.8**	**50.025**	**7.96**	**8.09**	**7.72**	**7.924**
		After	306.3	296.1	307.8	1.451	18.09	20.66	10.84	16.530
6	1Ph-N	Before	307.7	307.8	307.7	0	4.08	4.03	3.95	4.020
		Transient	**2.658**	**308.1**	**308.1**	**49.356**	**5.48**	**7.56**	**7.88**	**6.974**
		After	300.6	307.7	307.7	0.776	17.51	11.50	10.21	13.074
				MPPT Fuzzy Method						
1	Normal	Before	307.8	307.7	307.8	0	2.75	2.74	2.65	2.714
		Transient	**307.7**	**307.7**	**307.7**	**0**	**8.23**	**9.74**	**9.79**	**9.254**
		After	307.7	307.7	307.6	0	13.68	14.94	14.43	14.35
2	3 Ph-N	Before	307.8	307.8	307.8	0	2.72	2.78	2.61	2.704
		Transient	**1.332**	**1.351**	**1.306**	**1.605**	**5.38**	**172.84**	**181.97**	**120.064**
		After	301.7	300.6	241.9	7.278	24.26	24.80	56.05	35.037
3	3 Ph	Before	307.8	307.8	307.8	0	2.76	2.73	2.61	2.700
		Transient	**1.339**	**1.343**	**1.307**	**1.003**	**223.47**	**283.53**	**294.43**	**267.144**
		After	289.3	300.4	296.3	4.913	29.55	25.81	30.89	28.760
4	2 Ph-N	Before	307.8	307.8	307.8	0	2.73	2.79	2.61	2.710
		Transient	**2.242**	**2.269**	**308.4**	**195.676**	**4.90**	**102.82**	**11.16**	**39.627**
		After	301.0	301.5	307.6	1.396	20.97	22.70	15.70	19.790
5	2 Ph	Before	307.8	307.8	307.8	0	2.77	2.72	2.61	2.700
		Transient	**155.0**	**152.7**	**307.8**	**50.025**	**10.12**	**10.28**	**9.98**	**10.127**
		After	306.4	295.9	307.6	1.418	20.94	23.82	14.09	19.617
6	1Ph-N	Before	307.8	307.8	307.8	0	2.73	2.78	2.61	2.707
		Transient	**2.657**	**308.1**	**308.0**	**49.381**	**5.22**	**9.77**	**10.63**	**8,570**
		After	300.5	307.7	307.6	0.798	22.19	16.94	15.93	18.354

Figure 11 shows grid current waveform of multi PV connected to three phase grid on a PCC bus using MPPT P and O/MPPT Fuzzy method under normal condition, 3Ph-N, 2Ph-N, and 1Ph-N fault.

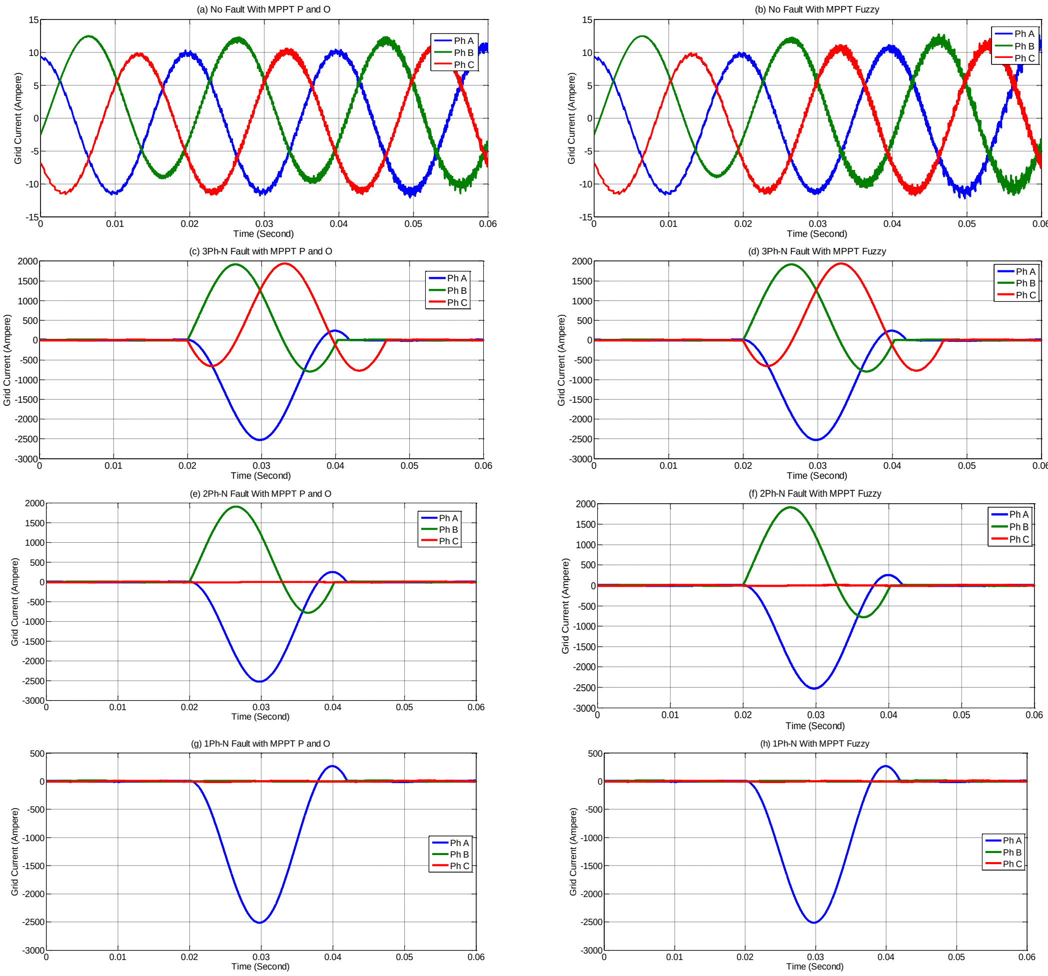
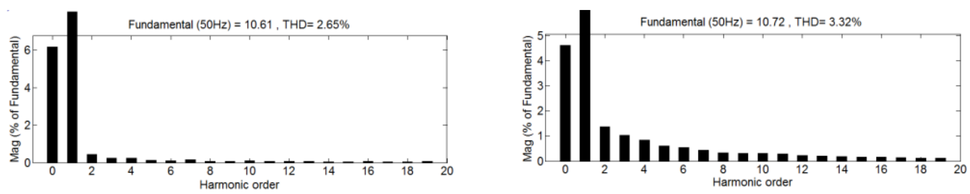
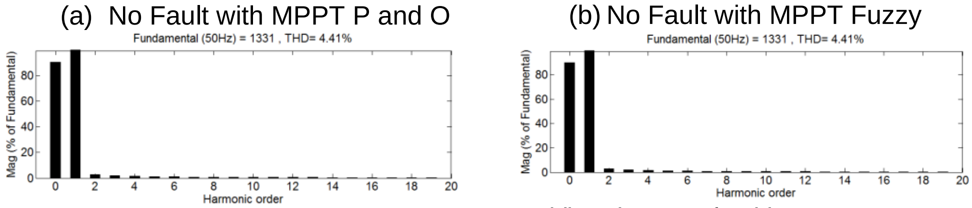


Figure 11. Current waveform of multi PV connected to a three phase grid on PCC bus

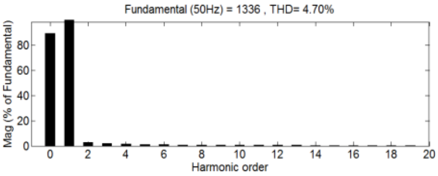
Figure 12 shows grid current harmonics spectra of phase A during transient phase due to the multi PV connected to three phase grid on PCC bus using MPPT P and O and MPPT Fuzzy method under normal condition, 3Ph-N, 2Ph-N, and 1Ph-N fault.



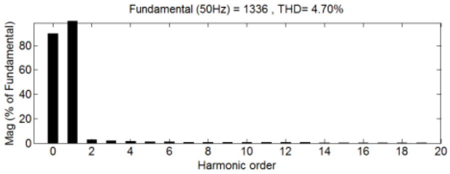
(a) No Fault with MPPT P and O (b) No Fault with MPPT Fuzzy



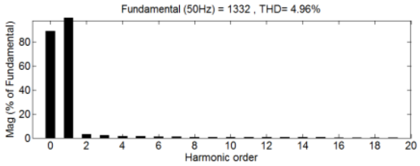
(c) 3Ph-N Fault with MPPT P and O (d) 3Ph-N Fault with MPPT Fuzzy



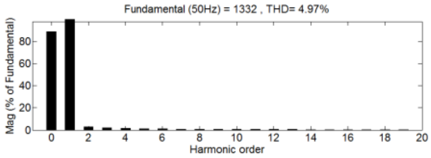
(e) 2Ph-N Fault with MPPT P and O



(f) 2Ph-N Fault with MPPT Fuzzy



(g) 1Ph-N Fault with MPPT P and O



(h) 1Ph-N with MPPT Fuzzy

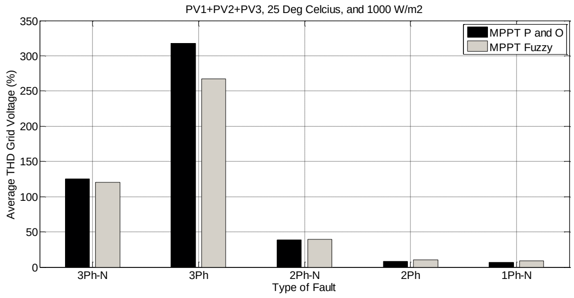
Figure 12. Current harmonics spectra of phase A during transient phase on PCC bus

Table 2 presents that under normal condition (no fault), phase current of multi PV (PV1+PV2 + PV3) using MPPT P and O method in transient phase are 10.61 A, 10.74 A, 10.69 A resulting in an unbalanced current of 0.562%. In short circuit faults, the highest unbalanced currents of transient phase is generated by 1Ph-N fault of 195.886% with current on phase A, B, and C of 1332 volt, 9.203 volt, 9.319 volt respectively. The 3Ph-N and 3Ph fault on transient phase produce an unbalanced current of equal to 2,283% resulted by phase current A, B, and C are 1331 A, 1359 A, 1239 A respectively. The implementation of MPPT Fuzzy method under normal condition and transient phase generates phase current of 10.61 A, 10.74 A, 10.69 A so as to produce an unbalanced current equal to 0.562%. If using MPPT Fuzzy method under fault on transient phase, the highest unbalanced current is generated by 2Ph-N faults of 195.886%. At the same condition the smallest unbalanced current is generated by 3Ph-N and 3Ph-N fault equal to 2.282%. In non-symmetrical fault, the use of MPPT P and O method gives an unbalanced current of transient phase slightly lower than MPPT Fuzzy method. While in symmetrical fault, MPPT P and O/MPPT Fuzzy method for controlling of output power of multi PV gives same unbalanced current of transient phase of 2,283%.

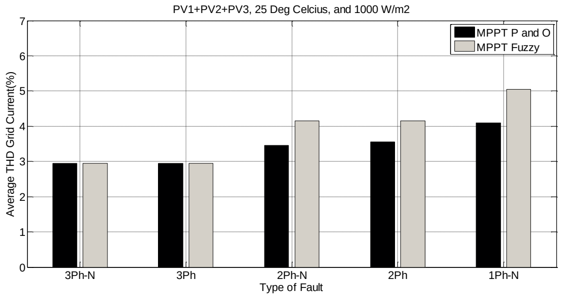
In normal condition, by using both MPPT P and O and MPPT Fuzzy method, the average THD current on transient phase are 3.090% and 3.787%, respectively. When using MPPT P and O, the highest average THD current is generated by 1Ph-N fault of 4,097%. In the same method, the smallest average THD voltage is generated by 3Ph-N and 3Ph equal to 2,947%. If using Fuzzy MPPT, the highest average THD current is generated by 1Ph-N fault of 5.044%. In the same method, the smallest average THD current is generated by 3Ph-N and 3Ph equal to 2,947%. In the symmetrical faults, both MPPT P and O and MPPT Fuzzy method produce average THD current during transient phase equal to 2,947%. Whereas in the case of non-symmetric fault, MPPT P and O resulted in average THD current of transient phase slightly smaller than MPPT Fuzzy method.

Table 4 presents that under normal condition, the voltage values on phase A, B, and C of multi PV using MPPT P and O method under transient phase are 308.8 volt, 308.7 volt, 307.8 volt, respectively, resulting in an unbalanced voltage of 0%. In the short circuit faults, the highest unbalanced voltage during transient phase is generated by a 2Ph-N fault of 195.677% with a phase voltage of A, B, and C respectively of 2.242 volt, 2.268 volts, and 308.4 volt. The 3Ph fault during transient phase produce the smallest unbalanced voltage of 1.279% resulted from phase voltage A, B, and C respectively of 1.347 volt, 1.325 volt, 1.318 volt. The use of MPPT Fuzzy method under normal condition and transient phase gives 308.8 volt, 308.7 volt, 307.8 volt, respectively, resulting in an unbalanced voltage equal to 0%. When using the MPPT Fuzzy method under short-circuit fault during transient phase, the highest unbalanced voltage is generated by a 2Ph-N fault of 195.676%. Under the same condition, the lowest unbalanced voltage is generated by 3Ph fault of 1.003%. In non-symmetrical faults (2Ph-N, 2Ph, and 1Ph-N), the implemantation of MPPT P and O and MPPT Fuzzy method to control output power of multi PV produces nominal unbalanced voltage during transient phase results a close the same value. While in symmetrical fault (3Ph-N and 3Ph) MPPT P and O and MPPT Fuzzy method produce different unbalance voltage on transient phase. During 3Ph-N fault on transient phase, MPPT P and O method results in an unbalanced transient phase voltage of 1.523% slightly lower than MPPT Fuzzy method of 1.605%. Otherwise during 3Ph fault on transient phase, MPPT Fuzzy produces an unbalanced voltage of 1.003% slightly lower than MPPT P and O of 1.279%.

In normal condition using both MPPT P and O and MPPT Fuzzy method, THD average voltages are 6.980% and 9.254%, respectively. If using MPPT P and O method, then the largest average THD voltage is generated by a 3Ph fault of 317.846%. By using the same method, the lowest average THD voltage is produced by 1Ph-N fault of 6.974%. If using Fuzzy MPPT method, the largest average THD voltage is also generated by a 3Ph fault of 267.144%. By using the same method, the lowest average THD voltage is generated by 1Ph-N fault of 8.570%. During symmetrical fault on transient phase, MPPT Fuzzy method results average THD voltage smaller than MPPT P and O. Otherwise during non-symmetrical fault on transient phase, MPPT P and O method results average THD voltage slightly lower than MPPT Fuzzy.



(a) Average THD voltage



(b) Average THD current

Figure 13. Performance of average voltage and current harmonic during transient phase

Figure 13.a describes that on symmetrical fault during transient phase (3Ph-N and 3Ph), MPPT Fuzzy method produces average THD voltage smaller than MPPT P and O method. Otherwise on non-symmetrical fault during transient phase (2Ph-N, 2Ph, and 1Ph-N), MPPT P and O method gives average THD voltage slightly smaller than MPPT Fuzzy method. Figure 14.b describes that on symmetrical fault during transient phase (3Ph-N and 3Ph), MPPT Fuzzy and and MPPT P and O method produce same average THD current. Whereas in the case of non-symmetrical fault during transient phase (2Ph-N, 2Ph, and 1P-N), MPPT P and O method resulted in average THD current slightly smaller than MPPT Fuzzy method. The MPPT P and O method and the MPPT Fuzzy method on all short circuit fault during transient phase (3Ph-N, 3Ph, 2Ph-N, 2Ph, and 1Ph-N) produce smaller current average THD current significantly depend on average THD voltage.

4. Conclusion

Comparative performance of multi PV connected grid under short circuit fault during transient phase to power quality using MPPT P and O/MPPT Fuzzy method has been presented. During transient phase, non-symmetrical faults (2Ph-N, 2Ph, and 1Ph-N) is capable to generate unbalance current/voltage greater depend on symietrical faults (3Ph-N and 3Ph). On symmetrical faults MPPT Fuzzy method produces average THD voltage smaller than MPPT P and O method. Otherwise on non symmetrical faults, MPPT P and O method gives average THD voltage slightly smaller than MPPT Fuzzy method. On symmetrical faults, MPPT Fuzzy/MPPT P and O method produce same average with THD current. Whereas in the case of non symmetrical fault, MPPT P and O method resulted in average THD current slightly smaller than MPPT Fuzzy method. The MPPT P and O/MPPT Fuzzy method on all short circuit faults during transient phase produce smaller current average THD depend on average THD voltage significantly. Futhermore the nominal of average THD current using both methods also meets THD limit prescribed in IEEE 519 standard.

Appendix

PV generator 1, 2, and 3: active power = 100 kW, temperature = 25^0 C, irradiance = 100 W/m^2; Three phase grid: short circuit power = 100 MVA, voltage = 380 volt (L-L), frequency = 50 Hz; Power transformer: rated power = 100 kVA, frequency = 50 Hz, voltage 380 Volt/20 kV (L-L), two winding type; Load 1, 2, and 3: active power = 20 kW, voltage = 380 volt (L-L), frequency = 50 Hz; Low Voltage Lines 1,2, and 3: resistance R = 0,1273 Ohm/km, inductance L = 93,37 mH/km, capasitance C = 1,274 µF/km; Length of Low Voltage Lines: Line 1, Line 2, Line 3 = 1 km; DC link capasitor: capacitance= 2000 μF, frequency = 4 kHz; PWM generator for DC/AC inverter: Sampling time= 5 x 10^{-6} Second; Fuzzy inference system = mamdani method; Fuzzy model composition = max-min; Input membership function: delta voltage=gbellmf, trimf, delta power: gbellmf, trimf; Output membership function: delta duty cycle = trimf.

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Lampiran 2.2

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Transient Power Quality Performance of Multi Photovoltaics using MPPT P and O/MPPT Fuzzy

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Abstract

This paper presents comparative performance of transient power quality due to multi PV integration to grid at both fixed temperature and solar irradiation connected using MPPT P and O/MPPT Fuzzy. This research is performed as five transient of short-circuit faults on PCC bus. An artificial intelligence with FLC is used to set duty cycle with step variable to control DC/DC boost converter, generate quick convergence to determine MPPT for controlling of PV output voltage and then its result is compared with MPPT P and O. During transient phase, non-symmetrical faults are capable of generate unbalance current/voltage greater than symmetrical faults. On symmetrical faults, MPPT Fuzzy produces average THD voltage/THD current smaller than MPPT P and O. Otherwise on non-symmetrical faults, MPPT P and O gives average THD voltage/THD current slightly smaller than MPPT Fuzzy. Both of MPPT P and O and MPPT Fuzzy on all short circuit faults during transient phase result significantly smaller current average THD current than average THD voltage and limits THD prescribed in IEEE 519.

Keywords: *Short Circuit, Transient, Power Quality, Multi PV, MPPT P and O, MPPT Fuzzy*

1. Introduction

The PV beside being able to generate power, it also results harmonics due to inverter as a medium to convert DC into AC voltage so capable to decrease power quality. The short circuit fault can cause rise of current and voltage drop in certain phases depend on fault types, so able to generate unbalance voltage and current on low voltage distribution network (grid). The research on power quality of PV connected grid to power system using LCL filter has been done Kon Keng Weng et. al. A number of power quality problems i.e. over voltage, less voltage, power fluctuations, inrush currents, low power factor, and current harmonics or THD will appear on microgrid power system. This research is conducted only on constant solar irradiance and temperature condition (1000 W/m^2 and 25^0 C) as environmental input parameters for PV systems [1]. The study on effect of solar radiation on grid connected to PV generator to power quality i.e. voltage/current hamonics, active/reactive power, and power factor correction has been investigated by Minas Patsalides, et.al. It considers two different scenarios of average and low radiation. The shortcoming of paper is not to consider effect of temperature as an input variable for PV generator [2]. Investigation of grid connected a single phase PV generator inverter using a current proportional resonant, proportional resonant integral, and genetic algorithm using an active filter to reduce current harmonics of inverter output has been studied by Renu et. al. The laxity of research is only done on a single phase PV as well as certain solar irradiance and temperature [3]. The dynamic analysis of power quality due to high penetration effect of distribution network connected to PV system under variable solar irradiance has been studied by Massoud Farhoodnea, et. al. It was performed on a 16 bus model and the result showed that high level penetration of grid connected PV will cause a number of power quality problems i.e. swell/flicker voltage, loss power factor and current harmonics. The system is only analyzed on voltage harmonics and did not consider the ambient temperature condition [4].

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Power quality characteristics in a number of three phase PV inverters at top roof PV i.e. harmonics distortion, voltage fluctuation, reactive power and power factor has been performed by K.P. Kontogianis, et. al [5]. A comparative study of MPPT between FLC and conventional PI controller has been presented for interfacing PV array with utility grid through a three-phase line-commutated inverter by Omid Zhoulai Bakhoda, et.al. FLC was dominating PI controller in many important aspects like i.e., provided active power for grid, output current shape of inverter, grid current and current THD [6]. A grid interfaced solar PV (SPV) power generating system in a three-phase four-wire (3P4W) distribution system has been proposed by Arun Kumar Verma, et.al. It consists of a SPV, a boost converter, a three leg VSC and a transformer connected at AC mains with power quality improvement. A FLC is utilized to extract MPP of a SPV system through control of an Insulated Gate Bipolar Transistor (IGBT) switch of the boost converter. This system was used for compensation of neutral current, harmonic currents, reactive power and to provide load balancing [7]. However, both of power quality analysis in both papers was only performed by using single PV. Power quality analysis due to integration of multi units of PV generator connected to three phase grid under variable solar irradiation level has been implemented by Amirullah, et.al. The research shows that grid voltage/current on PCC bus before use double tuned passive filter which only connected single PV still stable. The voltage/current became unstable, if PV installed on three phase grid was more than single generator. At level of solar irradiation was fixed, the greater number of PV connected to three-phase grid, then average THD of grid voltage/current also increased. At level of solar irradiation increased, average THD of grid voltage/current also increased. Double tuned passive filter was capable of reducing avarage THD of grid voltage/current. The PV in this research was still using MPPT with P and O algorithm and not using intelligent control [8].

Adaptive Neuro-fuzzy Inference System (ANFIS)-based improvement of MPPT with P and O Method for PV systems under different shading conditions has been investigated by Khaled Bataineh, et.al. The simulation show proposed algorithm efficiently reach MPP under uniform irradiation, sudden changes of irradiation, and partial shading [9]. The method for balancing line current and voltage, due to the presence of distributed generations (DGs) i.e. a number of single phase PV generation units in homes has been presented by Amirullah, et.al. The single phase PV generator is installed randomly on a 220 kV and 50 Hz three phase four wire distribution network using battery energy storage (BES) and three single phase bidirectional inverter circuits. The result shows that the combination of BES and three single phase bidirectional inverter able to reduce unbalanced line current/voltage. Otherwise, the combination of both circuit able to inreases current/voltage harmonics [10]. Power quality enhancement on low voltage of three phase grid caused by different level of PV generator integration using MPPT Fuzzy under variabel solar irradiance level on constant temperature and load has been investigated by Amirullah, et.al.. The application of MPPT Fuzzy was able to enhance profile of grid voltage and current THD due to different level of integration of PV generator to three phase grid corresponding with IEEE Standard 519-1992. MPPT Fuzzy was also able to improve input power factor better than MPPT P and O [11]. Rachid Belaidi, et.al has proposed a combined system of three-phase four-wire shunt active power filter and PV generator with MPPT P and O, to solve the power quality problems such as harmonic currents, poor power factor, and unbalanced load [12]. Salah Eddine Mankour, et al has investigated on modeling of a PV stand alone power system using two widely-adopted MPPT algorithms, P & O and incremental conductance method [13]. Bambang Purwahyudi, et. al has researched design of electrical characteristics of solar PV cell model by using self constructing neural network (SCNN) [14]. Julián A.C.C., et. al has used a mathematical model implemented in Matlab/Simulink to evaluate the performance of building integrated photovoltaic systems (BIPVS) [15]. Ahmad Saudi Samosir, et. al has investigated on modeling and simulation of MPPT used in solar PV power systems with fuzzy logic [16]. The researchs on enhancement of power quality and MPPT characteristics for PV in [1-16] were only analyzed in normal condition.

This paper presents comparative performance of power quality due to the multi PV integration at both fixed temperature and solar irradiation levels connected to 380 kV and 50 Hz distribution network using MPPT P and O/MPPT Fuzzy controller. The research is performed during transient disturbances of short-circuit fault on PCC bus based on five of short circuit faults. An artificial intelligence method with FLC is used to set duty cycle (D) with step variable to control DC/DC boost converter, generate quick convergence calculation to determine MPPT value for controlling of PV generator output voltage, and then its result is compared with MPPT

P and O method. The parameters are voltage/current unbalanced, voltage/current THD on each phase, and voltage/current average THD on PCC bus of three phase grid.

This paper is organized as follow. Section 2 presents proposed method i.e. proposed model of single PV generator using MPPT Fuzzy, model multi PV generator connected three phase grid under short circuit fault, simulation parameters, equivalent circuit, mathematical, and characteristic curve of PV model, MPPT P and O method, MPPT Fuzzy method, voltage and current harmonics, voltage and current unbalance. Section 3 describes comparative performance of multi PV connected grid under short circuit fault during transient phase to current/voltage unbalance and current/voltage THD of three phase grid using MPPT P and O/MPPT Fuzzy method. In this section, example cases studied are presented and the results are verified with those of Matlab/Simulink. Finally, the paper in concluded in Section 4.

2. Research Method

2.1. Proposed Model

Figure 1 shows model of a single PV system connected to a three phase grid. The DC/DC converter circuit consists of a boost converter circuit that serves to raise the DC output voltage from the PV generator. The DC output voltage of the boost converter circuit is then changed by a three phase DC/AC inverter into an AC voltage to three phase grid. The single PV model is then used as a reference to construct multiple (multi) PV models connected to grid through a three phase phase distribution transformer showed in Figure 2. This research uses three model group of PVs with an active power of 100 kW each. Besides connected three phase grid, multi PVs are also connected to three group of three phase loads with 20 kW of active power each. The aim of research is to compare performance of power quality due to the multi PV integration at both fixed temperature and solar irradiation levels connected to distribution network using MPPT P and O/MPPT Fuzzy. The research analysis includes transient disturbances of short-circuit fault on PCC bus based on a number of short circuit faults. An artificial intelligence method with FLC is used to set duty cycle (D) with step variable to control DC/DC boost converter, generate quick convergence calculation to determine MPPT value for controlling of PV output voltage, and then its result is compared with MPPT P and O method. The DC/DC converter produces a constant DC voltage as an input for DC/AC inverter using pulse with modulation (PWM).

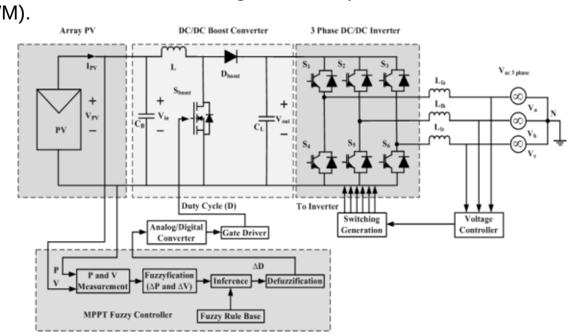

Figure 1. Proposed model of single PV using MPPT Fuzzy

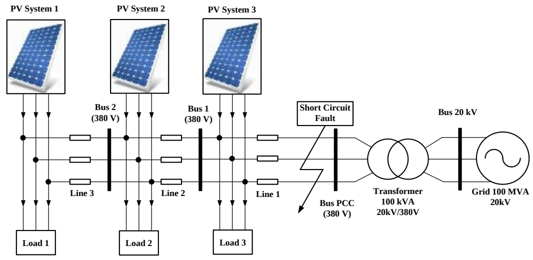

Figure 2. Proposed model of multi PV connected three phase grid under short circuit fault

There are two scenarios of multi PV connected three phase grids under fixed temperature and solar irradiation of 25^0 C and 400 W/m^2, i.e. using MPPT P and O and MPPT Fuzzy methods respectively. The transient state in each of MPPT controllers are indicated by five short-circuit faults, resulting in a total of ten fault scenarios i.e. three phases to ground (3Ph-N), three phases (3Ph), two phases to ground (2Ph-N), two phases (2 Ph), and single phase to ground (1Ph-N). Futhermore is to determine voltage/current unbalanced, voltage/current harmonics (THD) on each phase, and voltage/current average harmonics on PCC bus of three-phase low voltage grid. The final step is to validate the results referring to the ANSI/IEEE 241-1990 standard (unbalanced voltage and current) and IEEE Standard 519-1992 (average grid voltage and current harmonics). Simulation and analysis of this research use Matlab/Simulink. The simulation parameter values of proposed model are shown in Appendix Section.

2.2. Modelling of PV Array

Figure 3 shows the equivalent circuit of a solar panel. A solar panel is composed of several PV cells that have series, parallel, or series-parallel external connections [17].

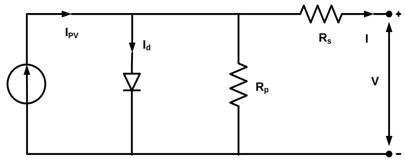

Figure 3. Equivalent circuit of solar panel

The V-I characteristic of a solar panel is showed in (1):

$$I = I_{PV} - I_o\left[\exp\left(\frac{V + R_S I}{aV_t}\right) - 1\right] - \frac{V + R_S I}{R_P} \quad (1)$$

where I_{PV} is the photovoltaic current, I_o is saturated reverse current, 'a' is the ideal diode constant, $V_t = N_S KTq^{-1}$ is the thermal voltage, N_S is the number of series cells, q is the electron charge, K is the Boltzmann constant, T is the temperature of p–n junction, R_S and R_P are series and parallel equivalent resistance of the solar panels. I_{PV} has a linear relation with light intensity and also varies with temperature variations. I_o is dependent on temperature variations. The values of I_{pv} and I_o are calculated as following (2) and (3):

$$I_{PV} = (I_{PV,n} + K_1 \Delta T)\frac{G}{G_n} I \quad (2)$$

$$I_o = \frac{I_{SC,n} + K_I \Delta T}{\exp(V_{OC,n} + K_V \Delta T)/aV_t - 1} \quad (3)$$

In which $I_{PV,n}$, $I_{SC,n}$ and $V_{OC,n}$ are photovoltaic current, short circuit current and open circuit voltage in standard conditions (T_n = 25 C and G_n = 1000 Wm^{-2}) respectively. K_I is the coefficient of short circuit current to temperature, $\Delta T = T - T_n$ is the temperature deviation from standard temperature, G is the light intensity and K_V is the ratio coefficient of open circuit voltage to temperature. Open circuit voltage, short circuit current and voltage-current corresponding to the maximum power are three important points of I-V characteristic of solar panel. These points are changed by variations of atmospheric conditions. By using (4) and (5) which are derived from PV model equations, short circuit current and open circuit voltage can be calculated in different atmospheric conditions.

$$I_{SC} = (I_{SC} + K_1 \Delta T)\frac{G}{G_n} \quad (4)$$

$$V_{OC} = V_{OC} + K_V \Delta T \quad (5)$$

2.3. MPPT P and O and MPPT Fuzzy

The initial research is to determine value of duty cycle (D) with a variable step to control DC/DC boost converter circuit with MPPT P and O. For PV converter, maximum power available is determined by PV cell characteristics, but this value often mismatches with the maximum power point (MPP) of the load. By implementing MPPT in PV systems, MPP can be maintained so that the number and size of PV panels can be reduced or energy yield can be optimized [18].

Due to moving of sun, which leads to change in irradiance, PV panels angle and variation of irradiance reaching the panels, energy generated from PV panels are absorbed does not constant over time. When this condition occurs, VI characteristics changes and MPP will move. If the system was previously operating at MPP, there will most probably a power loss with the same operating point and new condition. To overcome these problems, MPPT has been developed. The system includes no moving parts (where the modules are moved to track the sun). MPPT search for the maximum power independent based on environmental conditions (following changes in solar radiation and temperature) and maintain the PV terminal voltage remains constant at maximum value. The most used method of MPPT is P and O that algorithm is shown in Figure 4 [13] and its Matlab/Simulink model is presented in Figure 5.

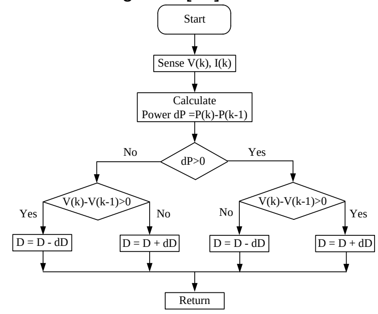

Figure 4. MPPT using P and O algorithm

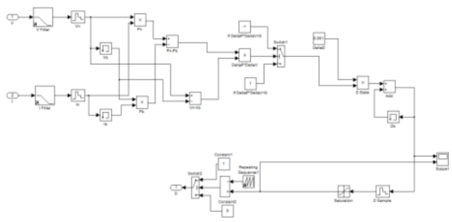

Figure 5. Matlab/Simulink for MPPT P and O

The same procedure for determining MPPT is using FLC. This method have been widely used in industrial process in the recent years due to their heuristic nature associated with simplicity, effectiveness and its multi rule based variable's consideration for both linear and non-linear parameter variation of the system. Fuzzy system is composed of knowledge based rules system. The main part of fuzzy is knowledge of base consisting of the If-Then rules. Fuzzy set theory is a new method of controlling the MPPT in obtaining the peak power point. The MPPT is implemented to obtain MPP operation voltage point faster with less overshoot and also it can minimize voltage fluctuation after MPP has been recognized. It also is capable to enhance power quality problem unbalance current/voltage and current/voltage harmonics. The control objective is to track maximum power will lead consequently to effective operation of the PV panel. To design the FLC, variables which represent the dynamic performance of the system should be chosen as the input to controller. Typical fuzzy based MPPT controller reffered to MPPT Fuzzy includes three basic components i.e. fuzzification, inference engine, and defuzzification block as shown in Figure 6 and its Matlab/Simulink model presented in Figure 7.

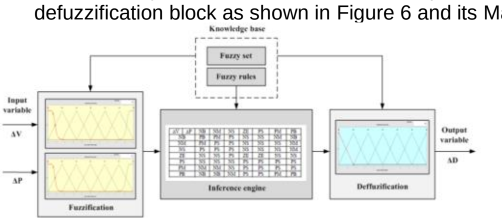

Figure 6. Structure of FLC

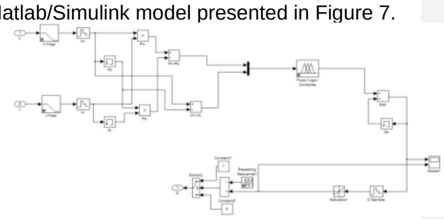

Figure 7. Matlab/Simulink for MPPT Fuzzy

Due account MPPT Fuzzy method is in terms of intelligence and speed. Fuzzy MPPT method is done by determining input variables, namely fuzzy control output power (ΔP) and output voltage (ΔV) PV generator, seven linguistic variables fuzzy sets, fuzzy operating system block (fuzzification, fuzzy rules, and defuzzification), Function ΔP and Δ V during fuzzification, a table fuzzy rule base, crisp values to determine duty cycle (D) in defuzzification phase with variable step to control DC /DC boost converter. Figure 8 shows Matlab/Simulink model for MPPT Fuzzy. During fuzzification phase shown in Figure 7, a number of input variables is calculated and converted into a linguistic variable based on the subset called membership function (MF). To translate value of voltage change and power change in, input fuzzy "change of voltage" and "change of power" is designed to use seven fuzzy variable called PB (Positive Big), PM (Positive Medium), NS (Negative Small), PS (Positive Small) ZE (Zero), NM (Negative Medium), and Negative Big (NB). voltage change (ΔV) and power changes (ΔP) is a proposed system input variables and output variable FLC is duty cycle change (ΔD). The membership functions i.e. voltage changes, power changes, and duty cycle change, each are shown in Figure 8 into Figure 10. Limit of input and output membership functions applied, determined by prior knowledge of parameter variation.

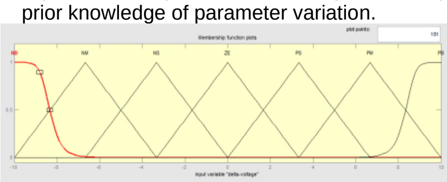

Figure 8. Input voltage change (delta voltage)

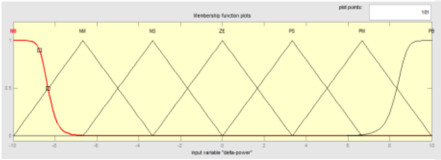

Figure 9. Input power change (delta power)

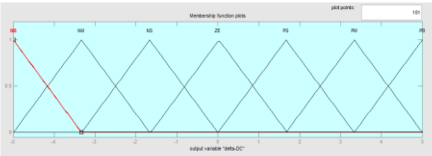

Figure 10. Output duty cycle change (delta D)

The fuzzy rule algorithm collects a number of fuzzy control rules in a specific order. This rule is used to control system to meet desired performance requirements, and they are designed from a knowledge of intelligent control systems. The fuzzy inference using a method that relates to a composition Mamdani Max-Min. Fuzzy inference system consists of three parts, namely rule base, database, and reasoning mechanism. Rule base consists of a number of If-Then rule for proper operation of controller. The If side of rule is called antecedent and Then side is called consequence. These rules may be regarded as similar response made by human thought processes and controllers using linguistic input variables, obtained after fuzzification for operation of these rules. The database consists of all user-defined membership function to be used in a number of these rules. Reasoning mechanism basically given processing rules based on specific rules and given conditions required result.

After determining ΔV and ΔP, these value are then converted into linguistic variables and use them as input functions for FLC. The output value is ΔD is generated using block inference and fuzzy rules as shown in Table 1. Finally defuzzification block operates to change value of ΔD is raised from linguistic variables into numeric variables back. Numeric variables that become inputs signal for the IGBT switch of DC/DC boost converter to be able to determine MPPT value for each generation PV accurately at the same time also improve power quality as a result of integration of multi PV to low voltage three phase grid under short circuit fault.

Table 1. Fuzzy Rules

ΔV ΔP	NB	NM	NS	ZE	PS	PM	PB
NB	PB	PM	PS	NS	NS	NM	NB
NM	PM	PS	PS	NS	NS	NS	NM
NS	PS	PS	PS	NS	NS	NS	NM
ZE	NS	NS	PS	ZE	ZE	NS	NS
PS	NS	NS	NS	PS	PS	PS	PS
PM	NM	NM	NS	PS	PS	PS	PS
PB	NB	NB	NM	PS	PS	PM	PB

2.4. Voltage and Current Harmonics

Power quality means quality of voltage and current. Power quality is determined based on the voltage and current value or the tolerance limit of equipment used. In general, current and voltage waveform of pure sinusoidal waves. One problem that occurs is non sinusoida or distorted current and voltage waves generated by harmonics in the power system [11].

Harmonic is distorted periodic steady state wave caused by the interaction between the shape of a sine wave at the fundamental frequency system with another wave component which is an integer multiples frequency of fundamental frequency. The most common harmonic index, which relates to the voltage waveform is THD (6), which is defined as the root mean square (rms) of the harmonics expressed as a percentage of the fundamental component as showed in [19]. For most applications, it is sufficient to consider the harmonic range from the 2nd to 25th, but most standards specify up to the 50th. Second harmonic index is current THD means the ratio of rms harmonic current value to rms fundamental current which expressed in (7) [11].

$$THD_V = \frac{\sqrt{\sum_{n=2}^{N} V_n^2}}{V_1} \times 100\,\% \quad (6) \qquad THD_I = \frac{\sqrt{\sum_{n=2}^{N} I_n^2}}{I_1} \times 100\,\% \quad (7)$$

Where V_n and I_n (the rms voltage and current at harmonic n), V_1 and I_1 (the fundamental rms voltage and current), N (the maximum harmonic order to be considered). The allowable maximum THD value for each country is different depending on the standard used. THD standards most often used in electric power system is IEEE 519-1992. There are two criteria used in analysis of harmonics distortion i.e. voltage distortion and current distortion limit [20].

2.5. Voltage and Current Unbalance

There are several standards that can be used to determine level of voltage unbalance in three phase systems, e.g. IEC, NEMA, and IEEE. In this study, value of unbalance voltage use (8) is based ANSI/IEEE 241-1990 Standard [21] as follows:

$$V(\%) = \frac{\left| V_{a\,\mathrm{varage}} - V_{a,b,c\,\mathrm{min\;or\;max}} \right|}{V_{a\,\mathrm{varage}}} \times 100\% \qquad (8)$$

By using (8), value of unbalance voltage expressed in percent (%) and is defined as follows; $V_{avarage}$ is the average value of maximum voltage on phase a, b, c, (volt), $V_{a,b,c\ min}$ is minimum voltage on phase a, b, c, (volt), $V_{a,b,c\ max}$ is maximum voltage on phase a, b, c (volt). By using the same equation, then percentage of unbalance current can be calculated by replacing voltage magnitude into current magnitude.

3. Results and Discussions

This research is started by determining the maximum and minimum of grid current in each phase, unbalanced current using (8), current THD on each phase using (7), and average THD of three phase current grids on PCC bus using MPPT P and O/MPPT Fuzzy method. By using the same procedure then obtained unbalanced voltage, voltage THD on each phase, and average voltage THD. Table 2 shows unbalanced current value, THD grid current, and average THD of grid current, multi PV connected on a three phase low voltage distribution network using MPPT P and O/MPPT Fuzzy method. There are five short-circuit faults i.e. 3Ph-N, 3Ph, 2Ph-N, 2Ph, and 1Ph-N. So there are three fault durations i.e. before fault, during fault (transient), and after fault phase with time durations are 0-0.02 sec, 0.02-0.04 sec, and 0.04-0.06 sec respectivelty. The simulation result of unbalanced current/voltage and average THD current/voltage is also presented as verification under five short circuit faults. The results analysis is conducted only on short circuit fault during transient phase.

Table 2. Unbalance Current and Average Current Harmonics

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No.	Fault Type	Fault Phase	Phase Current (V) A	B	C	Unba Current (%)	THD$_I$ (%) A	B	C	Avg THD$_I$ (%)
					MPPT P and O Method					
1	Normal	Before	10.51	10.67	10.52	0.978	2.34	1.65	1.87	1.954
		Transient	**10.61**	**10.74**	**10.69**	**0.562**	**2.65**	**3.22**	**3.40**	**3,090**
		After	10.85	10.97	10.90	0.581	4.11	4.34	3.63	4.020
2	3Ph-N	Before	10.51	10.66	10.52	0.916	2.35	1.62	1.86	1.944
		Transient	**1331**	**1359**	**1296**	**2.283**	**4.41**	**2.05**	**2.38**	**2.947**
		After	38.91	11.57	326.1	159.786	165	92.55	71.13	109.560
3	3Ph	Before	10.51	10.67	10.52	0.978	2.36	1.64	1.88	1.960
		Transient	**1331**	**1359**	**1296**	**2.283**	**4.41**	**2.05**	**2.38**	**2.947**
		After	103	11.98	102.3	42.213	110.84	90.27	110.05	103.720
4	2Ph-N	Before	10.51	10.66	10.52	0.915	2.34	1.62	1.86	1.947
		Transient	**1336**	**1350**	**7.671**	**50.353**	**4.70**	**1.76**	**3.91**	**3.457**
		After	41.92	11.69	10.98	94.705	164.26	73.46	4.47	80.730

5	2Ph	Before	10.51	10.66	10.52	0.915	2.35	1.63	1.88	1.954
		Transient	**1179**	**1179**	**10.32**	**49.347**	**3.67**	**3.67**	**3.33**	**3.557**
		After	17.71	15.06	10.98	21.440	154.01	180.83	4.96	113.267
6	1Ph-N	Before	10.51	10.66	10.58	0.725	2.34	1.62	1.86	1.940
		Transient	**1132**	**9.451**	**9.482**	**195.065**	**4.96**	**3.27**	**4.06**	**4.097**
		After	44.29	11.02	10.93	100.589	164.75	5.60	3.57	57.974
				MPPT Fuzzy Method						
1	Normal	Before	10.48	10.63	10.52	0.822	2.04	1.24	1.69	1.657
		Transient	**10.72**	**10.76**	**10.80**	**0.372**	**3.32**	**3.76**	**4.28**	**3.787**
		After	11.01	11.13	11.05	0.603	4.98	5.45	5.01	5.147
2	3Phasa-N	Before	10.48	10.63	10.52	0.822	2.04	1.25	1.69	1.660
		Transient	**1331**	**1359**	**1296**	**2.283**	**4.41**	**2.05**	**2.38**	**2.947**
		After	38.99	11.61	326.5	159.746	165.09	92.62	71.07	109.594
3	3Phasa	Before	10.48	10.63	10.52	0.822	2.04	1.24	1.69	1.657
		Transient	**1331**	**1359**	**1296**	**2.283**	**4.41**	**2.05**	**2.38**	**2.947**
		After	103	11.98	103.6	42.191	110.89	90.73	109.79	103.804
4	2Phasa-N	Before	10.48	10.63	10.52	0.822	2.05	1.25	1.69	1.664
		Transient	**1336**	**1350**	**7.475**	**50.364**	**4.70**	**1.76**	**6.0**	**4.154**
		After	42.16	11.98	11.18	93.631	163.75	72.36	6.61	80.907
5	2Phasa	Before	10.48	10.63	10.52	0.822	2.04	1.24	1.69	1.657
		Transient	**1179**	**1179**	**10.09**	**49.361**	**3.69**	**3.66**	**5.10**	**4.150**
		After	18.05	15.3	11.26	18.560	152.15	178.90	4.55	111.867
6	1Phase-N	Before	10.48	10.63	10.52	0.822	2.04	1.25	1.69	1.660
		Transient	**1332**	**9.203**	**9.319**	**195.886**	**4.97**	**4.88**	**5.28**	**5.044**
		After	44.42	11.30	11.40	98.540	164.46	7.64	6.75	59.617

Table 3 shows unbalanced current value, THD grid current, and average THD of grid current, multi PV connected on a three phase low voltage distribution network using MPPT P and O/ MPPT Fuzzy method.

Table 3. Unbalance Voltage and Average Voltage Harmonics

No.	Fault Type	Fault Phase	Phase Voltage (V)			Unba Voltage (%)	THD_V (%)			Avg THD_V (%)
			A	B	C		A	B	C	
				MPPT P and O Method						
1	Normal	Before	307.8	307.7	307.8	0	4.08	4.00	3.96	4.014
		Transient	**308.8**	**308.7**	**307.8**	**0**	**6.74**	**7.06**	**7.14**	**6.980**
		After	307.8	307.8	307.8	0	10.38	11.41	11.41	11.067
2	3 Ph-N	Before	307.7	307.7	307.7	0	4.12	4.05	3.96	4.044
		Transient	**1.332**	**1.350**	**1.307**	**1.523**	**6.50**	**179.32**	**189.46**	**125.094**
		After	301.7	300.4	241.9	7.240	16.94	20.0	53.83	31.924
3	3 Ph	Before	307.7	307.7	307.7	0	4.07	4.02	3.96	4.017
		Transient	**1.347**	**1.325**	**1.318**	**1.279**	**275.94**	**336.34**	**341.31**	**317.864**
		After	289.3	300.5	296.2	4.948	22.43	20.25	27.30	23.327
4	2 Ph-N	Before	307.7	307.8	307.7	0	4.07	4.03	3.98	4.027
		Transient	**2.242**	**2.268**	**308.4**	**195.677**	**5.36**	**106.86**	**7.83**	**39.017**
		After	301	301.5	307.7	1.418	18.51	20.16	10.94	16.537
5	2 Ph	Before	307.7	307.7	307.8	0	4.04	4.07	3.98	4.030
		Transient	**155.0**	**152.7**	**307.8**	**50.025**	**7.96**	**8.09**	**7.72**	**7.924**
		After	306.3	296.1	307.8	1.451	18.09	20.66	10.84	16.530
6	1Ph-N	Before	307.7	307.8	307.7	0	4.08	4.03	3.95	4.020
		Transient	**2.658**	**308.1**	**308.1**	**49.356**	**5.48**	**7.56**	**7.88**	**6.974**
		After	300.6	307.7	307.7	0.776	17.51	11.50	10.21	13.074
				MPPT Fuzzy Method						
1	Normal	Before	307.8	307.7	307.8	0	2.75	2.74	2.65	2.714
		Transient	**307.7**	**307.7**	**307.7**	**0**	**8.23**	**9.74**	**9.79**	**9.254**
		After	307.7	307.7	307.6	0	13.68	14.94	14.43	14.35
2	3 Ph-N	Before	307.8	307.8	307.8	0	2.72	2.78	2.61	2.704
		Transient	**1.332**	**1.351**	**1.306**	**1.605**	**5.38**	**172.84**	**181.97**	**120.064**
		After	301.7	300.6	241.9	7.278	24.26	24.80	56.05	35.037
3	3 Ph	Before	307.8	307.8	307.8	0	2.76	2.73	2.61	2.700
		Transient	**1.339**	**1.343**	**1.307**	**1.003**	**223.47**	**283.53**	**294.43**	**267.144**
		After	289.3	300.4	296.3	4.913	29.55	25.81	30.89	28.760
4	2 Ph-N	Before	307.8	307.8	307.8	0	2.73	2.79	2.61	2.710
		Transient	**2.242**	**2.269**	**308.4**	**195.676**	**4.90**	**102.82**	**11.16**	**39.627**
		After	301.0	301.5	307.6	1.396	20.97	22.70	15.70	19.790
5	2 Ph	Before	307.8	307.8	307.8	0	2.77	2.72	2.61	2.700
		Transient	**155.0**	**152.7**	**307.8**	**50.025**	**10.12**	**10.28**	**9.98**	**10.127**
		After	306.4	295.9	307.6	1.418	20.94	23.82	14.09	19.617
6	1Ph-N	Before	307.8	307.8	307.8	0	2.73	2.78	2.61	2.707
		Transient	**2.657**	**308.1**	**308.0**	**49.381**	**5.22**	**9.77**	**10.63**	**8,570**
		After	300.5	307.7	307.6	0.798	22.19	16.94	15.93	18.354

Figure 11 shows grid current waveform of multi PV connected to three phase grid on a PCC bus using MPPT P and O/MPPT Fuzzy method under normal condition, 3Ph-N, 2Ph-N, and 1Ph-N fault.

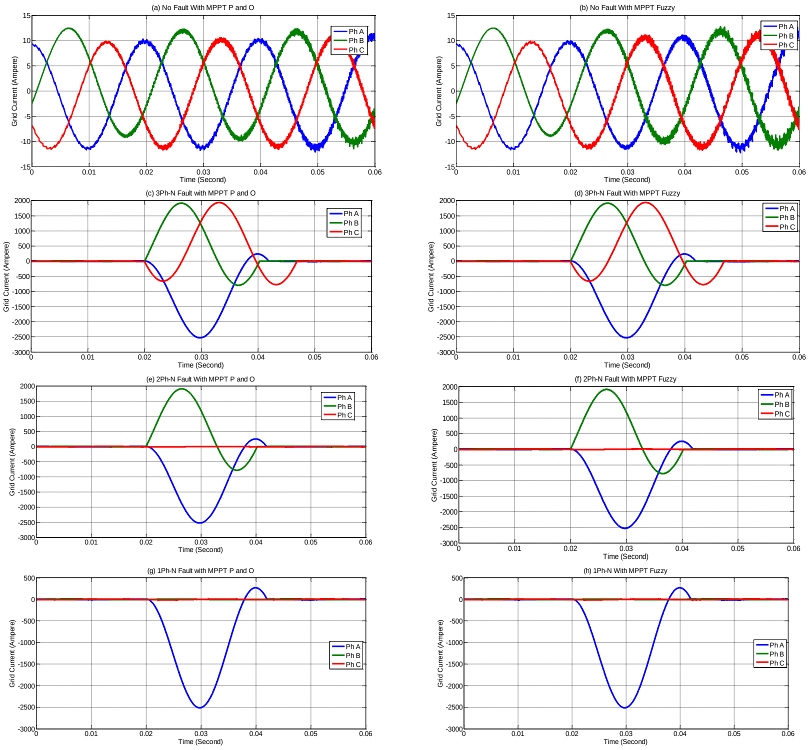
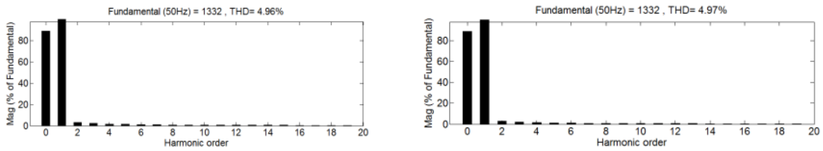


Figure 11. Current waveform of multi PV connected to a three phase grid on PCC bus

Figure 12 shows grid current harmonics spectra of phase A during transient phase due to the multi PV connected to three phase grid on PCC bus using MPPT P and O and MPPT Fuzzy method under 1Ph-N fault.



(a) MPPT P and O (b) MPPT Fuzzy

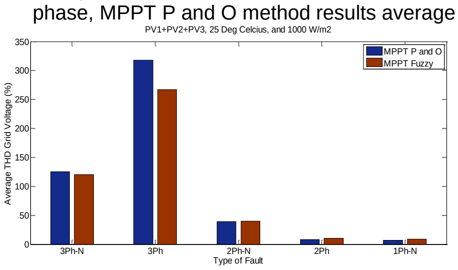
Figure 12. Current harmonics spectra of phase A under 1Ph-N fault

Table 2 presents that under normal condition (no fault), phase current of multi PV (PV1+PV2 + PV3) using MPPT P and O method in transient phase are 10.61 A, 10.74 A, 10.69 A resulting in an unbalanced current of 0.562%. In short circuit faults, the highest unbalanced currents of transient phase is generated by 1Ph-N fault of 195.886% with current on phase A, B, and C of 1332 volt, 9.203 volt, 9.319 volt respectively. The 3Ph-N and 3Ph fault on transient phase produce an unbalanced current of equal to 2,283% resulted by phase current A, B, and C are 1331 A, 1359 A, 1239 A respectively. The implementation of MPPT Fuzzy method under normal condition and transient phase generates phase current of 10.61 A, 10.74 A, 10.69 A so as to produce an unbalanced current equal to 0.562%. If using MPPT Fuzzy method under fault on transient phase, the highest unbalanced current is generated by 2Ph-N faults of 195.886%. At the same condition the smallest unbalanced current is generated by 3Ph-N and 3Ph-N fault equal to 2.282%. In non-symmetrical fault, the use of MPPT P and O method gives an unbalanced current of transient phase slightly lower than MPPT Fuzzy method. While in symmetrical fault, MPPT P and O/MPPT Fuzzy method for controlling of output power of multi PV gives same unbalanced current of transient phase of 2,283%.

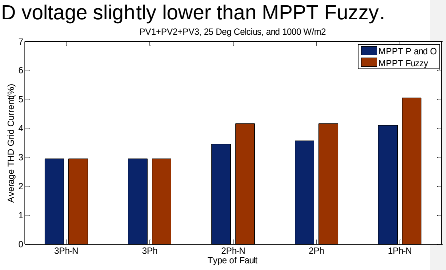
In normal condition, by using both MPPT P and O and MPPT Fuzzy method, the average THD current on transient phase are 3.090% and 3.787%, respectively. When using MPPT P and O, the highest average THD current is generated by 1Ph-N fault of 4,097%. In the same method, the smallest average THD voltage is generated by 3Ph-N and 3Ph equal to 2,947%. If using Fuzzy MPPT, the highest average THD current is generated by 1Ph-N fault of 5.044%. In the same method, the smallest average THD current is generated by 3Ph-N and 3Ph equal to 2,947%. In the symmetrical faults, both MPPT P and O and MPPT Fuzzy method produce average THD current during transient phase equal to 2,947%. Whereas in the case of non-symmetric fault, MPPT P and O resulted in average THD current of transient phase slightly smaller than MPPT Fuzzy method.

Table 4 presents that under normal condition, the voltage values on phase A, B, and C of multi PV using MPPT P and O method under transient phase are 308.8 volt, 308.7 volt, 307.8 volt, respectively, resulting in an unbalanced voltage of 0%. In the short circuit faults, the highest unbalanced voltage during transient phase is generated by a 2Ph-N fault of 195.677% with a phase voltage of A, B, and C respectively of 2.242 volt, 2.268 volts, and 308.4 volt. The 3Ph fault during transient phase produce the smallest unbalanced voltage of 1.279% resulted from phase voltage A, B, and C respectively of 1.347 volt, 1.325 volt, 1.318 volt. The use of MPPT Fuzzy method under normal condition and transient phase gives 308.8 volt, 308.7 volt, 307.8 volt, respectively, resulting in an unbalanced voltage equal to 0%. When using the MPPT Fuzzy method under short-circuit fault during transient phase, the highest unbalanced voltage is generated by a 2Ph-N fault of 195.676%. Under the same condition, the lowest unbalanced voltage is generated by 3Ph fault of 1.003%. In non-symmetrical faults (2Ph-N, 2Ph, and 1Ph-N), the implemantation of MPPT P and O and MPPT Fuzzy method to control output power of multi PV produces nominal unbalanced voltage during transient phase results a close the same value. While in symmetrical fault (3Ph-N and 3Ph) MPPT P and O and MPPT Fuzzy method produce different unbalance voltage on transient phase. During 3Ph-N fault on transient phase, MPPT P and O method results in an unbalanced transient phase voltage of 1.523% slightly lower than MPPT Fuzzy method of 1.605%. But during 3Ph fault on transient phase, MPPT Fuzzy produces an unbalanced voltage of 1.003% slightly lower than MPPT P and O of 1.279%.

In normal condition using both MPPT P and O and MPPT Fuzzy method, THD average voltages are 6.980% and 9.254%, respectively. If using MPPT P and O method, then the largest average THD voltage is generated by a 3Ph fault of 317.846%. By using the same method, the lowest average THD voltage is produced by 1Ph-N fault of 6.974%. If using Fuzzy MPPT method, the largest average THD voltage is also generated by a 3Ph fault of 267.144%. By using the same method, the lowest average THD voltage is generated by 1Ph-N fault of 8.570%. During symmetrical fault on transient phase, MPPT Fuzzy method results average THD voltage smaller than MPPT P and O. Otherwise during non-symmetrical fault on transient phase, MPPT P and O method results average THD voltage slightly lower than MPPT Fuzzy.



(a) Average THD voltage



(b) Average THD current

Figure 13. Performance of average voltage and current harmonic during transient phase

Figure 13.a describes that on symmetrical fault during transient phase (3Ph-N and 3Ph), MPPT Fuzzy method produces average THD voltage smaller than MPPT P and O method. Otherwise on non-symmetrical fault during transient phase (2Ph-N, 2Ph, and 1Ph-N), MPPT P and O method gives average THD voltage slightly smaller than MPPT Fuzzy method. Figure 14.b describes that on symmetrical fault during transient phase (3Ph-N and 3Ph), MPPT Fuzzy and and MPPT P and O method produce same average THD current. Whereas in the case of non-symmetrical fault during transient phase (2Ph-N, 2Ph, and 1P-N), MPPT P and O method resulted in average THD current slightly smaller than MPPT Fuzzy method. The MPPT P and O method and the MPPT Fuzzy method on all short circuit fault during transient phase (3Ph-N, 3Ph, 2Ph-N, 2Ph, and 1Ph-N) produce smaller current average THD current significantly depend on average THD voltage.

4. Conclusion

Comparative performance of multi PV connected grid under short circuit fault during transient phase to power quality using MPPT P and O/MPPT Fuzzy method has been presented. During transient phase, non-symmetrical faults (2Ph-N, 2Ph, and 1Ph-N) is capable to generate unbalance current/voltage greater depend on symietrical faults (3Ph-N and 3Ph). On symmetrical faults, MPPT Fuzzy results average THD voltage/THD current smaller than MPPT P and O. Otherwise on non-symmetrical faults, MPPT P and O gives average THD voltage/THD current slightly smaller than MPPT Fuzzy. The MPPT P and O/MPPT Fuzzy method on all short circuit faults during transient phase produce smaller current average THD depend on average THD voltage significantly. Futhermore the nominal of average THD current using both methods also meets THD limit prescribed in IEEE 519 standard.

Appendix

PV generator 1, 2, and 3: active power = 100 kW, temperature = 25^0 C, irradiance = 100 W/m^2; Three phase grid: short circuit power = 100 MVA, voltage = 380 volt (L-L), frequency = 50 Hz; Power transformer: rated power = 100 kVA, frequency = 50 Hz, voltage 380 Volt/20 kV (L-L), two winding type; Load 1, 2, and 3: active power = 20 kW, voltage = 380 volt (L-L), frequency = 50 Hz; Low Voltage Lines 1,2, and 3: resistance R = 0,1273 Ohm/km, inductance L = 93,37 mH/km, capasitance C = 1,274 μF/km; Length of Low Voltage Lines: Line 1, Line 2, Line 3 = 1 km; DC link capasitor: capacitance= 2000 μF, frequency = 4 kHz; PWM generator for DC/AC inverter: Sampling time= 5 x 10^{-6} Second; Fuzzy inference system = mamdani method; Fuzzy model composition = max-min; Input membership function: delta voltage=gbellmf, trimf, delta power: gbellmf, trimf; Output membership function: delta duty cycle = trimf.

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Transient Power Quality Performance of Multi Photovoltaics using MPPT P and O/MPPT Fuzzy

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Abstract

This paper presents comparative performance of transient power quality due to multi PV integration to grid at both fixed temperature and solar irradiation connected using MPPT P and O/MPPT Fuzzy. This research is performed as five transient of short-circuit faults on PCC bus. An artificial intelligence with FLC is used to set duty cycle with step variable to control DC/DC boost converter, generate quick convergence to determine MPPT for controlling of PV output voltage and then its result is compared with MPPT P and O. During transient phase, non-symmetrical faults are capable of generate unbalance current/voltage greater than symmetrical faults. On symmetrical faults, MPPT Fuzzy produces average THD voltage/THD current smaller than MPPT P and O. Otherwise on non-symmetrical faults, MPPT P and O gives average THD voltage/THD current slightly smaller than MPPT Fuzzy. Both of MPPT P and O and MPPT Fuzzy on all short circuit faults during transient phase result significantly smaller current average THD current than average THD voltage and limits THD prescribed in IEEE 519.

Keywords: *Short Circuit, Transient, Power Quality, Multi PV, MPPT P and O, MPPT Fuzzy*

1. Introduction

The PV beside being able to generate power, it also results harmonics due to inverter as a medium to convert DC into AC voltage so capable to decrease power quality. The short circuit fault can cause rise of current and voltage drop in certain phases depend on fault types, so able to generate unbalance voltage and current on low voltage distribution network (grid). The research on power quality of PV connected grid to power system using LCL filter has been done Kon Keng Weng et. al. A number of power quality problems i.e. over voltage, less voltage, power fluctuations, inrush currents, low power factor, and current harmonics or THD will appear on microgrid power system. This research is conducted only on constant solar irradiance and temperature condition (1000 W/m^2 and 25^0 C) as environmental input parameters for PV systems [1]. The study on effect of solar radiation on grid connected to PV generator to power quality i.e. voltage/current hamonics, active/reactive power, and power factor correction has been investigated by Minas Patsalides, et.al. It considers two different scenarios of average and low radiation. The shortcoming of paper is not to consider effect of temperature as an input variable for PV generator [2]. Investigation of grid connected a single phase PV generator inverter using a current proportional resonant, proportional resonant integral, and genetic algorithm using an active filter to reduce current harmonics of inverter output has been studied by Renu et. al. The laxity of research is only done on a single phase PV as well as certain solar irradiance and temperature [3]. The dynamic analysis of power quality due to high penetration effect of distribution network connected to PV system under variable solar irradiance has been studied by Massoud Farhoodnea, et. al. It was performed on a 16 bus model and the result showed that high level penetration of grid connected PV will cause a number of power quality problems i.e. swell/flicker voltage, loss power factor and current harmonics. The system is only analyzed on voltage harmonics and did not consider the ambient temperature condition [4].

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Power quality characteristics in a number of three phase PV inverters at top roof PV i.e. harmonics distortion, voltage fluctuation, reactive power and power factor has been performed by K.P. Kontogianis, et. al [5]. A comparative study of MPPT between FLC and conventional PI controller has been presented for interfacing PV array with utility grid through a three-phase line-commutated inverter by Omid Zhoulai Bakhoda, et.al. FLC was dominating PI controller in many important aspects like i.e., provided active power for grid, output current shape of inverter, grid current and current THD [6]. A grid interfaced solar PV (SPV) power generating system in a three-phase four-wire (3P4W) distribution system has been proposed by Arun Kumar Verma, et.al. It consists of a SPV, a boost converter, a three leg VSC and a transformer connected at AC mains with power quality improvement. A FLC is utilized to extract MPP of a SPV system through control of an Insulated Gate Bipolar Transistor (IGBT) switch of the boost converter. This system was used for compensation of neutral current, harmonic currents, reactive power and to provide load balancing [7]. However, both of power quality analysis in both papers was only performed by using single PV. Power quality analysis due to integration of multi units of PV generator connected to three phase grid under variable solar irradiation level has been implemented by Amirullah, et.al. The research shows that grid voltage/current on PCC bus before use double tuned passive filter which only connected single PV still stable. The voltage/current became unstable, if PV installed on three phase grid was more than single generator. At level of solar irradiation was fixed, the greater number of PV connected to three-phase grid, then average THD of grid voltage/current also increased. At level of solar irradiation increased, average THD of grid voltage/current also increased. Double tuned passive filter was capable of reducing avarage THD of grid voltage/current. The PV in this research was still using MPPT with P and O algorithm and not using intelligent control [8].

Adaptive Neuro-fuzzy Inference System (ANFIS)-based improvement of MPPT with P and O Method for PV systems under different shading conditions has been investigated by Khaled Bataineh, et.al. The simulation show proposed algorithm efficiently reach MPP under uniform irradiation, sudden changes of irradiation, and partial shading [9]. The method for balancing line current and voltage, due to the presence of distributed generations (DGs) i.e. a number of single phase PV generation units in homes has been presented by Amirullah, et.al. The single phase PV generator is installed randomly on a 220 kV and 50 Hz three phase four wire distribution network using battery energy storage (BES) and three single phase bidirectional inverter circuits. The result shows that the combination of BES and three single phase bidirectional inverter able to reduce unbalanced line current/voltage. Otherwise, the combination of both circuit able to inreases current/voltage harmonics [10]. Power quality enhancement on low voltage of three phase grid caused by different level of PV generator integration using MPPT Fuzzy under variabel solar irradiance level on constant temperature and load has been investigated by Amirullah, et.al.. The application of MPPT Fuzzy was able to enhance profile of grid voltage and current THD due to different level of integration of PV generator to three phase grid corresponding with IEEE Standard 519-1992. MPPT Fuzzy was also able to improve input power factor better than MPPT P and O [11]. Rachid Belaidi, et.al has proposed a combined system of three-phase four-wire shunt active power filter and PV generator with MPPT P and O, to solve the power quality problems such as harmonic currents, poor power factor, and unbalanced load [12]. Salah Eddine Mankour, et al has investigated on modeling of a PV stand alone power system using two widely-adopted MPPT algorithms, P & O and incremental conductance method [13]. Bambang Purwahyudi, et. al has researched design of electrical characteristics of solar PV cell model by using self constructing neural network (SCNN) [14]. Julián A.C.C., et. al has used a mathematical model implemented in Matlab/Simulink to evaluate the performance of building integrated photovoltaic systems (BIPVS) [15]. Ahmad Saudi Samosir, et. al has investigated on modeling and simulation of MPPT used in solar PV power systems with fuzzy logic [16]. The researchs on enhancement of power quality and MPPT characteristics for PV in [1-16] were only analyzed in normal condition.

This paper presents comparative performance of power quality due to the multi PV integration at both fixed temperature and solar irradiation levels connected to 380 kV and 50 Hz distribution network using MPPT P and O/MPPT Fuzzy controller. The research is performed during transient disturbances of short-circuit fault on PCC bus based on five of short circuit faults. An artificial intelligence method with FLC is used to set duty cycle (D) with step variable to control DC/DC boost converter, generate quick convergence calculation to determine MPPT value for controlling of PV generator output voltage, and then its result is compared with MPPT

P and O method. The parameters are voltage/current unbalanced, voltage/current THD on each phase, and voltage/current average THD on PCC bus of three phase grid.

This paper is organized as follow. Section 2 presents proposed method i.e. proposed model of single PV generator using MPPT Fuzzy, model multi PV generator connected three phase grid under short circuit fault, simulation parameters, equivalent circuit, mathematical, and characteristic curve of PV model, MPPT P and O method, MPPT Fuzzy method, voltage and current harmonics, voltage and current unbalance. Section 3 describes comparative performance of multi PV connected grid under short circuit fault during transient phase to current/voltage unbalance and current/voltage THD of three phase grid using MPPT P and O/MPPT Fuzzy method. In this section, example cases studied are presented and the results are verified with those of Matlab/Simulink. Finally, the paper in concluded in Section 4.

2. Research Method

2.1. Proposed Model

Figure 1 shows model of a single PV system connected to a three phase grid. The DC/DC converter circuit consists of a boost converter circuit that serves to raise the DC output voltage from the PV generator. The DC output voltage of the boost converter circuit is then changed by a three phase DC/AC inverter into an AC voltage to three phase grid. The single PV model is then used as a reference to construct multiple (multi) PV models connected to grid through a three phase phase distribution transformer showed in Figure 2. This research uses three model group of PVs with an active power of 100 kW each. Besides connected three phase grid, multi PVs are also connected to three group of three phase loads with 20 kW of active power each. The aim of research is to compare performance of power quality due to the multi PV integration at both fixed temperature and solar irradiation levels connected to distribution network using MPPT P and O/MPPT Fuzzy. The research analysis includes transient disturbances of short-circuit fault on PCC bus based on a number of short circuit faults. An artificial intelligence method with FLC is used to set duty cycle (D) with step variable to control DC/DC boost converter, generate quick convergence calculation to determine MPPT value for controlling of PV output voltage, and then its result is compared with MPPT P and O method. The DC/DC converter produces a constant DC voltage as an input for DC/AC inverter using pulse with modulation (PWM).

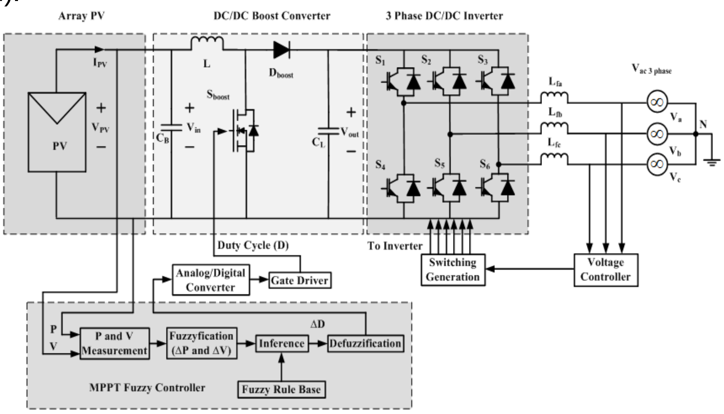


Figure 1. Proposed model of single PV using MPPT Fuzzy

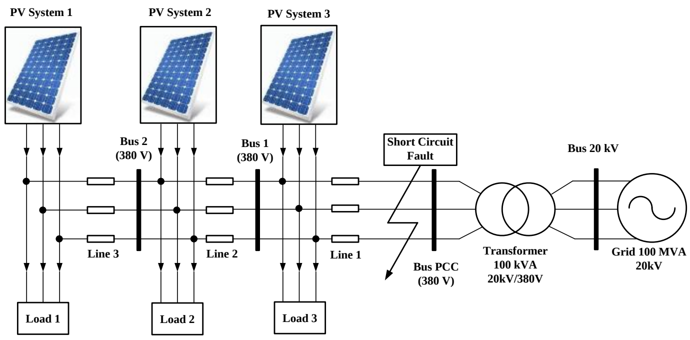


Figure 2. Proposed model of multi PV connected three phase grid under short circuit fault

There are two scenarios of multi PV connected three phase grids under fixed temperature and solar irradiation of 25^0 C and 400 W/m^2, i.e. using MPPT P and O and MPPT Fuzzy methods respectively. The transient state in each of MPPT controllers are indicated by five short-circuit faults, resulting in a total of ten fault scenarios i.e. three phases to ground (3Ph-N), three phases (3Ph), two phases to ground (2Ph-N), two phases (2 Ph), and single phase to ground (1Ph-N). Futhermore is to determine voltage/current unbalanced, voltage/current harmonics (THD) on each phase, and voltage/current average harmonics on PCC bus of three-phase low voltage grid. The final step is to validate the results referring to the ANSI/IEEE 241-1990 standard (unbalanced voltage and current) and IEEE Standard 519-1992 (average grid voltage and current harmonics). Simulation and analysis of this research use Matlab/Simulink. The simulation parameter values of proposed model are shown in Appendix Section.

2.2. Modelling of PV Array

Figure 3 shows the equivalent circuit of a solar panel. A solar panel is composed of several PV cells that have series, parallel, or series-parallel external connections [17].

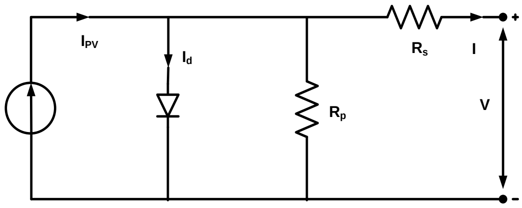


Figure 3. Equivalent circuit of solar panel

The V-I characteristic of a solar panel is showed in (1):

$$I = I_{PV} - I_o\left[\exp\left(\frac{V + R_S I}{aV_t}\right) - 1\right] - \frac{V + R_S I}{R_P} \tag{1}$$

where I_{PV} is the photovoltaic current, I_o is saturated reverse current, ‘a’ is the ideal diode constant, $V_t = N_S KTq^{-1}$ is the thermal voltage, N_S is the number of series cells, q is the electron charge, K is the Boltzmann constant, T is the temperature of p–n junction, R_S and R_P are series and parallel equivalent resistance of the solar panels. I_{PV} has a linear relation with light intensity and also varies with temperature variations. I_o is dependent on temperature variations. The values of I_{pv} and I_o are calculated as following (2) and (3):

$$I_{PV} = (I_{PV,n} + K_1 \Delta T)\frac{G}{G_n} I \tag{2}$$

$$I_o = \frac{I_{SC,n} + K_I \Delta T}{\exp(V_{OC,n} + K_V \Delta T)/aV_t - 1} \tag{3}$$

In which $I_{PV,n}$, $I_{SC,n}$ and $V_{OC,n}$ are photovoltaic current, short circuit current and open circuit voltage in standard conditions (T_n = 25 C and G_n = 1000 Wm^{-2}) respectively. K_I is the coefficient of short circuit current to temperature, $\Delta T = T - T_n$ is the temperature deviation from standard temperature, G is the light intensity and K_V is the ratio coefficient of open circuit voltage to temperature. Open circuit voltage, short circuit current and voltage-current corresponding to the maximum power are three important points of I-V characteristic of solar panel. These points are changed by variations of atmospheric conditions. By using (4) and (5) which are derived from PV model equations, short circuit current and open circuit voltage can be calculated in different atmospheric conditions.

$$I_{SC} = (I_{SC} + K_1 \Delta T)\frac{G}{G_n} \tag{4}$$

$$V_{OC} = V_{OC} + K_V \Delta T \tag{5}$$

2.3. MPPT P and O and MPPT Fuzzy

The initial research is to determine value of duty cycle (D) with a variable step to control DC/DC boost converter circuit with MPPT P and O. For PV converter, maximum power available is determined by PV cell characteristics, but this value often mismatches with the maximum power point (MPP) of the load. By implementing MPPT in PV systems, MPP can be maintained so that the number and size of PV panels can be reduced or energy yield can be optimized [18].

Due to moving of sun, which leads to change in irradiance, PV panels angle and variation of irradiance reaching the panels, energy generated from PV panels are absorbed does not constant over time. When this condition occurs, VI characteristics changes and MPP will move. If the system was previously operating at MPP, there will most probably a power loss with the same operating point and new condition. To overcome these problems, MPPT has been developed. The system includes no moving parts (where the modules are moved to track the sun). MPPT search for the maximum power independent based on environmental conditions (following changes in solar radiation and temperature) and maintain the PV terminal voltage remains constant at maximum value. The most used method of MPPT is P and O that algorithm is shown in Figure 4 [13] and its Matlab/Simulink model is presented in Figure 5.

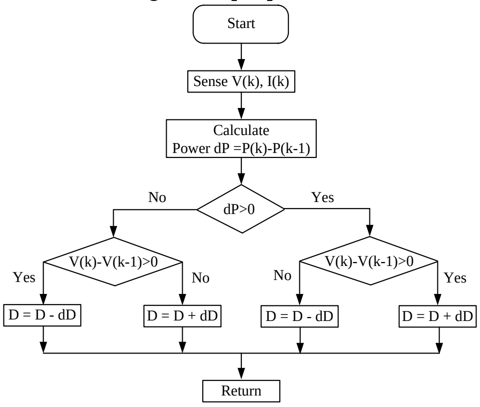


Figure 4. MPPT using P and O algorithm

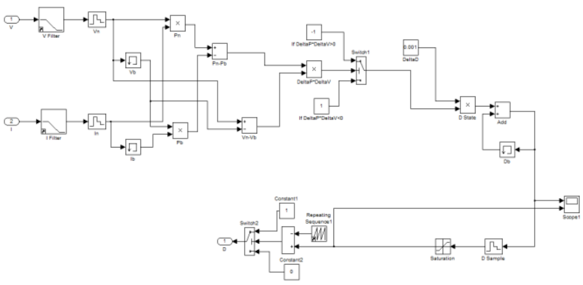


Figure 5. Matlab/Simulink for MPPT P and O

The same procedure for determining MPPT is using FLC. This method have been widely used in industrial process in the recent years due to their heuristic nature associated with simplicity, effectiveness and its multi rule based variable's consideration for both linear and non-linear parameter variation of the system. Fuzzy system is composed of knowledge based rules system. The main part of fuzzy is knowledge of base consisting of the If-Then rules. Fuzzy set theory is a new method of controlling the MPPT in obtaining the peak power point. The MPPT is implemented to obtain MPP operation voltage point faster with less overshoot and also it can minimize voltage fluctuation after MPP has been recognized. It also is capable to enhance power quality problem unbalance current/voltage and current/voltage harmonics. The control objective is to track maximum power will lead consequently to effective operation of the PV panel. To design the FLC, variables which represent the dynamic performance of the system should be chosen as the input to controller. Typical fuzzy based MPPT controller reffered to MPPT Fuzzy includes three basic components i.e. fuzzification, inference engine, and defuzzification block as shown in Figure 6 and its Matlab/Simulink model presented in Figure 7.

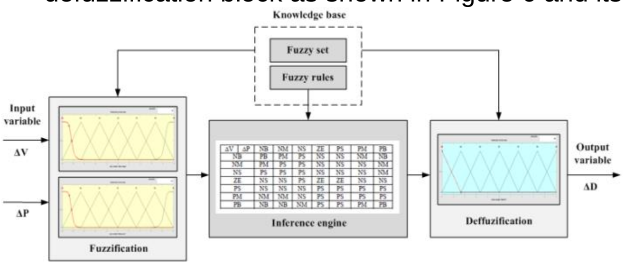


Figure 6. Structure of FLC

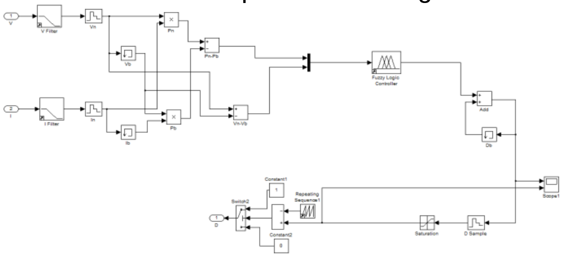


Figure 7. Matlab/Simulink for MPPT Fuzzy

Due account MPPT Fuzzy method is in terms of intelligence and speed. Fuzzy MPPT method is done by determining input variables, namely fuzzy control output power (ΔP) and output voltage (ΔV) PV generator, seven linguistic variables fuzzy sets, fuzzy operating system block (fuzzification, fuzzy rules, and defuzzification), Function ΔP and Δ V during fuzzification, a table fuzzy rule base, crisp values to determine duty cycle (D) in defuzzification phase with variable step to control DC /DC boost converter. Figure 8 shows Matlab/Simulink model for MPPT Fuzzy. During fuzzification phase shown in Figure 7, a number of input variables is calculated and converted into a linguistic variable based on the subset called membership function (MF). To translate value of voltage change and power change in, input fuzzy "change of voltage" and "change of power" is designed to use seven fuzzy variable called PB (Positive Big), PM (Positive Medium), NS (Negative Small), PS (Positive Small) ZE (Zero), NM (Negative Medium), and Negative Big (NB). voltage change (ΔV) and power changes (ΔP) is a proposed system input variables and output variable FLC is duty cycle change (ΔD). The membership functions i.e. voltage changes, power changes, and duty cycle change, each are shown in Figure 8 into Figure 10. Limit of input and output membership functions applied, determined by prior knowledge of parameter variation.

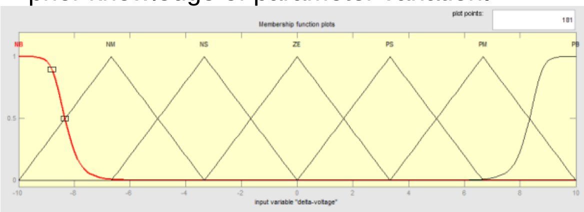


Figure 8. Input voltage change (delta voltage)

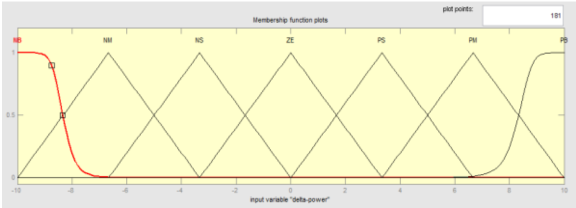


Figure 9. Input power change (delta power)

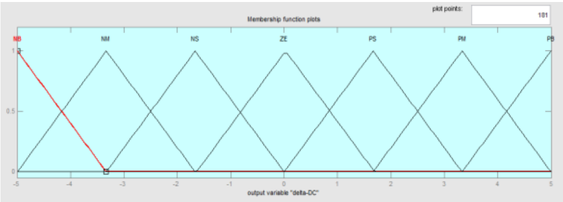


Figure 10. Output duty cycle change (delta D)

The fuzzy rule algorithm collects a number of fuzzy control rules in a specific order. This rule is used to control system to meet desired performance requirements, and they are designed from a knowledge of intelligent control systems. The fuzzy inference using a method that relates to a composition Mamdani Max-Min. Fuzzy inference system consists of three parts, namely rule base, database, and reasoning mechanism. Rule base consists of a number of If-Then rule for proper operation of controller. The If side of rule is called antecedent and Then side is called consequence. These rules may be regarded as similar response made by human thought processes and controllers using linguistic input variables, obtained after fuzzification for operation of these rules. The database consists of all user-defined membership function to be used in a number of these rules. Reasoning mechanism basically given processing rules based on specific rules and given conditions required result.

After determining ΔV and ΔP, these value are then converted into linguistic variables and use them as input functions for FLC. The output value is ΔD is generated using block inference and fuzzy rules as shown in Table 1. Finally defuzzification block operates to change value of ΔD is raised from linguistic variables into numeric variables back. Numeric variables that become inputs signal for the IGBT switch of DC/DC boost converter to be able to determine MPPT value for each generation PV accurately at the same time also improve power quality as a result of integration of multi PV to low voltage three phase grid under short circuit fault.

Table 1. Fuzzy Rules

ΔV ΔP	NB	NM	NS	ZE	PS	PM	PB
NB	PB	PM	PS	NS	NS	NM	NB
NM	PM	PS	PS	NS	NS	NS	NM
NS	PS	PS	PS	NS	NS	NS	NM
ZE	NS	NS	PS	ZE	ZE	NS	NS
PS	NS	NS	NS	PS	PS	PS	PS
PM	NM	NM	NS	PS	PS	PS	PS
PB	NB	NB	NM	PS	PS	PM	PB

2.4. Voltage and Current Harmonics

Power quality means quality of voltage and current. Power quality is determined based on the voltage and current value or the tolerance limit of equipment used. In general, current and voltage waveform of pure sinusoidal waves. One problem that occurs is non sinusoida or distorted current and voltage waves generated by harmonics in the power system [11].

Harmonic is distorted periodic steady state wave caused by the interaction between the shape of a sine wave at the fundamental frequency system with another wave component which is an integer multiples frequency of fundamental frequency. The most common harmonic index, which relates to the voltage waveform is THD (6), which is defined as the root mean square (rms) of the harmonics expressed as a percentage of the fundamental component as showed in [19]. For most applications, it is sufficient to consider the harmonic range from the 2nd to 25th, but most standards specify up to the 50th. Second harmonic index is current THD means the ratio of rms harmonic current value to rms fundamental current which expressed in (7) [11].

$$THD_V = \frac{\sqrt{\sum_{n=2}^{N} V_n^2}}{V_1} \times 100\,\% \quad (6) \qquad THD_I = \frac{\sqrt{\sum_{n=2}^{N} I_n^2}}{I_1} \times 100\,\% \quad (7)$$

Where V_n and I_n (the rms voltage and current at harmonic n), V_1 and I_1 (the fundamental rms voltage and current), N (the maximum harmonic order to be considered). The allowable maximum THD value for each country is different depending on the standard used. THD standards most often used in electric power system is IEEE 519-1992. There are two criteria used in analysis of harmonics distortion i.e. voltage distortion and current distortion limit [20].

2.5. Voltage and Current Unbalance

There are several standards that can be used to determine level of voltage unbalance in three phase systems, e.g. IEC, NEMA, and IEEE. In this study, value of unbalance voltage use (8) is based ANSI/IEEE 241-1990 Standard [21] as follows:

$$V(\%) = \frac{\left|V_{a\,\mathrm{var}\,age} - V_{a,b,c\,\min\, or\, \max}\right|}{V_{a\,\mathrm{var}\,age}} \times 100\% \qquad (8)$$

By using (8), value of unbalance voltage expressed in percent (%) and is defined as follows; $V_{avarage}$ is the average value of maximum voltage on phase a, b, c, (volt), $V_{a,b,c\ min}$ is minimum voltage on phase a, b, c, (volt), $V_{a,b,c\ max}$ is maximum voltage on phase a, b, c (volt). By using the same equation, then percentage of unbalance current can be calculated by replacing voltage magnitude into current magnitude.

3. Results and Discussions

This research is started by determining the maximum and minimum of grid current in each phase, unbalanced current using (8), current THD on each phase using (7), and average THD of three phase current grids on PCC bus using MPPT P and O/MPPT Fuzzy method. By using the same procedure then obtained unbalanced voltage, voltage THD on each phase, and average voltage THD. Table 2 shows unbalanced current value, THD grid current, and average THD of grid current, multi PV connected on a three phase low voltage distribution network using MPPT P and O/MPPT Fuzzy method. There are five short-circuit faults i.e. 3Ph-N, 3Ph, 2Ph-N, 2Ph, and 1Ph-N. So there are three fault durations i.e. before fault, during fault (transient), and after fault phase with time durations are 0-0.02 sec, 0.02-0.04 sec, and 0.04-0.06 sec respectivelty. The simulation result of unbalanced current/voltage and average THD current/voltage is also presented as verification under five short circuit faults. The results analysis is conducted only on short circuit fault during transient phase.

Table 2. Unbalance Current and Average Current Harmonics

No.	Fault Type	Fault Phase	Phase Current (V) A	B	C	Unba Current (%)	THD$_I$ (%) A	B	C	Avg THD$_I$ (%)
					MPPT P and O Method					
1	Normal	Before	10.51	10.67	10.52	0.978	2.34	1.65	1.87	1.954
		Transient	**10.61**	**10.74**	**10.69**	**0.562**	**2.65**	**3.22**	**3.40**	**3,090**
		After	10.85	10.97	10.90	0.581	4.11	4.34	3.63	4.020
2	3Ph-N	Before	10.51	10.66	10.52	0.916	2.35	1.62	1.86	1.944
		Transient	**1331**	**1359**	**1296**	**2.283**	**4.41**	**2.05**	**2.38**	**2.947**
		After	38.91	11.57	326.1	159.786	165	92.55	71.13	109.560
3	3Ph	Before	10.51	10.67	10.52	0.978	2.36	1.64	1.88	1.960
		Transient	**1331**	**1359**	**1296**	**2.283**	**4.41**	**2.05**	**2.38**	**2.947**
		After	103	11.98	102.3	42.213	110.84	90.27	110.05	103.720
4	2Ph-N	Before	10.51	10.66	10.52	0.915	2.34	1.62	1.86	1.947
		Transient	**1336**	**1350**	**7.671**	**50.353**	**4.70**	**1.76**	**3.91**	**3.457**
		After	41.92	11.69	10.98	94.705	164.26	73.46	4.47	80.730

5	2Ph	Before	10.51	10.66	10.52	0.915	2.35	1.63	1.88	1.954
		Transient	**1179**	**1179**	**10.32**	**49.347**	**3.67**	**3.67**	**3.33**	**3.557**
		After	17.71	15.06	10.98	21.440	154.01	180.83	4.96	113.267
6	1Ph-N	Before	10.51	10.66	10.58	0.725	2.34	1.62	1.86	1.940
		Transient	**1132**	**9.451**	**9.482**	**195.065**	**4.96**	**3.27**	**4.06**	**4.097**
		After	44.29	11.02	10.93	100.589	164.75	5.60	3.57	57.974
				MPPT Fuzzy Method						
1	Normal	Before	10.48	10.63	10.52	0.822	2.04	1.24	1.69	1.657
		Transient	**10.72**	**10.76**	**10.80**	**0.372**	**3.32**	**3.76**	**4.28**	**3.787**
		After	11.01	11.13	11.05	0.603	4.98	5.45	5.01	5.147
2	3Phasa-N	Before	10.48	10.63	10.52	0.822	2.04	1.25	1.69	1.660
		Transient	**1331**	**1359**	**1296**	**2.283**	**4.41**	**2.05**	**2.38**	**2.947**
		After	38.99	11.61	326.5	159.746	165.09	92.62	71.07	109.594
3	3Phasa	Before	10.48	10.63	10.52	0.822	2.04	1.24	1.69	1.657
		Transient	**1331**	**1359**	**1296**	**2.283**	**4.41**	**2.05**	**2.38**	**2.947**
		After	103	11.98	103.6	42.191	110.89	90.73	109.79	103.804
4	2Phasa-N	Before	10.48	10.63	10.52	0.822	2.05	1.25	1.69	1.664
		Transient	**1336**	**1350**	**7.475**	**50.364**	**4.70**	**1.76**	**6.0**	**4.154**
		After	42.16	11.98	11.18	93.631	163.75	72.36	6.61	80.907
5	2Phasa	Before	10.48	10.63	10.52	0.822	2.04	1.24	1.69	1.657
		Transient	**1179**	**1179**	**10.09**	**49.361**	**3.69**	**3.66**	**5.10**	**4.150**
		After	18.05	15.3	11.26	18.560	152.15	178.90	4.55	111.867
6	1Phase-N	Before	10.48	10.63	10.52	0.822	2.04	1.25	1.69	1.660
		Transient	**1332**	**9.203**	**9.319**	**195.886**	**4.97**	**4.88**	**5.28**	**5.044**
		After	44.42	11.30	11.40	98.540	164.46	7.64	6.75	59.617

Table 3 shows unbalanced current value, THD grid current, and average THD of grid current, multi PV connected on a three phase low voltage distribution network using MPPT P and O/ MPPT Fuzzy method.

Table 3. Unbalance Voltage and Average Voltage Harmonics

No.	Fault Type	Fault Phase	Phase Voltage (V)			Unba Voltage (%)	THD_V (%)			Avg THD_V (%)
			A	B	C		A	B	C	
				MPPT P and O Method						
1	Normal	Before	307.8	307.7	307.8	0	4.08	4.00	3.96	4.014
		Transient	**308.8**	**308.7**	**307.8**	**0**	**6.74**	**7.06**	**7.14**	**6.980**
		After	307.8	307.8	307.8	0	10.38	11.41	11.41	11.067
2	3 Ph-N	Before	307.7	307.7	307.7	0	4.12	4.05	3.96	4.044
		Transient	**1.332**	**1.350**	**1.307**	**1.523**	**6.50**	**179.32**	**189.46**	**125.094**
		After	301.7	300.4	241.9	7.240	16.94	20.0	53.83	31.924
3	3 Ph	Before	307.7	307.7	307.7	0	4.07	4.02	3.96	4.017
		Transient	**1.347**	**1.325**	**1.318**	**1.279**	**275.94**	**336.34**	**341.31**	**317.864**
		After	289.3	300.5	296.2	4.948	22.43	20.25	27.30	23.327
4	2 Ph-N	Before	307.7	307.8	307.7	0	4.07	4.03	3.98	4.027
		Transient	**2.242**	**2.268**	**308.4**	**195.677**	**5.36**	**106.86**	**7.83**	**39.017**
		After	301	301.5	307.7	1.418	18.51	20.16	10.94	16.537
5	2 Ph	Before	307.7	307.7	307.8	0	4.04	4.07	3.98	4.030
		Transient	**155.0**	**152.7**	**307.8**	**50.025**	**7.96**	**8.09**	**7.72**	**7.924**
		After	306.3	296.1	307.8	1.451	18.09	20.66	10.84	16.530
6	1Ph-N	Before	307.7	307.8	307.7	0	4.08	4.03	3.95	4.020
		Transient	**2.658**	**308.1**	**308.1**	**49.356**	**5.48**	**7.56**	**7.88**	**6.974**
		After	300.6	307.7	307.7	0.776	17.51	11.50	10.21	13.074
				MPPT Fuzzy Method						
1	Normal	Before	307.8	307.7	307.8	0	2.75	2.74	2.65	2.714
		Transient	**307.7**	**307.7**	**307.7**	**0**	**8.23**	**9.74**	**9.79**	**9.254**
		After	307.7	307.7	307.6	0	13.68	14.94	14.43	14.35
2	3 Ph-N	Before	307.8	307.8	307.8	0	2.72	2.78	2.61	2.704
		Transient	**1.332**	**1.351**	**1.306**	**1.605**	**5.38**	**172.84**	**181.97**	**120.064**
		After	301.7	300.6	241.9	7.278	24.26	24.80	56.05	35.037
3	3 Ph	Before	307.8	307.8	307.8	0	2.76	2.73	2.61	2.700
		Transient	**1.339**	**1.343**	**1.307**	**1.003**	**223.47**	**283.53**	**294.43**	**267.144**
		After	289.3	300.4	296.3	4.913	29.55	25.81	30.89	28.760
4	2 Ph-N	Before	307.8	307.8	307.8	0	2.73	2.79	2.61	2.710
		Transient	**2.242**	**2.269**	**308.4**	**195.676**	**4.90**	**102.82**	**11.16**	**39.627**
		After	301.0	301.5	307.6	1.396	20.97	22.70	15.70	19.790
5	2 Ph	Before	307.8	307.8	307.8	0	2.77	2.72	2.61	2.700
		Transient	**155.0**	**152.7**	**307.8**	**50.025**	**10.12**	**10.28**	**9.98**	**10.127**
		After	306.4	295.9	307.6	1.418	20.94	23.82	14.09	19.617
6	1Ph-N	Before	307.8	307.8	307.8	0	2.73	2.78	2.61	2.707
		Transient	**2.657**	**308.1**	**308.0**	**49.381**	**5.22**	**9.77**	**10.63**	**8,570**
		After	300.5	307.7	307.6	0.798	22.19	16.94	15.93	18.354

Figure 11 shows grid current waveform of multi PV connected to three phase grid on a PCC bus using MPPT P and O/MPPT Fuzzy method under normal condition, 3Ph-N, 2Ph-N, and 1Ph-N fault.

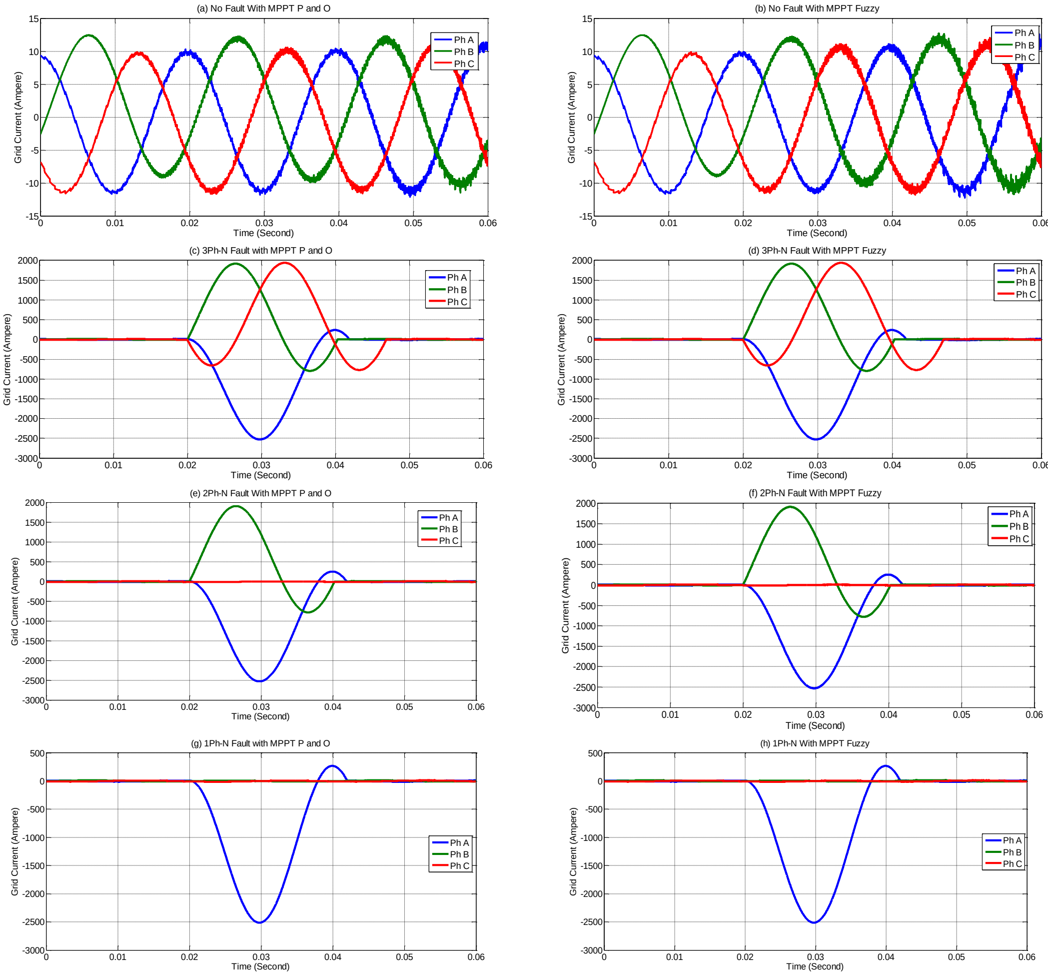
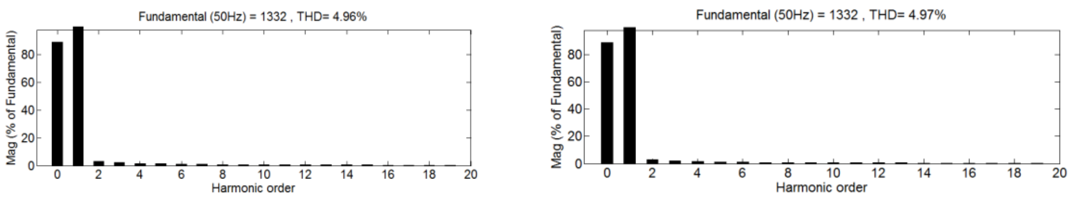


Figure 11. Current waveform of multi PV connected to a three phase grid on PCC bus

Figure 12 shows grid current harmonics spectra of phase A during transient phase due to the multi PV connected to three phase grid on PCC bus using MPPT P and O and MPPT Fuzzy method under 1Ph-N fault.



(a) MPPT P and O (b) MPPT Fuzzy

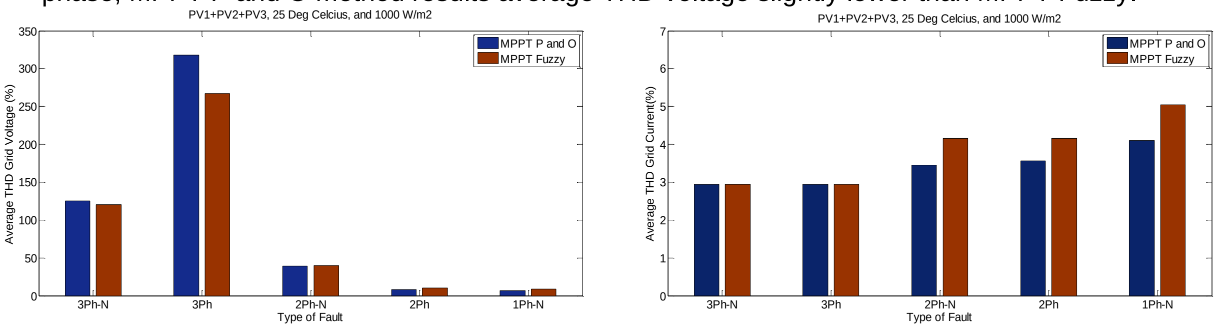
Figure 12. Current harmonics spectra of phase A under 1Ph-N fault

Table 2 presents that under normal condition (no fault), phase current of multi PV (PV1+PV2 + PV3) using MPPT P and O method in transient phase are 10.61 A, 10.74 A, 10.69 A resulting in an unbalanced current of 0.562%. In short circuit faults, the highest unbalanced currents of transient phase is generated by 1Ph-N fault of 195.886% with current on phase A, B, and C of 1332 volt, 9.203 volt, 9.319 volt respectively. The 3Ph-N and 3Ph fault on transient phase produce an unbalanced current of equal to 2,283% resulted by phase current A, B, and C are 1331 A, 1359 A, 1239 A respectively. The implementation of MPPT Fuzzy method under normal condition and transient phase generates phase current of 10.61 A, 10.74 A, 10.69 A so as to produce an unbalanced current equal to 0.562%. If using MPPT Fuzzy method under fault on transient phase, the highest unbalanced current is generated by 2Ph-N faults of 195.886%. At the same condition the smallest unbalanced current is generated by 3Ph-N and 3Ph-N fault equal to 2.282%. In non-symmetrical fault, the use of MPPT P and O method gives an unbalanced current of transient phase slightly lower than MPPT Fuzzy method. While in symmetrical fault, MPPT P and O/MPPT Fuzzy method for controlling of output power of multi PV gives same unbalanced current of transient phase of 2,283%.

In normal condition, by using both MPPT P and O and MPPT Fuzzy method, the average THD current on transient phase are 3.090% and 3.787%, respectively. When using MPPT P and O, the highest average THD current is generated by 1Ph-N fault of 4,097%. In the same method, the smallest average THD voltage is generated by 3Ph-N and 3Ph equal to 2,947%. If using Fuzzy MPPT, the highest average THD current is generated by 1Ph-N fault of 5.044%. In the same method, the smallest average THD current is generated by 3Ph-N and 3Ph equal to 2,947%. In the symmetrical faults, both MPPT P and O and MPPT Fuzzy method produce average THD current during transient phase equal to 2,947%. Whereas in the case of non-symmetric fault, MPPT P and O resulted in average THD current of transient phase slightly smaller than MPPT Fuzzy method.

Table 4 presents that under normal condition, the voltage values on phase A, B, and C of multi PV using MPPT P and O method under transient phase are 308.8 volt, 308.7 volt, 307.8 volt, respectively, resulting in an unbalanced voltage of 0%. In the short circuit faults, the highest unbalanced voltage during transient phase is generated by a 2Ph-N fault of 195.677% with a phase voltage of A, B, and C respectively of 2.242 volt, 2.268 volts, and 308.4 volt. The 3Ph fault during transient phase produce the smallest unbalanced voltage of 1.279% resulted from phase voltage A, B, and C respectively of 1.347 volt, 1.325 volt, 1.318 volt. The use of MPPT Fuzzy method under normal condition and transient phase gives 308.8 volt, 308.7 volt, 307.8 volt, respectively, resulting in an unbalanced voltage equal to 0%. When using the MPPT Fuzzy method under short-circuit fault during transient phase, the highest unbalanced voltage is generated by a 2Ph-N fault of 195.676%. Under the same condition, the lowest unbalanced voltage is generated by 3Ph fault of 1.003%. In non-symmetrical faults (2Ph-N, 2Ph, and 1Ph-N), the implemantation of MPPT P and O and MPPT Fuzzy method to control output power of multi PV produces nominal unbalanced voltage during transient phase results a close the same value. While in symmetrical fault (3Ph-N and 3Ph) MPPT P and O and MPPT Fuzzy method produce different unbalance voltage on transient phase. During 3Ph-N fault on transient phase, MPPT P and O method results in an unbalanced transient phase voltage of 1.523% slightly lower than MPPT Fuzzy method of 1.605%. But during 3Ph fault on transient phase, MPPT Fuzzy produces an unbalanced voltage of 1.003% slightly lower than MPPT P and O of 1.279%.

In normal condition using both MPPT P and O and MPPT Fuzzy method, THD average voltages are 6.980% and 9.254%, respectively. If using MPPT P and O method, then the largest average THD voltage is generated by a 3Ph fault of 317.846%. By using the same method, the lowest average THD voltage is produced by 1Ph-N fault of 6.974%. If using Fuzzy MPPT method, the largest average THD voltage is also generated by a 3Ph fault of 267.144%. By using the same method, the lowest average THD voltage is generated by 1Ph-N fault of 8.570%. During symmetrical fault on transient phase, MPPT Fuzzy method results average THD voltage smaller than MPPT P and O. Otherwise during non-symmetrical fault on transient phase, MPPT P and O method results average THD voltage slightly lower than MPPT Fuzzy.



(a) Average THD voltage (b) Average THD current

Figure 13. Performance of average voltage and current harmonic during transient phase

Figure 13.a describes that on symmetrical fault during transient phase (3Ph-N and 3Ph), MPPT Fuzzy method produces average THD voltage smaller than MPPT P and O method. Otherwise on non-symmetrical fault during transient phase (2Ph-N, 2Ph, and 1Ph-N), MPPT P and O method gives average THD voltage slightly smaller than MPPT Fuzzy method. Figure 14.b describes that on symmetrical fault during transient phase (3Ph-N and 3Ph), MPPT Fuzzy and and MPPT P and O method produce same average THD current. Whereas in the case of non-symmetrical fault during transient phase (2Ph-N, 2Ph, and 1P-N), MPPT P and O method resulted in average THD current slightly smaller than MPPT Fuzzy method. The MPPT P and O method and the MPPT Fuzzy method on all short circuit fault during transient phase (3Ph-N, 3Ph, 2Ph-N, 2Ph, and 1Ph-N) produce smaller current average THD current significantly depend on average THD voltage.

4. Conclusion

Comparative performance of multi PV connected grid under short circuit fault during transient phase to power quality using MPPT P and O/MPPT Fuzzy method has been presented. During transient phase, non-symmetrical faults (2Ph-N, 2Ph, and 1Ph-N) is capable to generate unbalance current/voltage greater depend on symietrical faults (3Ph-N and 3Ph). On symmetrical faults, MPPT Fuzzy results average THD voltage/THD current smaller than MPPT P and O. Otherwise on non-symmetrical faults, MPPT P and O gives average THD voltage/THD current slightly smaller than MPPT Fuzzy. The MPPT P and O/MPPT Fuzzy method on all short circuit faults during transient phase produce smaller current average THD depend on average THD voltage significantly. Futhermore the nominal of average THD current using both methods also meets THD limit prescribed in IEEE 519 standard.

Appendix

PV generator 1, 2, and 3: active power = 100 kW, temperature = 25^0 C, irradiance = 100 W/m^2; Three phase grid: short circuit power = 100 MVA, voltage = 380 volt (L-L), frequency = 50 Hz; Power transformer: rated power = 100 kVA, frequency = 50 Hz, voltage 380 Volt/20 kV (L-L), two winding type; Load 1, 2, and 3: active power = 20 kW, voltage = 380 volt (L-L), frequency = 50 Hz; Low Voltage Lines 1,2, and 3: resistance R = 0,1273 Ohm/km, inductance L = 93,37 mH/km, capasitance C = 1,274 μF/km; Length of Low Voltage Lines: Line 1, Line 2, Line 3 = 1 km; DC link capasitor: capacitance= 2000 μF, frequency = 4 kHz; PWM generator for DC/AC inverter: Sampling time= 5 x 10^{-6} Second; Fuzzy inference system = mamdani method; Fuzzy model composition = max-min; Input membership function: delta voltage=gbellmf, trimf, delta power: gbellmf, trimf; Output membership function: delta duty cycle = trimf.

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Lampiran 2.4

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Transient Power Quality Performance of Multi Photovoltaics using MPPT P and O/MPPT Fuzzy

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Abstract

This paper presents comparative performance of transient power quality due to multi PV integration to grid at both fixed temperature and solar irradiation connected using MPPT P and O/MPPT Fuzzy. This research is performed as five transient of short-circuit faults on PCC bus. An artificial intelligence with FLC is used to set duty cycle with step variable to control DC/DC boost converter, generate quick convergence to determine MPPT for controlling of PV output voltage and then its result is compared with MPPT P and O. During transient phase, non-symmetrical faults are capable of generate unbalance current/voltage greater than symmetrical faults. On symmetrical faults, MPPT Fuzzy produces average THD voltage/THD current smaller than MPPT P and O. Otherwise on non-symmetrical faults, MPPT P and O gives average THD voltage/THD current slightly smaller than MPPT Fuzzy. Both of MPPT P and O and MPPT Fuzzy on all short circuit faults during transient phase result significantly smaller current average THD current than average THD voltage and limits of THD prescribed in IEEE 519.

Keywords*: Short Circuit, Transient, Power Quality, Multi PV, MPPT P and O, MPPT Fuzzy*

1. Introduction

The PV beside being able to generate power, it also results harmonics due to inverter as a medium to convert DC into AC voltage so capable to decrease power quality. The short circuit fault can cause rise of current and voltage drop in certain phases depend on fault types, so able to generate unbalance voltage and current on low voltage distribution network (grid). The research on power quality of PV connected grid to power system using LCL filter has been done Kon Keng Weng et. al. A number of power quality problems i.e. over voltage, less voltage, power fluctuations, inrush currents, low power factor, and current harmonics or THD will appear on microgrid power system. This research is conducted only on constant solar irradiance and temperature condition (1000 W/m^2 and 25^0 C) as environmental input parameters for PV systems [1]. The study on effect of solar radiation on grid connected to PV generator to power quality has been investigated by Minas Patsalides, et.al. It considers two different scenarios of average and low radiation [2]. Investigation of grid connected a single phase PV inverter using a current proportional resonant, proportional resonant integral, and genetic algorithm using an active filter to reduce current harmonics of inverter output has been studied by Renu et. al. The laxity of research is only done on a single phase PV and certain irradiance and temperature [3]. The dynamic analysis of power quality due to high penetration effect of distribution network connected to PV under variable irradiance has been studied by Massoud Farhoodnea, et. al. The result showed that high level penetration of grid connected PV will cause a number of power quality problems. However, the research was only analyzed on voltage harmonics and did not consider the ambient temperature condition [4]. Power quality characteristics in a number of three phase PV inverters at top roof PV has been performed by K.P. Kontogianis, et. al [5]. A comparative study of MPPT between FLC and conventional PI controller has been presented for interfacing PV array with utility grid through a three-phase line-commutated inverter by Omid Zhoulai Bakhoda, et.al. FLC was dominating PI in many important aspects like i.e., provided active power for grid, output current shape of inverter, grid current and current THD [6]. A grid interfaced solar PV (SPV) power generating system in a 3P4W system has been proposed by Arun Kumar Verma, et.al. This system was used for compensation of neutral

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current, harmonic currents, reactive power and to provide load balancing [7]. However, both of power quality analysis in both papers was only performed by using single PV. Power quality due to integration of multi units of PV generator connected to three phase grid under variable solar irradiation level has been implemented by Amirullah, et.al. At level of solar irradiation was fixed, the greater number of PV connected to three-phase grid, then average THD of grid voltage/current also increased. At level of solar irradiation increased, average THD of grid voltage/current also increased. The PV in this research was still using MPPT with P and O algorithm and not using intelligent control [8].

Adaptive Neuro-fuzzy Inference System (ANFIS)-based improvement of MPPT P and O for PV under different shading conditions has been investigated by Khaled Bataineh, et.al. The simulation show proposed algorithm efficiently reach MPP under uniform irradiation, sudden changes of irradiation, and partial shading [9]. The method for balancing line current and voltage, due to the presence of distributed generations (DGs) i.e. a number of single phase PV generation units in homes has been presented by Amirullah, et.al. This research shows that the combination of Battery Energy Storage (BES) and three single phase bi-directional inverter able to reduce unbalanced line current/voltage. Otherwise, the combination of both circuit able to inreases current/voltage harmonics [10]. Power quality enhancement on low voltage of three phase grid caused by different level of PV integration using MPPT Fuzzy under variabel solar irradiance level on constant temperature and load has been investigated by Amirullah, et.al. It was able to enhance profile of grid voltage and current THD due to different level of integration of PV to three phase grid corresponding with IEEE Standard 519. MPPT Fuzzy was also able to improve input power factor better than MPPT P and O [11]. Rachid Belaidi, et.al has proposed a combined system of 3P4W shunt active filter and PV with MPPT P and O, to solve power quality such as harmonic currents, poor power factor, and unbalanced load [12]. Salah Eddine Mankour, et al has investigated on modeling of a PV stand alone power system using two widely-adopted MPPT algorithms, P & O and incremental conductance [13]. Bambang Purwahyudi, et. al has researched design of electrical characteristics of solar PV cell model by using self constructing neural network (SCNN) [14]. Julián A.C.C., et. al has used a mathematical model implemented in Matlab/Simulink to evaluate the performance of building integrated photovoltaic systems (BIPVS) [15]. Ahmad Saudi Samosir, et. al has investigated on modeling and simulation of MPPT used in solar power systems with fuzzy logic [16]. But the researchs on enhancement of power quality and MPPT characteristics for PV in [1-16] were only analyzed in normal condition.

This paper presents comparative performance of power quality due to the multi PV integration at both fixed temperature and solar irradiation levels connected to 380 kV and 50 Hz distribution network using MPPT P and O/MPPT Fuzzy controller. The research is performed during transient disturbances of short-circuit fault on PCC bus based on five of short circuit faults. An artificial intelligence method with FLC is used to set duty cycle (D) with step variable to control DC/DC boost converter, generate quick convergence calculation to determine MPPT value for controlling of PV generator output voltage, and then its result is compared with MPPT P and O method. The parameters are voltage/current unbalanced, voltage/current THD on each phase, and voltage/current average THD on PCC bus of three phase grid.

This paper is organized as follow. Section 2 presents proposed method i.e. proposed model of single PV using MPPT Fuzzy, model multi PV connected three phase grid under short circuit fault, simulation parameters, equivalent circuit, mathematical, and characteristic curve of PV model, MPPT P and O method, MPPT Fuzzy method, voltage and current harmonics, voltage and current unbalance. Section 3 describes comparative performance of multi PV connected grid under short circuit fault during transient phase to current/voltage unbalance and current/voltage THD of three phase grid using MPPT P and O/MPPT Fuzzy method. In this section, example cases studied are presented and the results are verified with those of Matlab/Simulink. Finally, the paper in concluded in Section 4.

2. Research Method

2.1. Proposed Model

Figure 1 shows model of a single PV system connected to a three phase grid. The DC/DC converter circuit consists of a boost converter circuit that serves to raise the DC output voltage from the PV. The DC output voltage of the boost converter circuit is then changed by a three phase DC/AC inverter into an AC voltage to three phase grid. The single PV model is then used as a reference to construct multiple (multi) PV models connected to grid through a three phase phase distribution transformer showed in Figure 2. This research uses three model group of PVs with an active power of 100 kW each. Besides connected three phase grid, multi PVs are also connected to three group of three phase loads with 20 kW of active power each. The aim of research is to compare performance of power quality due to the multi PV integration at both fixed temperature and solar irradiation levels connected to distribution network using MPPT P and O/MPPT Fuzzy. The research analysis includes transient disturbances of short-circuit fault on PCC bus based on a number of short circuit faults. An artificial intelligence with FLC is used to set duty cycle (D) with step variable to control DC/DC boost converter, generate quick convergence calculation to determine MPPT value for controlling of PV output voltage, and then its result is compared with MPPT P and O method. The DC/DC converter produces a constant DC voltage as an input for DC/AC inverter using pulse with modulation (PWM).

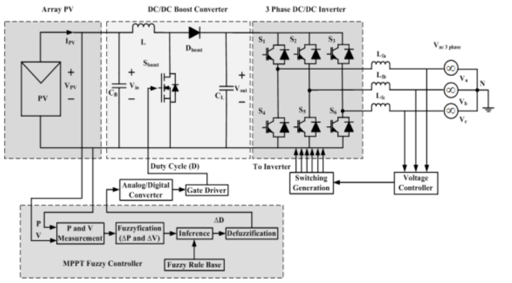


Figure 1. Proposed model of single PV using MPPT Fuzzy

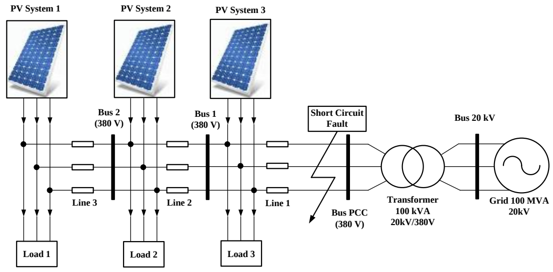


Figure 2. Proposed model of multi PV connected three phase grid under short circuit fault

There are two scenarios of multi PV connected three phase grids under fixed temperature and solar irradiation of 25^0 C and 1000 W/m^2, i.e. using MPPT P and O and MPPT Fuzzy methods respectively. The transient state in each of MPPT controllers are indicated by five short-circuit faults, resulting in a total of ten fault scenarios i.e. three phases to ground (3Ph-N), three phases (3Ph), two phases to ground (2Ph-N), two phases (2 Ph), and single phase to ground (1Ph-N). Futhermore is to determine voltage/current unbalanced, voltage/current harmonics (THD) on each phase, and voltage/current average harmonics on PCC bus of three-phase low voltage grid. The final step is to validate the results referring to the ANSI/IEEE 241-1990 standard (unbalanced voltage and current) and IEEE Standard 519-1992 (average grid voltage and current harmonics). Simulation and analysis of this research use Matlab/Simulink. The simulation parameter values of proposed model are shown in Appendix Section.

2.2. Modelling of PV Array

Figure 3 shows the equivalent circuit of a solar panel. A solar panel is composed of several PV cells that have series, parallel, or series-parallel external connections [17].

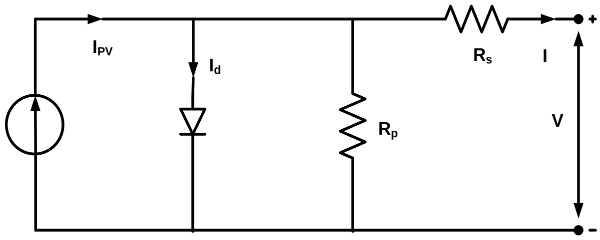


Figure 3. Equivalent circuit of solar panel

The V-I characteristic of a solar panel is showed in (1):

$$I = I_{PV} - I_o\left[\exp\left(\frac{V + R_S I}{aV_t}\right) - 1\right] - \frac{V + R_S I}{R_P} \tag{1}$$

where I_{PV} is the photovoltaic current, I_o is saturated reverse current, 'a' is the ideal diode constant, $V_t = N_S K T q^{-1}$ is the thermal voltage, N_S is the number of series cells, q is the electron charge, K is the Boltzmann constant, T is the temperature of p–n junction, R_S and R_P are series and parallel equivalent resistance of the solar panels. I_{PV} has a linear relation with light intensity and also varies with temperature variations. I_o is dependent on temperature variations.

2.3. MPPT P and O and MPPT Fuzzy

The initial research is to determine value of duty cycle (D) with a variable step to control DC/DC boost converter circuit with MPPT P and O. For PV converter, maximum power available is determined by PV cell characteristics, but this value often mismatches with the maximum power point (MPP) of the load. By implementing MPPT in PV systems, MPP can be maintained so that the number and size of PV panels can be reduced or energy yield can be optimized [18]. Because of moving of sun, PV panels angle, and variation of irradiance reaching the panels, energy generated from PV panels are absorbed does not constant over time. When this condition occurs, VI characteristics changes and MPP will move. To overcome these problems, MPPT has been developed. The system includes no moving parts. MPPT search for the maximum power independent based on environmental conditions (following changes in solar radiation and temperature) and maintain the PV terminal voltage remains constant at maximum value. The most used method of MPPT is P and O that algorithm is shown in Figure 4 [13] and its Matlab/Simulink model is presented in Figure 5.

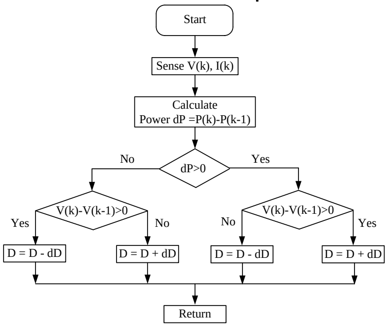


Figure 4. MPPT using P and O algorithm

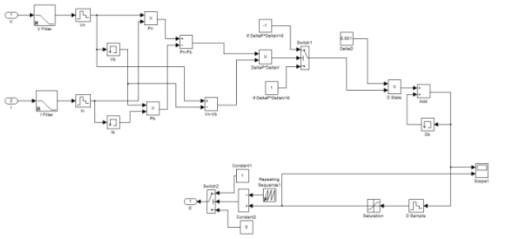


Figure 5. Matlab/Simulink for MPPT P and O

The same procedure for determining MPPT is using FLC. Fuzzy set theory is a new method of controlling the MPPT in obtaining the peak power point. The MPPT is implemented to obtain MPP operation voltage point faster with less overshoot and also it can minimize voltage fluctuation after MPP has been recognized. It also is capable to enhance power quality problem unbalance current/voltage and current/voltage harmonics. Typical fuzzy based MPPT controller reffered to MPPT Fuzzy includes three basic components i.e. fuzzification, inference engine, and defuzzification block as shown in Figure 6 and its Matlab/Simulink presented in Figure 7.

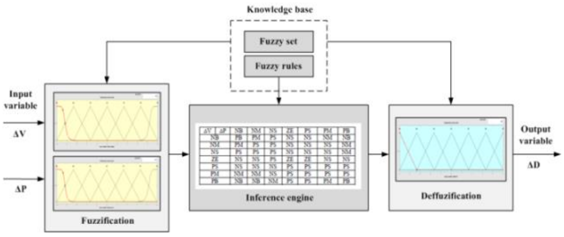


Figure 6. Structure of FLC

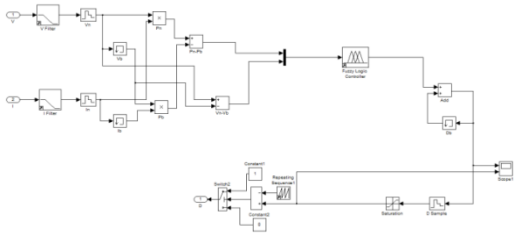


Figure 7. Matlab/Simulink for MPPT Fuzzy

Fuzzy MPPT method is done by determining input variables, namely fuzzy control output power (ΔP) and output voltage (ΔV) PV generator, seven linguistic variables fuzzy sets, fuzzy operating system block (fuzzification, fuzzy rules, and defuzzification), Function ΔP and Δ V during fuzzification, a table fuzzy rule base, crisp values to determine duty cycle (D) in defuzzification phase with variable step to control DC/DC boost converter. Figure 8 shows Matlab/Simulink model for MPPT Fuzzy. During fuzzification phase shown in Figure 7, a number of input variables is calculated and converted into a linguistic variable based on the subset called membership function (MF). To translate value of voltage change and power change in, input fuzzy "change of voltage" and "change of power" is designed to use seven fuzzy variable called PB (Positive Big), PM (Positive Medium), NS (Negative Small), PS (Positive Small) ZE (Zero), NM (Negative Medium), and Negative Big (NB). voltage change (ΔV) and power changes (ΔP) is a proposed system input variables and output variable FLC is duty cycle change (ΔD). The membership functions i.e. voltage changes, power changes, and duty cycle change, each are shown in Figure 8 into Figure 10.

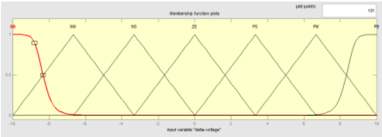


Figure 8. Input voltage change (delta voltage)

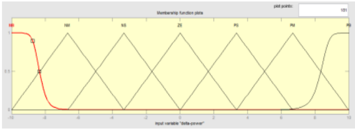


Figure 9. Input power change (delta power)

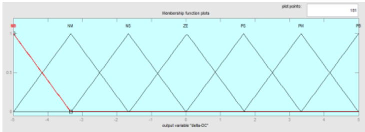


Figure 10. Output duty cycle change (delta D)

The fuzzy inference using a method that relates to a composition Mamdani Max-Min. Fuzzy inference system consists of three parts, namely rule base, database, and reasoning mechanism. After determining ΔV and ΔP, these value are then converted into linguistic variables and use them as input functions for FLC. The output value is ΔD is generated using block inference and fuzzy rules as shown in Table 1. Finally defuzzification block operates to change value of ΔD is raised from linguistic variables into numeric variables back. Numeric variables that become inputs signal for the IGBT switch of DC/DC boost converter to be able to determine MPPT for each generation PV accurately at the same time also improve power quality as a result of integration of multi PV to low voltage three phase grid under short circuit.

Table 1. Fuzzy Rules

ΔV ΔP	NB	NM	NS	ZE	PS	PM	PB
NB	PB	PM	PS	NS	NS	NM	NB
NM	PM	PS	PS	NS	NS	NS	NM
NS	PS	PS	PS	NS	NS	NS	NM
ZE	NS	NS	PS	ZE	ZE	NS	NS
PS	NS	NS	NS	PS	PS	PS	PS
PM	NM	NM	NS	PS	PS	PS	PS
PB	NB	NB	NM	PS	PS	PM	PB

2.4. Voltage and Current Harmonics/Unbalance

Generally, current and voltage waveforms are pure sinusoidal. One problem that occurs is non sinusoida or distorted current and voltage waves generated by harmonics in power system [11]. Harmonic is distorted periodic steady state wave caused by the interaction between the shape of a sine wave at the fundamental frequency system with another wave component which is an integer multiples frequency of fundamental frequency. The most common harmonic index, which relates to voltage waveform is THD (2), which is defined as the root mean square (rms) of harmonics expressed as a percentage of fundamental component as showed in [19]. Second harmonic index is current THD means the ratio of rms harmonic current value to rms fundamental current which expressed in (3) [11].

$$THD_V = \frac{\sqrt{\sum_{n=2}^{N} V_n^2}}{V_1} \times 100\,\% \quad (2) \qquad THD_I = \frac{\sqrt{\sum_{n=2}^{N} I_n^2}}{I_1} \times 100\,\% \quad (3) \qquad V(\%) = \frac{\left|V_{a\,var\,age} - V_{a,b,c\,\min\,or\,\max}\right|}{V_{a\,var\,age}} \times 100\,\% \quad (4)$$

Where V_n and I_n (the rms voltage and current at harmonic n), V_1 and I_1 (the fundamental rms voltage and current), N (the maximum harmonic order to be considered). The allowable maximum THD value for each country is different depending on the standard used. THD standards most often used in electric power system is IEEE 519-1992. There are two criteria used in analysis of harmonics distortion i.e. voltage distortion and current distortion limit [20]. The value of unbalance voltage use (8) is based ANSI/IEEE 241-1990 is showed in (4) [21]. By using (4), value of unbalance voltage expressed in percent (%) and is defined as follows; $V_{avarage}$ is the average value of maximum voltage on phase a, b, c, (volt), $V_{a,b,c\ min}$ is minimum voltage on phase a, b, c, (volt), $V_{a,b,c\ max}$ is maximum voltage on phase a, b, c (volt). By the same way, then unbalance current (%) can be calculated by replacing voltage into current magnitude.

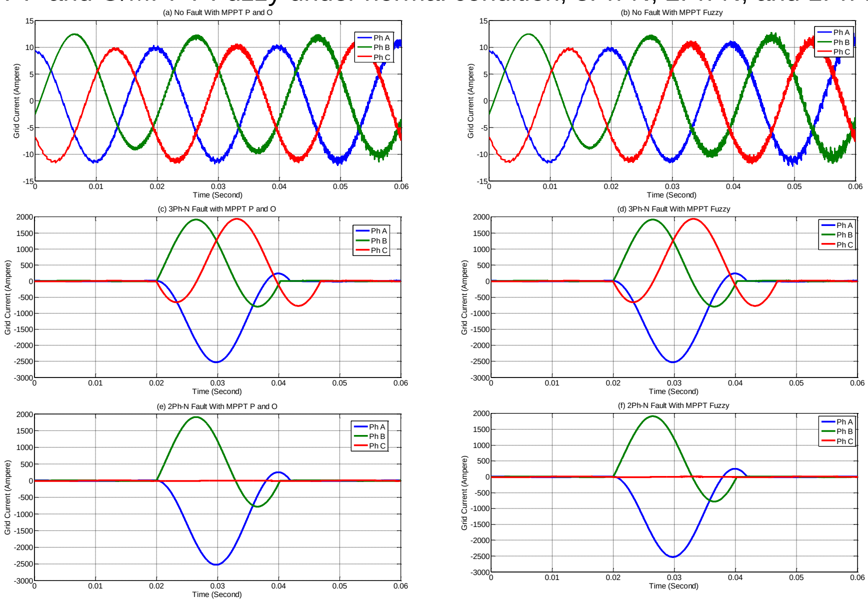
3. Results and Discussions

This research is started by determining the maximum and minimum of grid current in each phase, unbalanced current using (3), current THD on each phase using (3), and average THD of three phase current grids on PCC bus using MPPT P and O/MPPT Fuzzy. By using the same procedure then obtained unbalanced voltage, voltage THD on each phase, and average voltage THD. Table 2 shows unbalanced current, THD grid current, and average THD of grid current of multi PV connected on a three phase low voltage distribution network using MPPT P and O/MPPT Fuzzy. Because, there are five short-circuit faults then there are three fault durations i.e. before, during (transient), and after fault phase with time durations are 0-0.02 sec, 0.02-0.04 sec, and 0.04-0.06 sec respectivelty. The simulation result of unbalanced current/voltage and average THD current/voltage is also presented as verification under five short circuit faults. The results analysis is conducted only on short circuit fault during transient.

Table 2. Unbalance Current and Average Current Harmonics

No.	Fault Type	Fault Phase	Phase Current (V) A	B	C	Unba Current (%)	THD_I (%) A	B	C	Avg THD_I (%)
			MPPT P and O Method							
1	Normal	Before	10.51	10.67	10.52	0.978	2.34	1.65	1.87	1.954
		Transient	**10.61**	**10.74**	**10.69**	**0.562**	**2.65**	**3.22**	**3.40**	**3,090**
		After	10.85	10.97	10.90	0.581	4.11	4.34	3.63	4.020
2	3Ph-N	Before	10.51	10.66	10.52	0.916	2.35	1.62	1.86	1.944
		Transient	**1331**	**1359**	**1296**	**2.283**	**4.41**	**2.05**	**2.38**	**2.947**
		After	38.91	11.57	326.1	159.786	165	92.55	71.13	109.560
3	3Ph	Before	10.51	10.67	10.52	0.978	2.36	1.64	1.88	1.960
		Transient	**1331**	**1359**	**1296**	**2.283**	**4.41**	**2.05**	**2.38**	**2.947**
		After	103	11.98	102.3	42.213	110.84	90.27	110.05	103.720
4	2Ph-N	Before	10.51	10.66	10.52	0.915	2.34	1.62	1.86	1.947
		Transient	**1336**	**1350**	**7.671**	**50.353**	**4.70**	**1.76**	**3.91**	**3.457**
		After	41.92	11.69	10.98	94.705	164.26	73.46	4.47	80.730
5	2Ph	Before	10.51	10.66	10.52	0.915	2.35	1.63	1.88	1.954
		Transient	**1179**	**1179**	**10.32**	**49.347**	**3.67**	**3.67**	**3.33**	**3.557**
		After	17.71	15.06	10.98	21.440	154.01	180.83	4.96	113.267
6	1Ph-N	Before	10.51	10.66	10.58	0.725	2.34	1.62	1.86	1.940
		Transient	**1132**	**9.451**	**9.482**	**195.065**	**4.96**	**3.27**	**4.06**	**4.097**
		After	44.29	11.02	10.93	100.589	164.75	5.60	3.57	57.974
			MPPT Fuzzy Method							
1	Normal	Before	10.48	10.63	10.52	0.822	2.04	1.24	1.69	1.657
		Transient	**10.72**	**10.76**	**10.80**	**0.372**	**3.32**	**3.76**	**4.28**	**3.787**
		After	11.01	11.13	11.05	0.603	4.98	5.45	5.01	5.147
2	3Phasa-N	Before	10.48	10.63	10.52	0.822	2.04	1.25	1.69	1.660
		Transient	**1331**	**1359**	**1296**	**2.283**	**4.41**	**2.05**	**2.38**	**2.947**
		After	38.99	11.61	326.5	159.746	165.09	92.62	71.07	109.594
3	3Phasa	Before	10.48	10.63	10.52	0.822	2.04	1.24	1.69	1.657
		Transient	**1331**	**1359**	**1296**	**2.283**	**4.41**	**2.05**	**2.38**	**2.947**
		After	103	11.98	103.6	42.191	110.89	90.73	109.79	103.804
4	2Phasa-N	Before	10.48	10.63	10.52	0.822	2.05	1.25	1.69	1.664
		Transient	**1336**	**1350**	**7.475**	**50.364**	**4.70**	**1.76**	**6.0**	**4.154**
		After	42.16	11.98	11.18	93.631	163.75	72.36	6.61	80.907
5	2Phasa	Before	10.48	10.63	10.52	0.822	2.04	1.24	1.69	1.657
		Transient	**1179**	**1179**	**10.09**	**49.361**	**3.69**	**3.66**	**5.10**	**4.150**
		After	18.05	15.3	11.26	18.560	152.15	178.90	4.55	111.867
6	1Phase-N	Before	10.48	10.63	10.52	0.822	2.04	1.25	1.69	1.660
		Transient	**1332**	**9.203**	**9.319**	**195.886**	**4.97**	**4.88**	**5.28**	**5.044**
		After	44.42	11.30	11.40	98.540	164.46	7.64	6.75	59.617

Figure 11 shows current waveform of multi PV connected to three phase grid on a PCC bus using MPPT P and O/MPPT Fuzzy under normal condition, 3Ph-N, 2Ph-N, and 1Ph-N fault.



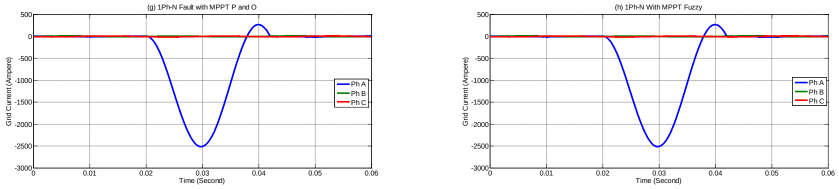


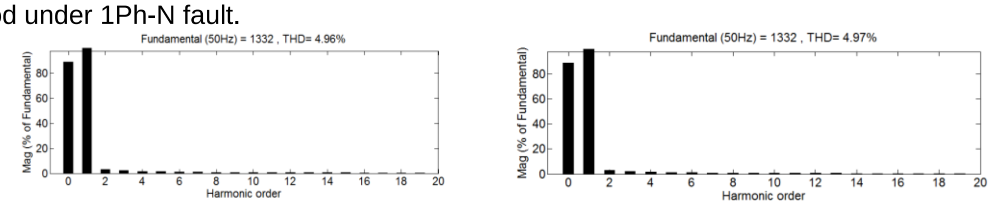
Figure 11. Current waveform of multi PV connected to a three phase grid on PCC bus

Table 3 shows unbalanced current, THD grid current, and average THD of grid current, multi PV connected on a three phase low voltage grid using MPPT P and O/ MPPT Fuzzy.

Table 3. Unbalance Voltage and Average Voltage Harmonics

No.	Fault Type	Fault Phase	Phase Voltage (V) A	B	C	Unba Voltage (%)	THD_V (%) A	B	C	Avg THD_V (%)
			MPPT P and O Method							
1	Normal	Before	307.8	307.7	307.8	0	4.08	4.00	3.96	4.014
		Transient	**308.8**	**308.7**	**307.8**	**0**	**6.74**	**7.06**	**7.14**	**6.980**
		After	307.8	307.8	307.8	0	10.38	11.41	11.41	11.067
2	3 Ph-N	Before	307.7	307.7	307.7	0	4.12	4.05	3.96	4.044
		Transient	**1.332**	**1.350**	**1.307**	**1.523**	**6.50**	**179.32**	**189.46**	**125.094**
		After	301.7	300.4	241.9	7.240	16.94	20.0	53.83	31.924
3	3 Ph	Before	307.7	307.7	307.7	0	4.07	4.02	3.96	4.017
		Transient	**1.347**	**1.325**	**1.318**	**1.279**	**275.94**	**336.34**	**341.31**	**317.864**
		After	289.3	300.5	296.2	4.948	22.43	20.25	27.30	23.327
4	2 Ph-N	Before	307.7	307.8	307.7	0	4.07	4.03	3.98	4.027
		Transient	**2.242**	**2.268**	**308.4**	**195.677**	**5.36**	**106.86**	**7.83**	**39.017**
		After	301	301.5	307.7	1.418	18.51	20.16	10.94	16.537
5	2 Ph	Before	307.7	307.7	307.8	0	4.04	4.07	3.98	4.030
		Transient	**155.0**	**152.7**	**307.8**	**50.025**	**7.96**	**8.09**	**7.72**	**7.924**
		After	306.3	296.1	307.8	1.451	18.09	20.66	10.84	16.530
6	1Ph-N	Before	307.7	307.8	307.7	0	4.08	4.03	3.95	4.020
		Transient	**2.658**	**308.1**	**308.1**	**49.356**	**5.48**	**7.56**	**7.88**	**6.974**
		After	300.6	307.7	307.7	0.776	17.51	11.50	10.21	13.074
			MPPT Fuzzy Method							
1	Normal	Before	307.8	307.7	307.8	0	2.75	2.74	2.65	2.714
		Transient	**307.7**	**307.7**	**307.7**	**0**	**8.23**	**9.74**	**9.79**	**9.254**
		After	307.7	307.7	307.6	0	13.68	14.94	14.43	14.35
2	3 Ph-N	Before	307.8	307.8	307.8	0	2.72	2.78	2.61	2.704
		Transient	**1.332**	**1.351**	**1.306**	**1.605**	**5.38**	**172.84**	**181.97**	**120.064**
		After	301.7	300.6	241.9	7.278	24.26	24.80	56.05	35.037
3	3 Ph	Before	307.8	307.8	307.8	0	2.76	2.73	2.61	2.700
		Transient	**1.339**	**1.343**	**1.307**	**1.003**	**223.47**	**283.53**	**294.43**	**267.144**
		After	289.3	300.4	296.3	4.913	29.55	25.81	30.89	28.760
4	2 Ph-N	Before	307.8	307.8	307.8	0	2.73	2.79	2.61	2.710
		Transient	**2.242**	**2.269**	**308.4**	**195.676**	**4.90**	**102.82**	**11.16**	**39.627**
		After	301.0	301.5	307.6	1.396	20.97	22.70	15.70	19.790
5	2 Ph	Before	307.8	307.8	307.8	0	2.77	2.72	2.61	2.700
		Transient	**155.0**	**152.7**	**307.8**	**50.025**	**10.12**	**10.28**	**9.98**	**10.127**
		After	306.4	295.9	307.6	1.418	20.94	23.82	14.09	19.617
6	1Ph-N	Before	307.8	307.8	307.8	0	2.73	2.78	2.61	2.707
		Transient	**2.657**	**308.1**	**308.0**	**49.381**	**5.22**	**9.77**	**10.63**	**8,570**
		After	300.5	307.7	307.6	0.798	22.19	16.94	15.93	18.354

Figure 12 shows grid current harmonics spectra of phase A during transient phase due to the multi PV connected to three phase grid on PCC bus using MPPT P and O and MPPT Fuzzy method under 1Ph-N fault.



(a) MPPT P and O (b) MPPT Fuzzy

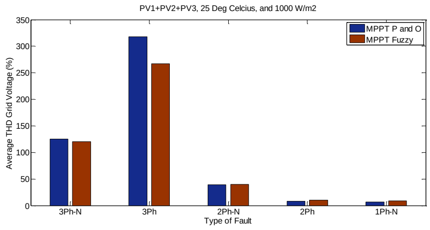
Figure 12. Current harmonics spectra of phase A under 1Ph-N fault

Table 2 presents that under normal condition (no fault), phase current of multi PV (PV1+PV2 + PV3) using MPPT P and O method in transient phase are 10.61 A, 10.74 A, 10.69 A resulting in an unbalanced current of 0.562%. In short circuit faults, the highest unbalanced currents of transient phase is generated by 1Ph-N fault of 195.886% with current on phase A, B, and C of 1332 volt, 9.203 volt, 9.319 volt respectively. The 3Ph-N and 3Ph fault on transient phase produce an unbalanced current of equal to 2,283% resulted by phase current A, B, and C are 1331 A, 1359 A, 1239 A respectively. The implementation of MPPT Fuzzy method under normal condition and transient phase generates phase current of 10.61 A, 10.74 A, 10.69 A so as to produce an unbalanced current equal to 0.562%. If using MPPT Fuzzy method under fault on transient phase, the highest unbalanced current is generated by 2Ph-N faults of 195.886%. At the same condition the smallest unbalanced current is generated by 3Ph-N and 3Ph-N fault equal to 2.282%. In non-symmetrical fault, the use of MPPT P and O method gives an unbalanced current of transient phase slightly lower than MPPT Fuzzy method. While in symmetrical fault, MPPT P and O/MPPT Fuzzy method for controlling of output power of multi PV gives same unbalanced current of transient phase of 2,283%.

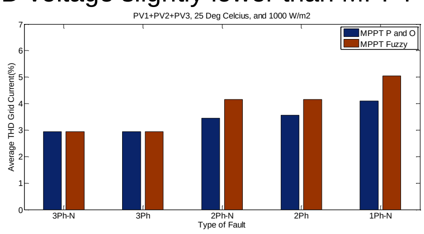
In normal condition, by using both MPPT P and O and MPPT Fuzzy method, the average THD current on transient phase are 3.090% and 3.787%, respectively. When using MPPT P and O, the highest average THD current is generated by 1Ph-N fault of 4,097%. In the same method, the smallest average THD voltage is generated by 3Ph-N and 3Ph equal to 2,947%. If using Fuzzy MPPT, the highest average THD current is generated by 1Ph-N fault of 5.044%. In the same method, the smallest average THD current is generated by 3Ph-N and 3Ph equal to 2,947%. In the symmetrical faults, both MPPT P and O and MPPT Fuzzy method produce average THD current during transient phase equal to 2,947%. Whereas in the case of non-symmetric fault, MPPT P and O resulted in average THD current of transient phase slightly smaller than MPPT Fuzzy method.

Table 3 presents that under normal condition, the voltage values on phase A, B, and C of multi PV using MPPT P and O method under transient phase are 308.8 volt, 308.7 volt, 307.8 volt, respectively, resulting in an unbalanced voltage of 0%. In the short circuit faults, the highest unbalanced voltage during transient phase is generated by a 2Ph-N fault of 195.677% with a phase voltage of A, B, and C respectively of 2.242 volt, 2.268 volts, and 308.4 volt. The 3Ph fault during transient phase produce the smallest unbalanced voltage of 1.279% resulted from phase voltage A, B, and C respectively of 1.347 volt, 1.325 volt, 1.318 volt. The use of MPPT Fuzzy method under normal condition and transient phase gives 308.8 volt, 308.7 volt, 307.8 volt, respectively, resulting in an unbalanced voltage equal to 0%. When using the MPPT Fuzzy method under short-circuit fault during transient phase, the highest unbalanced voltage is generated by a 2Ph-N fault of 195.676%. Under the same condition, the lowest unbalanced voltage is generated by 3Ph fault of 1.003%. In non-symmetrical faults (2Ph-N, 2Ph, and 1Ph-N), the implemantation of MPPT P and O and MPPT Fuzzy method to control output power of multi PV produces nominal unbalanced voltage during transient phase results a close the same value. While in symmetrical fault (3Ph-N and 3Ph) MPPT P and O and MPPT Fuzzy method produce different unbalance voltage on transient phase. During 3Ph-N fault on transient phase, MPPT P and O method results in an unbalanced transient phase voltage of 1.523% slightly lower than MPPT Fuzzy method of 1.605%. But during 3Ph fault on transient phase, MPPT Fuzzy produces an unbalanced voltage of 1.003% slightly lower than MPPT P and O of 1.279%.

In normal condition using both MPPT P and O and MPPT Fuzzy method, THD average voltages are 6.980% and 9.254%, respectively. If using MPPT P and O method, then the largest average THD voltage is generated by a 3Ph fault of 317.846%. By using the same method, the lowest average THD voltage is produced by 1Ph-N fault of 6.974%. If using Fuzzy MPPT method, the largest average THD voltage is also generated by a 3Ph fault of 267.144%. By using the same method, the lowest average THD voltage is generated by 1Ph-N fault of 8.570%. During symmetrical fault on transient phase, MPPT Fuzzy method results average THD voltage smaller than MPPT P and O. Otherwise during non-symmetrical fault on transient phase, MPPT P and O method results average THD voltage slightly lower than MPPT Fuzzy.



(a) Average THD voltage



(b) Average THD current

Figure 13. Performance of average voltage and current harmonic during transient phase

Figure 13.a describes that on symmetrical fault during transient phase (3Ph-N and 3Ph), MPPT Fuzzy method produces average THD voltage smaller than MPPT P and O method. Otherwise on non-symmetrical fault during transient phase (2Ph-N, 2Ph, and 1Ph-N), MPPT P and O method gives average THD voltage slightly smaller than MPPT Fuzzy method. Figure 14.b describes that on symmetrical fault during transient phase (3Ph-N and 3Ph), MPPT Fuzzy and and MPPT P and O method produce same average THD current. Whereas in the case of non-symmetrical fault during transient phase (2Ph-N, 2Ph, and 1P-N), MPPT P and O method resulted in average THD current slightly smaller than MPPT Fuzzy method. The MPPT P and O method and the MPPT Fuzzy method on all short circuit fault during transient phase (3Ph-N, 3Ph, 2Ph-N, 2Ph, and 1Ph-N) produce smaller current average THD current significantly depend on average THD voltage.

4. Conclusion

Comparative performance of multi PVs connected grid under short circuit fault during transient phase to power quality using MPPT P and O/MPPT Fuzzy method has been presented. During transient phase, non-symmetrical faults (2Ph-N, 2Ph, and 1Ph-N) is capable to generate unbalance current/voltage greater depend on symmetrical faults (3Ph-N and 3Ph). On symmetrical faults, MPPT Fuzzy results average THD voltage/THD current smaller than MPPT P and O. Otherwise on non-symmetrical faults, MPPT P and O gives average THD voltage/THD current slightly smaller than MPPT Fuzzy. The MPPT P and O/MPPT Fuzzy method on all short circuit faults during transient phase produce smaller current average THD depend on average THD voltage significantly. Futhermore the nominal of average THD current using both methods also meets THD limit prescribed in IEEE 519 standard.

Appendix

PV generator 1, 2, and 3: active power = 100 kW, temperature = 25^0 C, irradiance = 1000 W/m^2; Three phase grid: short circuit power = 100 MVA, voltage = 380 volt (L-L), frequency = 50 Hz; Power transformer: rated power = 100 kVA, frequency = 50 Hz, voltage 380 Volt/20 kV (L-L), two winding type; Load 1, 2, and 3: active power = 20 kW, voltage = 380 volt (L-L), frequency = 50 Hz; Low Voltage Lines 1,2, and 3: resistance R = 0,1273 Ohm/km, inductance L = 93,37 mH/km, capasitance C = 1,274 μF/km; Length of Low Voltage Lines: Line 1, Line 2, Line 3 = 1 km; DC link capasitor: capacitance= 2000 μF, frequency = 4 kHz; PWM generator for DC/AC inverter: Sampling time= 5×10^{-6} Second; Fuzzy inference system = mamdani method; Fuzzy model composition = max-min; Input membership function: delta voltage=gbellmf, trimf, delta power: gbellmf, trimf; Output membership function: delta duty cycle = trimf.

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Lampiran 2.5

Letter of Acceptance (LoA)

ICW-TELKOMNIKA 2018

LEMBAGA PENERBITAN DAN PUBLIKASI ILMIAH
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Website: http://lppi.uad.ac.id, email: lppi@uad.ac.id

Yogyakarta, August 15, 2018

No. : L6/037/ICW/VIII/2018

To:
Amirullah Amirullah
Institut Teknologi Sepuluh Nopember, Indonesia

Dear Sir/Madam,

Your paper #9897 (‘Transient Power Quality Performance of Multi Photovoltaics using MPPT P and O/MPPT Fuzzy’) for ICW-TELKOMNIKA 2018 was evaluated by anonymous referees by single blind peer review for contribution, originality, relevance, and presentation. Congratulations, your paper is **ACCEPTED** for 1st International Conference and Workshop on Telecommunication, Computing, Electronics and Control 2018 (ICW-TELKOMNIKA 2018). This conference will be held in September, 18-21 2018 in Yogyakarta, Indonesia. All presented papers in this conference (after revisions based upon feedback at the conference & workshop, if necessary) will be published in the TELKOMNIKA Telecommunication Computing Electronics and Control (Scopus indexed journal, SJR Q3).

If you have any question, please contact our committee on icw.telkomnika@journal.uad.ac.id cc: tole@journal.uad.ac.id.

Thank you for your contribution to ICW TELKOMNIKA 2018 and we look forward to meeting you on the conference.

Sincerely yours,

Tole Sutikno, M.T., Ph.D.
NIY. 60010310

Lampiran 2.6

Bukti Pembayaran Makalah

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Lampiran 2.7

Invitation Letter

ICW-TELKOMNIKA 2018

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September, 18-21,2018 | Royal Ambarrukmo Hotel, Yogyakarta
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Nomor : L6/S19/29/B2/IX/2018 Yogyakarta: September 7, 2018
Subject : Invitation Letter as Presenter

To:

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On behalf of the 2018, International Conference and Workshop on Telecommunication, Computing, Electrical, Electronics and Control (ICW-TELKOMNIKA), I am pleased to inform you that your paper has been accepted by the 2018 ICW-TELKOMNIKA Technical Committee after review for technical merits.

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168.	1570465322	The System Architecture Approach of Social Media and Online Newspaper Credibility Measurement	Rakhmat Arianto, Harco Leslie Hendric Spits Warnars, Edi Abdurachman, Yaya Heryadi, Ford Lumban Gaol	Rakhmat Arianto
169.	1570465328	e-KTP 1.0: A Novel Interoperability Framework to Utilize Indonesian Electronic Identity Card	Rolly Maulana Awangga, Intan Nurma Yulita, And Nisa Hanum Harani	Nisa Hanum Harani
170.	1570465332	Seller Reputation Impact on Sales Performance in Public E-Marketplace Bukalapak	M. Ammar Fauzan, Amna Shifia Nisafani, Arif Wibisono	M. Ammar Fauzan
171.	1570465336	Discretization on Bayesian Networks in Determining the Level of Damage to Buildings	Devni Prima Sari, Dedi Rosadi, Adhitya Ronnie Effendie, Danardono	Devni Prima Sari
172.	1570465346	Voice Recognition System for Controlling Electrical Appliances in Smart Hospital Room	Eva Inaiyah Agustin, Riky Tri Yunardi, Aji Akbar Firdaus	Eva Inaiyah Agustin
173.	1570465347	UDP Protocol for Multi-Task Assignment in "Void Loop" Robot Soccer	Irma Damayanti, Simon Siregar, M. Ikhsan Sani	Simon Siregar
174.	1570465359	The Use of Mobile-Assisted Virtual Reality in Fear of Darkness Therapy	Erick Paulus, Mira Suryani, Puspita Adhi Kusuma Wijayanti, Firdaus Perdana Yusuf, Aulia Iskandarsyah	Mira Suryani
175.	1570465361	Integrating Fuzzy Logic and Genetic Algorithm for Upwelling Prediction in Maninjau Lake	Muhammad Rofiq, Yogie Susdyastama Putra, Wayan Firdaus Mahmudy, Herman Tolle, Ida Wahyuni, Philip Faster Eka Adipraja, Hafrijal Syandri	Muhammad Rofiq
176.	1570465366	Cognitive Artificial-Intelligence for Doernenburg DGA Interpretation	Karel Octavianus Bachri, Umar Khayam, Bambang Anggoro Soedjarno, Arwin Datumaya Wahyudi Sumari, Adang Suwandi Ahmad	Karel Octavianus Bachri
177.	1570465427	Prediction of PID Control Model on PLC	Erwani Merry Sartika, Rudi Sarjono, Diki Dwi Saputra	Erwani Merry Sartika
178.	1570465883	Sub-1 GHz Wireless Nodes Performance Evaluation for Intelligent Greenhouse System	I Nyoman Kusuma Wardana, Ngakan Nyoman Kutha Krisnawijaya, I Wayan Aditya Suranata	I Nyoman Kusuma Wardana
179.	1570466078	Cyst and Tumor Classifications on Human Dental Panoramic Images Using Statistical Modeling Approach	Nur Chamidah, Kinanti Hanugera Gusti, Eko Tjahjono, And Budi Lestari	Kinanti Hanugera Gusti

No.	Paper ID	Paper Title	Names of Author(s)	Presenting Author
180.	1570466661	Private Cloud Storage Implementation Using OpenStack Swift	Agustinus Noertjahyana, Juan Reno, Henry Novianus Palit, Justinus Andjarwirawan	Henry Novianus Palit
181.	1570466671	A Scoring Rubric for Automatic Short Answer Grading System	Uswatun Hasanah, Adhistya Erna Permanasari, Sri Suning Kusumawardani, Feddy Setio Pribadi	Uswatun Hasanah
182.	1570466831	Alpha-Cut and Constraint Exploration Approach on Quadratic Programming Problem	Y. Dasril, Zahriladha Zakaria, I. B. Mohd	Yosza Dasril
183.	1570467744	Hiding Data in Images Using Steganography Techniques with Lossy and Lossless Compression Algorithms	Osama Fouad Abdelwahab,Aziza I. Hussein,Hamdy M. Kelash,Hesham F. A. Hamed	Osama Fouad Abdelwahab
184.	1570468772	Towards Adaptive Sensor-Cloud for Internet of Things	I Made Murwantara, Hendra Tjahyadi, Pujianto Yugopuspito, Arnold Aribowo, Irene Lazarusli	Irene Lazarusli
185.	1570469175	An Electrical Power Control System for Explorer-class Remotely Operated Underwater Vehicle (ROV)	Muhammad Ikhsan Sani, Simon Siregar, Muhammad Muchlis Kurnia, Dzikri Hasbialloh	Muhammad Ikhsan Sani
186.	1570469434	An Architectural Design of IoT-Cloud Platform for N. Edward	Adhitya Bhawiyuga; Dany Primanita Kartikasari; Kasyful Amron; Moch Wildan Habibie; Ocki Bagus Pratama	Dany Primanita Kartikasari
187.	1570469436	Simulation of MOS Sensor to Detect Meat Classification	Budi Gunawan, Salman Alfarisi, Gunanjar Satrio, Arief Sudarmaji, Malvin, Krisyarangga	Salman Alfarisi
188.	1570469461	Neurocomputing Fundamental Climate Analysis	Rezzy Eko Caraka, Sakhinah Abu Bakar, Muhammad Tahmid, Hasbi Yasin, Isma Dwi Kurniawan	Rezzy Eko Caraka
189.	1570469480	Power Loss Analysis of DC Current Modules based Multilevel Current-Source Inverters	Suroso, Winarsis, Daru Tri Nugroho, Wahyu Tri Cahyanto	Suroso
190.	1570469489	"Magic Boosed" an Elementary School Geometry Textbook with Marker-Based Augmented Reality	Reza Andrea, Siti Lailiyah, Fahrul Agus, Ramadiani	Siti Lailiyah
191.	1570469531	Sampling Frequency Influence on the Musical Instruments Tone Recognition	Linggo Sumarno, Kuntoro Adi	Linggo Sumarno
192.	1570469567	An Adaptive Internal Model for Load Frequency Control Using Extreme Learning Machine	Adelhard Beni Rehiara, He Chongkai, Yutaka Sasaki, Naoto Yorino, Yoshifumi Zoka	Adelhard B. Rehiara
193.	1570469577	Performance Analysis of Tunnel Broker Through Open Virtual Private Network	Rendy Munadi, Danu Dwi Sanjoyo, Doan Perdana, Fidar Adjie	Danu Dwi Sanjoyo

No.	Paper ID	Paper Title	Names of Author(s)	Presenting Author
194.	1570469614	Design and Realization of Array Spiral Labyrinth Microstrip Antenna for DVB-T Application	Indra Surjati, Syah Alam, Juliarto Karnadi	Syah Alam
195.	1570469634	Development of a Low-Cost Transradial Myoelectric Hand Using Tendon-spring Mechanism	Mochammad Ariyanto, Rifky Ismail, Joga D. Setiawan, Elga P. Yuandi	Mochammad Ariyanto
196.	1570469650	Combination of Arima Model-Fuzzy Alpha Cut to Enhance Interval Width of Crime Forecasting	Yaya Sudarya Triana, Astari Retnowardhani	Yaya Sudarya Triana
197.	1570469654	Remote Sensing Technology for Disaster Mitigation and Regional Infrastructure Planning to Support Sustainable Development Based on Energy Conservation in Urban Area: A Review	Muhammad Dimyati, Akhmad Fauzy, Anggara Setyabawana Putra	Anggara Setyabawana Putra
198.	1570469679	Sequential Order vs Random Order in Operators of Variable Neighborhood Descent Method	Darmawan Satyananda, Sapti Wahyuningsih	Darmawan Satyananda
199.	1570469683	e-KTP 1.1: Decentralised Interoperability Network using Distributed Hash Table	Rolly Maulana Awangga*, Nisa Hanum Harani , And Muhammad Yusril Helmi	Nisa Hanum Harani
200.	1570469704	Low-Cost Communication System for Explorer-class Underwater Remotely Operated Vehicle	Simon Siregar, Muhammad Ikhsan Sani, Muhammad Muchlis Kurnia, Dzikri Hasbialloh	Simon Siregar
201.	1570469705	Suitability Analysis of Rice Varieties Using Learning Vector Quantization and Remote Sensing Images	Annisa Apriliani, Retno Kusumaningrum, Sukmawati Nur Endah, Yudo Prasetyo	Retno Kusumaningrum
202.	1570469714	VRLA Battery State-of-Health Estimation based on Charging Time	Akhmad Zainuri, Unggul Wibawa, Mochammad Rusli, Rini Nur Hasanah, Rosihan Arby Harahap	Akhmad Zainuri
203.	1570469715	Time and Cost Optimization of Business Process RMA using PERT and Goal Programming	Gita Intani Budiawati And Riyanarto Sarno	Gita Intani Budiawati
204.	1570470159	Automatic Control of Electrical Appliances using Bluetooth	Ankita Hitesh Harkare,Sagar Welekar, Abhishek Maheswari, Suraj Motwani	Ankita Hitesh Harkare
205.	1570470386	Detection of The Air Pollution Based on an Infrared Image Using Image Processing	S. R. Sulistiyanti; F. X. A. Setyawan; M. Komarudin	S. R. Sulistiyanti

No.	Paper ID	Paper Title	Names of Author(s)	Presenting Author
206.	1570470406	The Antecedent of Citizen Intention Use of e-Government Service	Taqwa Hariguna, Chung-Wen Hung, Husni Teja Sukmana	Taqwa Hariguna
207.	1570470458	Development of Low Cost Vehicle-based Driving Simulator for Drowsiness Detection	Ignatius Deradjad Pranowo; Dian Artanto; Muhammad Prayadi Sulistyanto	Dian Artanto
208.	1570470819	Distributed Light-weight IoT Platform for Rapid Application Development and Deployment	A.Karim Mohamed Ibrahim, Rozeha A. Rashid, A. Hadi Fikri A. Hamid, M. Adib Sarijari, Muhammad Ariff Baharudin	Rozeha A. Rashid
209.	1570471520	FPGA-based implementation of speech recognition for automobile robot control using MFCC algorithm	Bayuaji Kurniadhani, Sugondo Hadiyoso, Suci Aulia, Rita Magdalena	Suci Aulia
210.	1570471783	Velocity Measurement based on Inertial Measuring Unit (IMU)	Waru Djuriatno, Eka Maulana, Hasan, Effendi Dodi Arisandi, Wijono	Waru Djuriatno
211.	1570471947	Optical Sensor Based on Dye Sensitized Solar Cell (DSSC) with Tobacco Chlorophyll	Eka Maulana, Rahmadwati, Sapriesty Nainy Sari, Akhmad Sabarudin	Rahmadwati
212.	1570471994	GNSS interference Reduction Method For CORS Site Planning	Reza Septiawan, Agung Syetiawan, Arief Rufiyanto, Nashrullah Taufik, Budi Sulistya, Erik Madyo Putro	Reza Septiawan
213.	1570473474	Air Pollution Monitoring System Using LoRa Modul as Transceiver system	Mia Rosmiati, Moch. Fachru Rizal, Fitri Susanti And Gilang Fahreza Alfisyahrin	Mia Rosmiati
214.	1570473483	Study of DC Motor Power Requirement at Arduino Smart Irrigation System	Folkes E. Laumal, Darmawan Napitupulu, Oktaf Brilian Kharisma, Kusa B. N. Nope, Robinson A. Wadu	Folkes E. Laumal
215.	1570473666	Wireless Sensor Node Implementation Using 6LowPAN and MQTT Communication Protocols	Achmad Basuki, Kasyful Amron, Sabriansyah Rizqika Akbar, Eko Sakti Pramukantoro, Adhitya Bhawiyuga	Achmad Basuki
216.	1570473692	Plasma Generator Based on Design Six Stage Cockcroft-Walton Voltage Multiplier 12 kV	Wijono, Dony Darmawan Putra, Eka Maulana, Waru Djuriatno	Wijono
217.	1570473696	Nonlinearity Compensation of Low Frequency Loudspeaker Response Using Internal Model Controller	Erni Yudaningtyas Achsanul Khabib, Waru Djuriatno, Dionysius J.D.H. Santjojo, Adharul Muttaqin, Ponco Siwindarto, Zakiyah Amalia	Erni Yudaningtyas

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Rundown Acara

ICW-TELKOMNIKA 2018

1st International Conference and Workshop on Telecommunication, Computing, Electrical, Electronics and Control

1st ICW-TELKOMNIKA 2018

Royal Ambarukmo Hotel

Tuesday-Thursday, 18-20 September 2018

Event Schedule

Tuesday, 18 September 2018

TIME	AGENDA					
07:30-08:00	**Registration**					
08:00-09:30	**Opening Ceremony**					
09:30-09:45	**Coffee Break**					
09:45-10:45	**Keynote Speaker 1: "Nature Grasping by a Cable-Driven Under-Actuated Anthropomorphic Robotic Hand" Prof. Dr. Nadia Magnenat Thalmann Nanyang Technological University (NTU), Singapore and University of Geneva, Switzerland**					
10:45-11:45	**Keynote Speaker 2: "Technology, Innovation and Entrepreneurship through Industry 4.0" Dr. Ing. Ilham Akbar Habibie President Director PT. Ilthabi Rekatama, Indonesia**					
11:45-13:00	**Lunch Break**					
13:00-15:00	**Parallel Session 1**					
	Room Karaton 1	Room Karaton 2	Room Pemandengan 1	Room Pemandengan 2	Room Pemandengan 3	Room Pemandengan 4
15:00-15:30	**Coffee Break**					
15:30-17:00	**Parallel Session 2**					
	Room Karaton 1	Room Karaton 2	Room Pemandengan 1	Room Pemandengan 2	Room Pemandengan 3	Room Pemandengan 4
17:00-17:30	**Speech from Editor in Chief TELKOMNIKA Tole Sutikno, Ph.D**					
17:30-19:00	**Break and Dinner**					
19:00-22:30	**Parallel Session 3**					
	Room Karaton 1	Room Karaton 2	Room Pemandengan 1	Room Pemandengan 2	Room Pemandengan 3	Room Pemandengan 4

Wednesday, 19 September 2018

<table>
<tr><th>TIME</th><th colspan="6">AGENDA</th></tr>
<tr><td>07:30-08:00</td><td colspan="6">Registration</td></tr>
<tr><td>08:00-09:00</td><td colspan="6">Keynote Speaker 3:
“Intelligent Autonomous Systems”
Prof. Dr. Er Meng Joo
Nanyang Technological University (NTU), Singapore</td></tr>
<tr><td>09:00-09:15</td><td colspan="6">Coffee Break</td></tr>
<tr><td>09:15-10:15</td><td colspan="6">Keynote Speaker 4:
“Walking and Grasping in Animation, VR and Robotics”
Prof. Dr. Daniel Thalmann
École Polytechnique Fédérale de Lausanne, Switzerland</td></tr>
<tr><td rowspan="2">10:15-11:45</td><td colspan="6">Parallel Session 4</td></tr>
<tr><td>Room Karaton 1</td><td>Room Karaton 2</td><td>Room Pemandengan 1</td><td>Room Pemandengan 2</td><td>Room Pemandengan 3</td><td>Room Pemandengan 4</td></tr>
<tr><td>11:45-12:30</td><td colspan="6">Lunch Break</td></tr>
<tr><td rowspan="2">12:30-14:00</td><td colspan="6">Parallel Session 5</td></tr>
<tr><td>Room Karaton 1</td><td>Room Karaton 2</td><td>Room Pemandengan 1</td><td>Room Pemandengan 2</td><td>Room Pemandengan 3</td><td>Room Pemandengan 4</td></tr>
<tr><td>14:00-15:00</td><td colspan="6">Workshop on Scientific Writing session 1:
“Writing an Article Effectively and Coherently in Both of IMRaD & Unstructured Styles”
Prof. Dr. Daniel Thalmann</td></tr>
<tr><td>15:00-16:00</td><td colspan="6">Workshop on Scientific Writing session 2:
“Key Principles and Best Practices for Effective Writing of High Impact Publications”
Assoc. Prof. Dr. M Nadzir Marsono</td></tr>
<tr><td>16:00-16:30</td><td colspan="6">Coffee Break</td></tr>
<tr><td rowspan="3">16:30-18:00</td><td colspan="6">Tutorial</td></tr>
<tr><td colspan="3">Room Karaton Ballroom</td><td colspan="3">Room Karaton Ballroom</td></tr>
<tr><td colspan="3">“Living and Playing in Virtual Reality: A few Case Studies”
Prof. Dr. Daniel Thalmann</td><td colspan="3">Prof. Dr. Er Meng Joo</td></tr>
<tr><td>18:00-19:00</td><td colspan="6">Break</td></tr>
<tr><td>19:00-21:30</td><td colspan="6">Gala Dinner and Awards</td></tr>
</table>

Thursday, 20 September 2018

<table>
<tr><th>TIME</th><th colspan="6">AGENDA</th></tr>
<tr><td>07:30-08:00</td><td colspan="6">Registration</td></tr>
<tr><td>08.00-08.30</td><td colspan="6">Speech from Dr. Muhammad Dimyati
Ministry of Research, Technology and Higher Education of the Republic of Indonesia</td></tr>
<tr><td rowspan="2">08:30-10:00</td><td colspan="6">Manuscrip Mentoring and Coaching</td></tr>
<tr><td>Room Karaton 1</td><td>Room Karaton 2</td><td>Room Pemandengan 1</td><td>Room Pemandengan 2</td><td>Room Pemandengan 3</td><td>Room Pemandengan 4</td></tr>
<tr><td>10:00.10:15</td><td colspan="6">Coffee Break</td></tr>
<tr><td rowspan="2">10:15-11:45</td><td colspan="6">Manuscrip Mentoring and Coaching</td></tr>
<tr><td>Room Karaton 1</td><td>Room Karaton 2</td><td>Room Pemandengan 1</td><td>Room Pemandengan 2</td><td>Room Pemandengan 3</td><td>Room Pemandengan 4</td></tr>
<tr><td>11:45-13:00</td><td colspan="6">Lunch</td></tr>
<tr><td rowspan="2">13:00-14:30</td><td colspan="6">Manuscrip Mentoring and Coaching</td></tr>
<tr><td>Room Karaton 1</td><td>Room Karaton 2</td><td>Room Pemandengan 1</td><td>Room Pemandengan 2</td><td>Room Pemandengan 3</td><td>Room Pemandengan 4</td></tr>
<tr><td>14:30-15:00</td><td colspan="6">Coffee Break</td></tr>
<tr><td>15:00-17:00</td><td colspan="6">Closing</td></tr>
</table>

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Presentation Schedule

ICW-TELKOMNIKA 2018

Presentation Schedule

1st International Conference and Workshop on Telecommunication, Computing, Electrical, Electronics and Control 1st ICW-TELKOMNIKA 2018 Tuesday, September 18, 2018 Karaton Ballroom 1				
NO	**TIME**	**ID PAPER**	**TITLE**	**PRESENTER**
1.	13:00-13:15	10414	A Small RLSA Antennas Utilizing the Specification of Back Fires 17 dBi LAN Antennas	Teddy Purnamirza
2.	13:15-13:30	1570465883	Sub-1 GHz Wireless Nodes Performance Evaluation for Intelligent Greenhouse System	I Nyoman Kusuma Wardana
3.	13:30-13:45	8859	Implementation Model Arcitecture Software Defined Network Using Raspberry Pi: A Review Paper	Oki Marzuqi
4.	13:45-14:00	10162	Hybrid Filter Scheme for Optimizing Indoor Mobile Cooperative Tracking System	Rafina Destiarti Ainul
5.	14:00-14:15	1570452660	Losses in S-bend silica optical waveguides	Ary Syahriar
6.	14:15-14:30	1570469704	Low-Cost Communication System for Explorer-class Underwater Remotely Operated Vehicle	Simon Siregar
7.	14:30-14:45	1570462024	A Coupled-Line Balun for Ultra-Wideband Single-Balanced Diode Mixer	Noor Azwan Shairi
8.	14:45-15:00	1570469614	Design and Realization of Array Spiral Labyrinth Microstrip Antenna for DVB-T Application	Syah Alam
9.	15:30-15:45	1570473666	Wireless Sensor Node Implementation Using 6LowPAN and MQTEL Communication Protocols	Achmad Basuki
10.	15:45-16:00	1570470458	Development of Low Cost Vehicle-based Driving Simulator for Drowsiness Detection	Dian Artanto
11.	16:00-16:15	1570471994	GNSS Interference Reduction Method for CORS Site Planning	Reza Septiawan
12.	16:15-16:30	1570465154	Performance of Genetic Network Programming Usintg Two-Stage Reinforcement Learning Topics	Yogi Dwi Mahandi
13.	16:30-16:45	8705	Cladding effects on Silica Directional Couplers	Ary Syahriar
14.	16:45-17:00	10133	The QCM Based Electronic Nose System Implemented on FPGA	Misbah

Presentation Schedule

1st International Conference and Workshop on Telecommunication, Computing, Electrical, Electronics and Control 1st ICW-TELKOMNIKA 2018 Tuesday, September 18, 2018 Karaton Ballroom 1				
15.	19:00-19:15	10363	The Use of General Volatile MOS Gas Sensors in Discriminating Formalin Content	Arief Sudarmaji
16.	19:15-19:30	1570469436	Simulation of MOS Sensor to Detect Meat Classification	Salman Alfarisi
17.	19:30-19:45	1570469634	Development of a Low-Cost Transradial Myoelectric Hand Using Tendon-spring Mechanism	Mochammad Ariyanto
18.	19:45-20:00	1570456895	Comparison of Semiconductor Lasers at wavelength 980nm & 1480nm using InGaAs for EDFA Pumping Scheme	Satyo Pradana
19.	20:00-20:15	1570461743	A Compact Reconfigurable Dual Band-Notched Ultra-Wideband Antenna using Varactor Diodes	Zahriladha Zakaria
20.	20:15-20:30	1570462262	Improving Performance of IPv6 Packets Transmission by Increasing MTU Size	Supriyanto Praptodiyono
21.	20:30-20:45	1570465163	A Novel Compact Dual-Band Bandpass Filter for WLAN and WiMAX Applications	Nurhasniza Edward
22.	20:45-21:00	1570463916	Dual-Band Aperture Coupled Antenna with Harmonic Suppression Capability	Faza Syahirah
23.	21:00-21:15	10565	Challenge Overview of Electronic Nose Data Processing for Beef Quality Assessment	Dedy Rahman Wijaya
24.	21:15-21:30	1570465068	2:45 GHz Rectenna with High Gain for RF Energy Harvesting	Faza Syahirah
25.	21:30-21:45	9563	Thermodynamic Performance and Wave Propagation Sensor System of Fiber Bragg Grating in Liquid Media	Romi F. Syahputra
26.	21:45-22:00	10533	Influence of Input Power in Ar/H2 Thermal Plasma with Silicon Powder by Numerical Simulation	Yulianta Siregar

Presentation Schedule

1st International Conference and Workshop on Telecommunication, Computing, Electrical, Electronics and Control

1st ICW-TELKOMNIKA 2018

Wednesday, September 19, 2018
Karaton Ballroom 1

NO	TIME	ID PAPER	TITLE	PRESENTER
1.	10:15-10:30	9993	Fabrication of pH Sensor Based on Fiber Optic Coated Bromophenol Blue and Cresol Red Simultaneously	Fredy Kurniawan
2.	10:30-10:45	9029	Electromagnetic Interference Shielding in Unmanned Aerial Vehicle Against Lightning Strike	Diah Permata
3.	10:45-11:00	10116	Analyzing the Deformation of Copper Conductor from a Fire Impact Caused by Electricity Using Sem-Eds and Micro-Xrf Instruments	Didik Notosudjono
4.	11:00-11:15	1570465118	Improved Echocardiography Segmentation using Active Shape Model and Optical Flow	Riyanto Sigit
5.	11:15-11:30	1570463311	Comparison of Dynamic Performance between DFIG and FCWECS during Grid Fault	A. M. Shiddiq Yunus
6.	11:30-11:45	1570469175	An Electrical Power Control System for Explorer-class Remotely Operated Underwater Vehicle (ROV)	Muhammad Ikhsan Sani
7.	12:30-12:45	1570469567	An Adaptive Internal Model for Load Frequency Control Using Extreme Learning Machine	Adelhard B. Rehiara
8.	12:45-13:00	1570473692	Plasma Generator Based on Design Six Stage Cockcroft-Walton Voltage Multiplier 12 kV	Wijono
9.	13:00-13:15	9687	Electro Magnetic Characteristics Measurement of Organic Material Absorber	Reza/Arief
10.	13:15-13:30	1570464970	Determination of Solid Material Permittivity Using T-Ring Resonator For Food Industry	Zahrilada. Zakaria
11.	13:30-13:45	9968	Loss Quantization of Reflectarray Antenna Based on Organic Substrate Materials	Hasan Ijaz Malik

Presentation Schedule

1st International Conference and Workshop on Telecommunication, Computing, Electrical, Electronics and Control

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Tuesday, September 18, 2018
Karaton Ballroom 2

NO	TIME	ID PAPER	TITLE	PRESENTER
1.	13:00-13:15	9468	Radial Derivative And Radial Inversion For Interpreting 4D Gravity Anomaly Due To Fluids Injection Arround Reservoir	Muhammad Zuhdi
2.	13:15-13:30	10318	Formal Expansion Method for Solving an Electrical Circuit Model	Sudi Mungkasi
3.	13:30-13:45	1570459736	User Log Data Acquisition Based on Implicit Feedback Using Collaborative Filtering Method	Muhammad Yusril Helmi Seyawan
4.	13:45-14:00	1570464938	Reference Broadcast Synchronization and Time Division Multiple Access Implementation on WSN	Mochammad Hannats Hanafi Ichsan
5.	14:00-14:15	1570464943	WSN Performance based on Node Placement by Genetic Algorithm at Smart Home Environment	Mochammad Hannats Hanafi Ichsan
6.	14:15-14:30	1570464411	Natural Automatic Musical Note Player using Time-Frequency Analysis on Human Play	Khafiizh Hastuti
7.	14:30-14:45	9237	Ontology Design of Family Planning Field Officer for Family Planning Agency Using OWL and RDF	Muhammad Firman Kahfi
8.	14:45-15:00	9933	Detection of Immovable Objects on Visually Impaired People Walking Aids	Abdurrasyid
9.	15:30-15:45	1570465359	The Use of Mobile-Assisted Virtual Reality in Fear of Darkness Therapy	Mira Suryani
10.	15:45-16:00	1570469489	"Magic Boosed" an Elementary School Geometry Textbook with Marker-Based Augmented Reality	Siti Lailiyah
11.	16:00-16:15	1570469480	Power Loss Analysis of DC Current Modules based Multilevel Current-Source Inverters	Suroso

Presentation Schedule

1st International Conference and Workshop on Telecommunication, Computing, Electrical, Electronics and Control

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Tuesday, September 18, 2018

Karaton Ballroom 2

12.	16:15-16:30	10407	Repair and Replacement Strategy for Optimizing Cost and Time of Warranty Process	Ardy Januantoro
13.	16:30-16:45	8640	The Step Construction of Penalized Spline in Electrical Power Load Data	Rezzy Eko Caraka
14.	16:45-17:00	9660	Statistical Tuning Chart for Mapping Porosity Thickness: A Case Study of Channel Sand Bodies in the Kutei Basin Reservoir	Abdul Haris
15.	19:00-19:15	1570456185	Initial Framework Development to Forecast Real Time Rice Production	Dodisutarma Lapihu
16.	19:15-19:30	8999	Usability of BLESS-implemented Class Room: A case study of Mixtio	Astari Retnowardhani
17.	19:30-19:45	9107	Publication of SOP Using Semantic Networks on Personnel System: University of Singaperbangsa Karawang Case Study	Intan Purnamasari
18.	19:45-20:00	9394	Noise or Outlier on DBSCAN And K-Means Algorithm Using RFM Model In Customer Behaviour	Siti Monalisa
19.	20:00-20:15	9634	Technology Acceptance Model to Test GO-JEK Acceptance in Salatiga	Dhea Arvie
20.	20:15-20:30	9883	The Readiness of Palm Oil Industry in Enterprise Resource Planning	Darius Antoni
21.	20:30-20:45	10050	Information Quality Risk Assessment using Threat Scenario Dependency Model and Extended Risk Matrix Approach	Fitasari Wiharni
22.	20:45-21:00	10165	Security Risk Analysis of Bring Your Own Device (BYOD) System in Manufacturing Company at Tangerang	Astari Retnowardhani
23.	21:00-21:15	1570457134	Big 5 ASEAN Capital Markets Forecasting using Hybrid WEMA Method	Seng Hansun

Presentation Schedule

1st International Conference and Workshop on Telecommunication, Computing, Electrical, Electronics and Control 1st ICW-TELKOMNIKA 2018 Tuesday, September 18, 2018 Karaton Ballroom 2				
24.	21:15-21:30	10096	Hybrid Model for Forecasting Space-Time Data with Calendar Variation Effects	I Made Gde Meranggi Dana
25.	21:30-21:45	9384	Secret Key Identification of AES,DES and BC3 Encryption Device using Power Analysis Attack	Septafiansyah Dwi Putra
26.	21:45-22:00	1570464953	Wi-Fi Password Stealing Program Using USB Rubber Ducky	Hansen Edrick Harianto

Presentation Schedule

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Wednesday, September 19, 2018
Karaton Ballroom 2

NO	TIME	ID PAPER	TITLE	PRESENTER
1.	10:15-10:30	1570465148	User Authentication Using Zero Knowledge Proof with Guillou-Quisquater Method	Dennis Gunawan
2.	10:30-10:45	1570468772	Towards Adaptive Sensor-Cloud for Internet of Things	Irene Lazarusli
3.	10:45-11:00	9191	Evaluation of Network Security Based on Next Generation Intrusion Prevention System	Nico Surantha
4.	11:00-11:15	9638	Speech Recognition Application for the Speech Impaired Using the Android-Based Google Cloud Speech API	Nashrul Hakiem
5.	11:15-11:30	10198	A Low-Cost GPS NTP Server for Time Synchronization	Heri Andrianto
6.	11:30-11:45	1570463800	A Comparison of Tools on Android Devices for Email Forensics	Bashor Fauzan Muthohirin
7.	12:30-12:45	1570466661	Private Cloud Storage Implementation Using OpenStack Swift	Henry Novianus Palit
8.	12:45-13:00	1570469715	Time and Cost Optimization of Business Process RMA using PERT and Goal Programming	Gita Intani Budiawati
9.	13:00-13:15	1570465319	Cellular-based Internet Gateway Device for Bridging IoT Infrastructure and Cloud Data Storage	Eko Sakti Pramukantoro
10.	13:15-13:30	9144	Content Pattern Capacity Participants Exam of Mobile Learning for Assessment	Heri Nurdianto

Presentation Schedule

1st International Conference and Workshop on Telecommunication, Computing, Electrical, Electronics and Control 1st ICW-TELKOMNIKA 2018 Tuesday, September 18, 2018 Pemandengan 1				
NO	**TIME**	**ID Paper**	**TITLE**	**PRESENTER**
1.	13:00-13:15	9450	A Preliminary Study on The Development Rapid Method to Classify Protein Content of Wheat flour using Bioelectrical Properties and Artificial Neural Network	Sucipto
2.	13:15-13:30	9466	Particle Filter with Integrated Multiple Features for Object Detection and Tracking	Muhammad Attamimi
3.	13:30-13:45	10144	Vehicle Detection Using Background Subtraction And Clustering Algorithms	Yuslena Sari
4.	13:45-14:00	1570470386	Detection Air Pollution Based on Infrared Image Processing	S. R. Sulistiyanti
5.	14:00-14:15	10155	Active SLAM-Based Mobile Robot Olfaction Navigation for Gas Distribution Mapping	Duddy Soegiarto
6.	14:15-14:30	1570463247	Low Cost NodeMcu Based Development Water Rocket Measurement System Applied to STEM Education	Andi Susilo
7.	14:30-14:45	9547	An Artificial Neural Network Approach for Detecting Skin Cancer	Julius Santony
8.	14:45-15:00	9764	Digital Book for Assessment and Evaluation Courses Based on Kvisoft-Kelase Asynchronous Pattern	Dewa Gede Hendra Divayana
9.	15:30-15:45	10090	A Gamification Framework to Enhance Students' Intrinsic Motivation on MOOC	Rujianto Eko Saputro
10.	15:45-16:00	10129	Traffic Congestion Prevention by Optimizing Traffic Lights' Setting Using Fuzzy Mamdani Method	Dian Hartanti
11.	16:00-16:15	1570469434	An Architectural Design of Iot-Cloud Platform for Iot-Cloud Computing Integration	Dany Primanita Kartikasari
12.	16:15-16:30	1570469577	Performance Analysis of Tunnel Broker Through Open Virtual Private Network	Danu Dwi Sanjoyo
13.	16:30-16:45	1570461324	Automatic Face and VLP's Recognition for Smart Parking System 84	Suci Aulia

Presentation Schedule

1st International Conference and Workshop on Telecommunication, Computing, Electrical, Electronics and Control 1st ICW-TELKOMNIKA 2018 Tuesday, September 18, 2018 Pemandengan 1				
14.	16:45-17:00	1570462773	Application of Force Sensor and EMG signals for Rehabilitation Robot Arm	Riky Tri Yunardi
15.	19:00-19:15	1570464534	fit-NES: Wearable Bracelet for Heart Rate Monitoring	Muhammad Ikhsan Sani
16.	19:15-19:30	8694	Type 2 Fuzzy Sliding Mode Control (T2FSMC) with Firefly Algorithm Optimization on Solar Panel	Zainullah Zuhri
17.	19:30-19:45	9255	Analysis UAV Multicopter for Air Photography In New International Yogyakarta Airports	Indreswari Suroso
18.	19:45-20:00	10112	Transfer Function and Stabilizability of Non-Autonomous Riesz-spectral Systems	Sutrima
19.	20:00-20:15	10326	Bioinspired Algorithms to Select Textural Features for Predicting Nitrogen Content in Spinach	Yusuf Hendrawan
20.	20:15-20:30	10397	Real-time Systems for Monitoring and Warning on Water Urban Rivers	Sabam Parjuangan
21.	20:30-20:45	1570465346	Voice Recognition System for Controlling Electrical Appliances in Smart Hospital Room	Eva Inaiyah Agustin
22.	20:45-21:00	10152	Implementation Integration of VaaMSN with SEMAR for Air Monitoring Solution	Sritrusta Sukaridhoto
23.	21:00-21:15	1570473474	Air Pollution Monitoring System Using LoRa Modul as Transceiver system	Moch. Fachru Rizal
24.	21:15-21:30	1570465347	UDP Protocol for Multi-Task Assignment in "Void Loop" Robot Soccer	Simon Siregar
25.	21:30-21:45	1570469654	Remote Sensing Technology for Disaster Mitigation and Regional Infrastructure Planning to Support Sustainable Development Based on Energy Conservation in Urban Area: A Review	Anggara Setyabawana Putra
26.	21:45-22:00	8558	Design of Electro Cardiograph Machine	Bambang Guruh Irianto

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1st International Conference and Workshop on Telecommunication, Computing, Electrical, Electronics and Control 1st ICW-TELKOMNIKA 2018 Wednesday, September 19, 2018 Pemandengan 1				
NO	**TIME**	**ID PAPER**	**TITLE**	**PRESENTER**
1.	10:15-10:30	1570465336	Discretization on Bayesian Networks in Determining the Level of Damage to Buildings	Devni Prima Sari
2.	10:30-10:45	1570464824	An Idea of Intuitive Mobile Diopter Calculator for Myopia Patient	Komang Candra Brata
3.	10:45-11:00	10121	Internet of Things: Smart Garbage Monitoring System with Real Time Database	Dadan Nur Ramadan
4.	11:00-11:15	1570464584	Transistor Mismatch Effect on Common-Mode Gain of Cross-Coupled Amplifier	Zainul Abidin
5.	11:15-11:30	1570465097	Design of Radar Display of Indonesian Airspace Monitoring Application	Sulistyaningsih
6.	11:30-11:45	1570473696	Nonlinearity Compensation of Low-Frequency Loudspeaker Response Using Internal Model Controller	Erni Yudaningtyas
7.	12:30-12:45	1570471947	Optical Sensor Based on Dye Sensitized Solar Cell (DSSC) with Tobacco Chlorophyll	Eka Maulana
8.	12:45-13:00	1570464964	Extraction of Significant Variables of EEG Signal for Post-Stroke Analysis	Esmeralda Contessa Djamal
9.	13:00-13:15	10149	Near Infrared Sensor for Glucose Solution Monitoring	Engelin Shintadewi Julian
10.	13:15-13:30	9162	Coordination of Blade Pitch Controller and BES using Firefly Algorithm for Frequency Stabilization in Wind Power System	Teguh Aryo Nugroho
11.	13:30-13:45	10146	Simulation of Mixed-Load Testing Process in an Electronic Manufacturing Company	Hayati Mukti Asih

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Tuesday, September 18, 2018
Pemandengan 2

NO	TIME	ID Paper	TITLE	PRESENTER
1.	13:00-13:15	8249	Speed Limiter Integrated Fatigue Analyzer (SLIFA): Engineering Design and Concept	Fajar Anggara
2.	13:15-13:30	10114	Ambient Light Adaptive LED Light Dimmer	Saidah
3.	13:30-13:45	1570464699	Design and Construction Human Footstep Power Generator using Ultrasonic Sensor	Anang Sularsa
4.	13:45-14:00	1570473483	Study of DC Motor Power Requirement at Arduino Smart Irrigation System	Folkes E. Laumal
5.	14:00-14:15	9265	Development of the Internet of Things at Hydroponic System Using Raspberry Pi	Rony Baskoro Lukito
6.	14:15-14:30	1570464001	Analysis of Switching and Matching Stubs in Reconfigurable Power Divider with SPDT Switch Function	Noor Azwan Shairi
7.	14:30-14:45	1570465427	Prediction of PID Control Model on PLC	Erwani Merry Sartika
8.	14:45-15:00	10180	Architecture Design for A Multi-Sensor Information Fusion Processor	Catherine Olivia Sereati
9.	15:30-15:45	1570470159	Automatic Control of Electrical Appliances using Bluetooth	Ankita Hitesh Harkare
10.	15:45-16:00	1570471783	Velocity Measurement based on Inertial Measuring Unit (IMU)	Waru Djuriatno
11.	16:00-16:15	10245	The Design of Smart Notification on Android Gadget for Academic Announcement	Ahmad Sanmorino
12.	16:15-16:30	9306	Performance Evaluation of Centralized Reconfigurable Transmitting Power Scheme in Wireless Network-on-Chip	Muhammad Nadzir Marsono
13.	16:30-16:45	1570464929	Voltage Regulation of Boost Converter using Observer Based Sliding Mode Controller	Ramadhani Kurniawan Subroto

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Tuesday, September 18, 2018
Pemandengan 2

14.	16:45-17:00	1570469714	VRLA Battery State-of-Health Estimation based on Charging Time	Akhmad Zainuri
15.	19:00-19:15	9905	Optimal SVC Allocation via Symbiotic Organisms Search for Voltage Security Improvement	Ismail Musirin
16.	19:15-19:30	10054	Optimization a Scheduling Algorithm of CA in LTE Advanced System	Sarmad K. Ibrahim
17.	19:30-19:45	10436	High Secure Buffer based Physical Unclonable Functions (PUF's) for Device Authentication	A.Surendar
18.	19:45-20:00	9390	Investigating Customers' Acceptance of E−Purchasing: Integrating UTAUT with TAM	Mansour Naser Alraja
19.	20:00-20:15	8666	The Classification of Type Cell Blast on Acute Myeloid Leukemia (AML) Based on Image Morphology of White Blood Cell	Esti Suryani
20.	20:15-20:30	9017	Number Plate Recognition Letters Used Vehicle Area Feature Extraction	Fitri Damayanti
21.	20:30-20:45	9797	Classification of Breast Cancer Grade Using Physical Parameters and K-Nearest Neighbor Method	Anak Agung Ngurah Gunawan
22.	20:45-21:00	1570463716	A Colour-based Building Recognition using Support Vector Machine	Mas Rina Mustaffa
23.	21:00-21:15	1570464369	Parallel Random Projection Using the R High Performance Computing for Planted Motif Search	Lala Septem Riza
24.	21:15-21:30	1570465366	Cognitive Artificial-Intelligence for Doernenburg DGA Interpretation	Karel Octavianus Bachri
25.	21:30-21:45	1570466831	Alpha-Cut and Constraint Exploration Approach on Quadratic Programming Problem	Yosza Dasril
26.	21:45-22:00	1570469679	Sequential Order vs Random Order in Operators of Variable Neighborhood Descent Method	Darmawan Satyananda

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Wednesday, September 19, 2018
Pemandengan 2

NO	TIME	ID Paper	TITLE	PRESENTER
1.	10:15-10:30	8955	Stochastic Computing Correlation Utilization in Convolutional Neural Network Basic Functions	Hamdan Abdellatef
2.	10:30-10:45	1570469531	Sampling Frequency Influence on the Musical Instruments Tone Recognition	Linggo Sumarno
3.	10:45-11:00	8939	Markerless Motion Capture for 3D Human Model Animation using Depth Camera	Maulahikmah Galinium
4.	11:00-11:15	9648	Integrated AHP and Omax in Balanced Scorecard Dashboard Model for Performance Measurement Tools	Okfalisa
5.	11:15-11:30	9897	Transient Power Quality Performance of Multi Photovoltaics using MPPT P and O/MPPT Fuzzy	Amirullah
6.	11:30-11:45	10408	AHP-TOPSIS for Analyze Job Performance with Factor Evaluation System and Process Mining	Gabriel Sophia
7.	12:30-12:45	1570471520	FPGA-based implementation of speech recognition for automobile robot control using MFCC algorithm	Suci Aulia
8.	12:45-13:00	9711	Government Role in Influencing Creative Economy and Economic Growth that Impact on Community Purchasing Power	Dedeh Maryani
9.	13:00-13:15	8730	A Novel Structure of A Low Cost Zero Bias Broadband Microstrip Power Limiter	Khalifa Echchakhaoui
10.	13:15-13:30	9177	RS Codes Downlink LTE System over LTE-MIMO Channel	Ghasan Ali Hussain
11.	13:30-13:45	11000	Ternary Content Addressable Memory for Longest Prefix Matching Based on Random Access Memory on Field Programmable Gate Array	Muhammad Nadzir Marsono

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1st International Conference and Workshop on Telecommunication, Computing, Electrical, Electronics and Control 1st ICW-TELKOMNIKA 2018 Tuesday, September 18, 2018 Pemandengan 3				
NO	**TIME**	**ID Paper**	**TITLE**	**PRESENTER**
1.	13:00-13:15	7247	Information Technology Investment Analysis of Hospitality Using Information Economics Approach	Eva Novianti
2.	13:15-13:30	9811	Numerical Method for Evaluating E-Cash Security	Dany Eka Saputra
3.	13:30-13:45	1570466671	A Scoring Rubric for Automatic Short Answer Grading System	Uswatun Hasanah
4.	13:45-14:00	8614	New Framework for Information System Development On IM for Low Cost Solution	I Made Sukarsa
5.	14:00-14:15	9266	Performance Measurement Of Security Level Within Academic Information System	Endang Kurniawan
6.	14:15-14:30	9948	Information Sharing System in Supply Chain with Pull System	Teguh Andriyanto
7.	14:30-14:45	10284	Load Balancing Clustering on Moodle LMS to Overcome Performance Issue of e-Learning System	Mujiono
8.	14:45-15:00	1570464077	The Implementation of Web Scraping on Monitoring Task System Integrated with GitHub	Restiyana Dwi Astuti
9.	15:30-15:45	1570465306	Measuring the Quality of E-Commerce Websites using Analytical Hierarchy Process	Umar Abdul Aziz
10.	15:45-16:00	1570465328	e-KTP 1.0: A Novel Interoperability Framework to Utilize Indonesian Electronic Identity Card	Nisa Hanum Harani
11.	16:00-16:15	1570465332	Seller Reputation Impact on Sales Performance in Public E-Marketplace Bukalapak	M: Ammar Fauzan
12.	16:15-16:30	1570469683	e-KTP 1.1: Decentralised Interoperability Network using Distributed Hash Table	Nisa Hanum Harani
13.	16:30-16:45	1570470406	The Antecedent of Citizen Intention Use of e-Government Service	Taqwa Hariguna

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Pemandengan 3

14.	16:45-17:00	9083	SERO - The Software Ecosystems Reference Ontology	Eko Handoyo
15.	19:00-19:15	9770	PID Control Design for Biofuel Furnace using Arduin	Agus Budianto
16.	19:15-19:30	9236	Image de-nosing in underwater colored noise using discrete wavelet transform and pre-whitening filter	Mohanad Najm Abdulwahed
17.	19:30-19:45	9246	Design and Analysis of broadband Elliptical Microstrip Patch Antenna for Wireless Communication	Ali Khalid Jassim
18.	19:45-20:00	10016	Design of Dual Band Microstrip Antenna for Wi-Fi and WiMax Applications	Zainab S. Jameel
19.	20:00-20:15	9478	Fuzzy Rule-Based Classification Systems for the Gender Prediction from Handwriting	Lala Septem Riza
20.	20:15-20:30	10183	Comparison of Stemming Algorithms on Indonesian Text Processing	Afian Syafaadi Rizki
21.	20:30-20:45	1570464670	Cluster-based Water Level Patterns Detection	Seng Hansun
22.	20:45-21:00	1570465069	Stereo Matching Algorithm Based on Absolute Differences for Multiple Objects Detection	Melvin Gan Yeou Wei
23.	21:00-21:15	1570469705	Suitability Analysis of Rice Varieties Using Learning Vector Quantization and Remote Sensing Images	Retno Kusumaningrum
24.	21:15-21:30	10330	Proposed Model for Interference Estimation in Code Division Multiple Access	Dalal kanaan Taher
25.	21:30-21:45	10157	Inclined Image Recognition for Aerial Mapping Using Deep Learning and Tree Based Models	Muhammad Attamimi
26.	21:45-22:00	10546	Design on Lung TB Detection System Based on Statistical Features of X-ray Image Histogram	Ratnasari Nur Rohmah

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Pemandengan 3

NO	TIME	ID Paper	TITLE	PRESENTER
1.	10:15-10:30	1570463954	Biometric Identification using Augmented Data Base	Regina Lionnie
2.	10:30-10:45	1570464514	Face Recognition Smart Cane using Haar-Like Features and Eigenfaces	Gita Indah Hapsari
3.	10:45-11:00	9513	Optimization of Steganography in Flash Live Video (FLV) Files Using 'Distributed Among All of the Video Tags' Method with Additional Compression and Encryption	Dwi Arraziqi
4.	11:00-11:15	9722	Filter Technique of Medical Image on Multiple Morphological Gradient (MMG) Method	Jufriadif Na`am
5.	11:15-11:30	1570467744	Hiding Data in Images Using Steganography Techniques with Lossy and Lossless Compression Algorithms	Osama Fouad AbdelWahab
6.	11:30-11:45	1570464221	Region of Interest and Color Moment Method for Freshwater Fish Identification	Gibtha Fitri Laxmi
7.	12:30-12:45	1570469650	Combination of Arima Model-Fuzzy Alpha Cut to Enhance Interval Width of Crime Forecasting	Yaya Sudarya Triana
8.	12:45-13:00	1570466078	Cyst and Tumor Classifications on Human Dental Panoramic Images Using Statistical Modeling Approach	Kinanti Hanugera Gusti
9.	13:00-13:15	10193	Different multilayer substrate approaches to improve array antenna characteristics for radar applications	Nadia Chater
10.	13:15-13:30	10111	Modified DCT-Based Audio Watermarking Optimization using Genetics Algorithm	Ledya Novamizanti

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Tuesday, September 18, 2018
Pemandengan 4

NO	TIME	ID Paper	TITLE	PRESENTER
1.	13:00-13:15	9621	Autonomous Collaborative Decentralized-Community Networks for Security-and Privacy-Critical Domains	Heerok Banerjee
2.	13:15-13:30	9691	Solving University Course Timetabling Using Reinforced Island Model Genetic Algorithm	Alfian Akbar Gozali
3.	13:30-13:45	9761	The Strategy of Enhancing Article Citation and H-Index on SINTA to Improve Tertiary Reputation	Untung Rahardja
4.	13:45-14:00	9794	New Instances Classification Framework on Quran Ontology Applied to Question Answering System	Fandy Setyo Utomo
5.	14:00-14:15	9938	A Review of Energy-aware Cloud Computing Surveys	Azlan Ismail
6.	14:15-14:30	1570465222	Remote Interpreter API Model for Supporting Computer Programming Adaptive Learning	Ignasius Agus Leonardo
7.	14:30-14:45	1570465322	The System Architecture Approach of Social Media and Online Newspaper Credibility Measurement	Rakhmat Arianto
8.	14:45-15:00	1570469461	Neurocomputing Fundamental Climate Analysis	Rezzy Eko Caraka
9.	15:30-15:45	9278	A Novel Key Management Protocol for Vehicular Cloud Security	Nayana Hegde
10.	15:45-16:00	9475	Message Oriented Middleware For Library‘S Metadata Exchange	Ni Wayan Wisswani
11.	16:00-16:15	10167	Smart Taxi Security System Design with Internet of Things (IOT)	Indrianto
12.	16:15-16:30	10384	Design Mobile App for Promotions Museum using Gamification Method: Case Study Indonesia	Novian Adi Prasetyo
13.	16:30-16:45	1570456180	Design and Implementation of RFID-Based Conveyor Belt on Warehouse Management System	Bayu Rahmad Azhari
14.	16:45-17:00	9799	Software Development of Lung Disease Detector Caused by Cigarettes	Sri Widodo

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1st International Conference and Workshop on Telecommunication, Computing, Electrical, Electronics and Control 1st ICW-TELKOMNIKA 2018 Tuesday, September 18, 2018 Pemandengan 4				
15.	19:00-19:15	1570463482	Blood Image Analysis to Detect Malaria Using Filtering Image Edges & Classification	Tariq Jamil Saifullah Khanzada
16.	19:15-19:30	10494	Proposed P-shaped Microstrip antenna array for wireless communication applications	Noor Baqir Hassan
17.	19:30-19:45	10091	Comparison of Raindrop Size Distribution Characteristics Across the Southeast Asia Region	Jafri Din
18.	19:45-20:00	9832	Comparison between Trigonometric, and Traditional DDS, in 90 nm Technology	Di Nunzio Luca
19.	20:00-20:15	8222	Prototype Distributed Application In Banking Transaction Using Remote Method Invocation	Agus Cahyo Nugroho
20.	20:15-20:30	8762	Design of Feature Application Setting Dashboard on Svara Using User-Centred Design Method	Muhammad Yusril Helmi Setyawan
21.	20:30-20:45	8976	Image Forgery Detection Using Error Level Analysis And Deep Learning	Ida Bagus Kresna Sudiatmika
22.	20:45-21:00	9101	Clustering Analysis of Learning Style on Anggana High School Student	Siti Lailiyah
23.	21:00-21:15	10145	Modeling and Prediction of Wetland Rice Production using Support Vector Regression	Yuslena Sari
24.	21:15-21:30	10328	Assessing Students' Continuance Intention in Using Multimedia Online Learning	Akmal
25.	21:30-21:45	1570459730	Utilization of K-Nearest Neighbor Algorithm to Determine Standard Operational Procedures Based on Implicit Feedback	Muhammad Yusril Helmi Setyawan
26.	21:45-22:00	1570462179	Determining Strategies on Playing Badminton by Using the Knuth-Morris-Pratt Algorithm	Lala Septem Riza

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Pemandengan 4

NO	TIME	ID Paper	TITLE	PRESENTER
1.	10:15-10:30	1570462339	Fuzzy Sequential Model for Strategic Planning of Small and Medium Scale Industries	Imam Santoso
2.	10:30-10:45	1570464128	Modelling and Implementation of 9tka Game with MaxN Algorithm	Irene Astuti Lazarusli
3.	10:45-11:00	1570464738	Data Stream Mining Techniques: A Review	Hany Alashwal
4.	11:00-11:15	1570465361	Integrating Fuzzy Logic and Genetic Algorithm for Upwelling Prediction in Maninjau Lake	Muhammad Rofiq
5.	11:15-11:30	1570463950	Classification of Neovascularization using Deep Convolutional Neural Network	Wahyudi Setiawan
6.	11:30-11:45	9304	Recognition Facial Expression of 3d Image-Based Using Facial Action Coding System (FACS)	Hardianto Wibowo
7.	12:30-12:45	1570470819	Distributed Light-weight IoT Platform for Rapid Application Development and Deployment	Rozeha A. Rashid
8.	12:45-13:00	10437	Secure Code Generation for Multi-Level Mutual Authentication	Gregor Alexander Aramice
9.	13:00-13:15	10470	Adaptive Super-Twisting Nonsingular Terminal Sliding-Mode-Control: Application to Unmanned Aerial Manipulator	Samah Riache
10.	13:15-13:30	9187	2FYSH: Two-Factor Authentication You Should Have for Password Replacement	Hargyo Tri Nugroho I.
11.	13:30-13:45	8979	Optimal Control for Torpedo Motion Based on Fuzzy-PSO Advantage Technical	Viet-Dung Do

Lampiran 2.10

Sertifikat Pemakalah

ICW-TELKOMNIKA 2018

ICW 2018 TELKOMNIKA

2018 1st INTERNATIONAL CONFERENCE AND WORKSHOP ON TELECOMMUNICATION, COMPUTING, ELECTRICAL, ELECTRONICS AND CONTROL

September 18-21, 2018 | Royal Ambarrukmo Hotel, Yogyakarta, Indonesia

CERTIFICATE OF APPRECIATION

is awarded to

Amirullah

In recognition and appreciation of your contribution as

Presenter

for paper entitled

Transient Power Quality Performance of Multi Photovoltaics using MPPT P and O/MPPT Fuzzy

Tole Sutikno, Ph.D.
Director, LPPI UAD

Anton Yudhana, Ph.D.
Conference Chair

Tuesday, 18 September 2018

<table>
<tr><th>TIME</th><th colspan="6">AGENDA</th></tr>
<tr><td>09:45-10:45</td><td colspan="6">Keynote Speaker 1: “Humanoid Robot” Prof. Dr. Nadia Magnenat Thalmann, Nanyang Technological University (NTU), Singapore and University of Geneva, Switzerland</td></tr>
<tr><td>10:45-11:45</td><td colspan="6">Keynote Speaker 2: “Technology, Innovation and Entrepreneurship through Industry 4.0” Dr. Ing. Ilham Akbar Habibie, President Director PT. Ilthabi Rekatama, Indonesia</td></tr>
<tr><td rowspan="2">13:00-15:00</td><td colspan="6">Parallel Session 1</td></tr>
<tr><td>Room Karaton 1</td><td>Room Karaton 2</td><td>Room Pemandengan 1</td><td>Room Pemandengan 2</td><td>Room Pemandengan 3</td><td>Room Pemandengan 4</td></tr>
<tr><td rowspan="2">15:30-17:00</td><td colspan="6">Parallel Session 2</td></tr>
<tr><td>Room Karaton 1</td><td>Room Karaton 2</td><td>Room Pemandengan 1</td><td>Room Pemandengan 2</td><td>Room Pemandengan 3</td><td>Room Pemandengan 4</td></tr>
<tr><td>17:00-17:30</td><td colspan="6">Speech from Dr. Muhammad Dimyati, Ministry of Research, Technology and Higher Education of the Republic of Indonesia</td></tr>
<tr><td rowspan="2">19:00-22:30</td><td colspan="6">Parallel Session 3</td></tr>
<tr><td>Room Karaton 1</td><td>Room Karaton 2</td><td>Room Pemandengan 1</td><td>Room Pemandengan 2</td><td>Room Pemandengan 3</td><td>Room Pemandengan 4</td></tr>
</table>

Wednesday, 19 September 2018

<table>
<tr><th>TIME</th><th colspan="6">AGENDA</th></tr>
<tr><td>08:00-09:00</td><td colspan="6">Keynote Speaker 3: “Intelligent Autonomous Systems” Prof. Dr. Er Meng Joo, Nanyang Technological University (NTU), Singapore</td></tr>
<tr><td>09:15-10:15</td><td colspan="6">Keynote Speaker 4: “Virtual Reality” Prof. Dr. Daniel Thalmann, École Polytechnique Fédérale de Lausanne, Switzerland</td></tr>
<tr><td rowspan="2">10:15-11:45</td><td colspan="6">Parallel Session 4</td></tr>
<tr><td>Room Karaton 1</td><td>Room Karaton 2</td><td>Room Pemandengan 1</td><td>Room Pemandengan 2</td><td>Room Pemandengan 3</td><td>Room Pemandengan 4</td></tr>
<tr><td rowspan="2">12:30-14:00</td><td colspan="6">Parallel Session 5</td></tr>
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<tr><td>14:00-15:00</td><td colspan="6">Workshop on Scientific Writing session 1: “Writing an Article Effectively and Coherently in Both of IMRaD & Unstructured Styles” Prof. Dr. Daniel Thalmann</td></tr>
<tr><td>15:00-16:00</td><td colspan="6">Workshop on Scientific Writing session 2: “Key Principles and Best Practices for Effective Writing of High Impact Publications” Assoc. Prof. Dr. M Nadzir Marsono</td></tr>
<tr><td></td><td colspan="6">Tutorial</td></tr>
<tr><td>16:30-18:00</td><td colspan="3">Room Karaton Ballroom
Prof. Dr. Daniel Thalmann</td><td colspan="3">Room Karaton Ballroom
Prof. Dr. Er Meng Joo</td></tr>
<tr><td>19:00-21:30</td><td colspan="6">Gala Dinner and Awards</td></tr>
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Thursday, 20 September 2018

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<tr><th>TIME</th><th colspan="6">AGENDA</th></tr>
<tr><td>08.00-08.30</td><td colspan="6">Speech from Editor in Chief</td></tr>
<tr><td rowspan="2">08:30-10:00</td><td colspan="6">Manuscrip Mentoring and Coaching</td></tr>
<tr><td>Room Karaton 1</td><td>Room Karaton 2</td><td>Room Pemandengan 1</td><td>Room Pemandengan 2</td><td>Room Pemandengan 3</td><td>Room Pemandengan 4</td></tr>
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<tr><td rowspan="2">13:00-14:30</td><td colspan="6">Manuscrip Mentoring and Coaching</td></tr>
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</table>

Lampiran 2.11

Comment Reviewer

ICW-TELKOMNIKA 2018

Review should be based your expert for improving this paper. Please review to point out any deficiencies in the text and, if necessary, please provide instructions and suggestions on the amendments or modifications to the text.

General Data

ID Paper	:	9897
Tittle	:	Transient Power Quality Performance of Multi Photovoltaics using MPPT P and O/MPPT Fuzzy
Authors	:	Amirullah, Agus Kiswantono, OntosenoPenangsang, Adi Soeprijanto

Transient Power Quality Performance of Multi Photovoltaics using MPPT P and O/MPPT Fuzzy
Comments:
Title must be rewritten properly by following grammar. Affiliations must follow template. At abstract, many sentences are too long and they must be proof read to follow grammar properly. Several typo are found for the use of units, i.e. 380 kV. In the body of text, many sentences are too long and they must be proof read to follow grammar properly. The sentences must be written in proper grammar English and they must not be taken directly from a translating machine such as google translation. Proof reading is urgently required for the manuscript. Poor images and poor fonts for Fig. 1 - 13. No significant reason why the work was carried out to observe harmonics during in fault transient period, because faults shall be removed by protection system.

Lampiran 2.12

Form Comment Review

ICW-TELKOMNIKA 2018

2018 1st International Conference and Workshop on Telecommunication, Computing, Electrical, Electronics and Control (ICW TELKOMNIKA 2018)

RESPONSE TO MENTOR(S) COMMENTS

ID Paper	:	9897
Tittle	:	Transient Power Quality Performance of Multi Photovoltaics using MPPT P and O/MPPT Fuzzy
Authors	:	Amirullah, Agus Kiswantono, OntosenoPenangsang, Adi Soeprijanto

1. Mentor's Comment #1 : Title must be rewritten properly by following grammar.

   Respond to Comment #1 : I compare MPPT P and O with MPPT Fuzzy on performance of transient power quality due to multi PV integration to grid under fixed temperature and solar irradiation. Sign "/" in the title means "or" before I used "and" but my supervisor (author 3 and 4) didn't agree because "and" means combination of two methods and they proposed to use "/" that means comparation of two methods. I use this title because in TELKOMNIKA template maximum 10 words in English.

2. Mentor's Comment #2 : Affiliations must follow template.

   Respond to Comment #2 : Done I have revised it in correspondence author depend on TELKOMNIKA template.

3. Mentor's Comment #3 : At abstract, many sentences are too long and they must be proof read to follow grammar properly.

   Respond to Comment #3 : Done I have revised it and with keyword too.

4. Mentor's Comment #4 : Several typo are found for the use of units, i.e. 380 kV.

   Respond to Comment #4 : Done I have revised it in Introduction paragraph 3.

5. Mentor's Comment #5 : In the body of text, many sentences are too long and they must be proof read to follow grammar properly. The sentences must be written in proper grammar English and they must not be taken directly from a translating machine such as google translation. Proof reading is urgently required for the manuscript.

   Respond to Comment #5 : Done I have revised it in Introduction paragraph 3 and overall in Table 1 and 2 and the analysis. In both table I have revised content of table from 3 fault duration (before fault, during fault/transient, and after fault) into only during fault/transient in accordance with the title & results analysis.

6. Mentor’s Comment #6 : Poor images and poor fonts for Fig. 1 - 13.

   Respond to Comment #6 : Done I have enlarged them.

7. Mentor’s Comment #7 : No significant reason why the work was carried out to observe harmonics during in fault transient period, because faults shall be removed by protection system.

   Respond to Comment #7 : The operation of distribution system is not only takes place under normal condition but also under transient disturbances i.e. short circuit fault period. The short circuit fault can cause rise of current and voltage drop in certain phases depend on fault types, so it is able to generate unbalance voltage and current on low voltage distribution network (grid). The PV (for example rooftop PV technology connected grid/PLN) has developed in major cities in Indonesia with increasing installed capacity. Integration of multi PVs as one of renewable energy source besides being able to generate power, it also results harmonics due to inverter as a medium to convert DC into AC voltage and it is capable to decrease power quality. In this paper I only observe performance of harmonics and unbalance during in fault transient period using MPPT P and O/MPPT Fuzzy caused penetration of multi PVs and do not discuss protection system.

Lampiran 2.13

Makalah yang Sudah Dipresentasikan/Direview di ICW-TELKOMNIKA 2018 Selanjutnya Dipublikasikan di Jurnal TELKOMNIKA

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Transient Power Quality Performance of Multi Photovoltaics using MPPT P and O/MPPT Fuzzy

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Abstract

This paper presents comparative performance of transient power quality due to multi photovoltaic (PV) integration to grid at both fixed temperature and solar irradiation connected using Maximum Power Point Tracking Perturb and Observe (MPPT P and O)/MPPT Fuzzy. This research is performed as five transient of short-circuit faults on point common coupling (PCC) bus. An artificial intelligence with fuzzy logic controller (FLC) is used to set duty cycle with step variable to control DC/DC boost converter, generate quick convergence to determine MPPT for controlling of PV output voltage. Furthermore the result is compared with MPPT P and O. During transient phase, non-symmetrical faults are able to result an unbalance current/voltage greater than symmetrical faults. On symmetrical faults, MPPT Fuzzy is able to result an average THD voltage/THD current smaller than MPPT P and O. Otherwise on non-symmetrical faults, MPPT P and O is able to result an average THD voltage/THD current slightly smaller than MPPT Fuzzy. Both of MPPT P and O and MPPT Fuzzy on all short circuit faults during transient phase are able to result significantly smaller current average THD current than average THD voltage and limits of THD prescribed in IEEE 519. This research is simulated using Matlab/Simulink environment.

Keywords*: MPPT Fuzzy, MPPT P and O, Multi Photovoltaics, Power Quality, Short Circuit, Transient*

1. Introduction

The PV beside being able to generate power, it also results harmonics due to inverter as a medium to convert DC into AC voltage and is capable to decrease power quality. The short circuit fault can cause rise of current and voltage drop in certain phases depend on fault types, so it is able to generate unbalance voltage and current on low voltage distribution network (grid). The research on power quality of PV connected grid to power system using LCL filter has been done Kon Keng Weng et. al. A number of power quality problems i.e. over voltage, less voltage, power fluctuations, inrush currents, low power factor, and current harmonics or THD will appear on microgrid power system. This research is conducted only on constant solar irradiance and temperature condition (1000 W/m^2 and 25^0 C) as environmental input parameters for PV systems [1]. The study on effect of solar radiation on grid connected to PV generator to power quality has been investigated by Minas Patsalides, et.al. It considers two different scenarios of average and low radiation [2]. Investigation of grid connected a single phase PV inverter using a current proportional resonant, proportional resonant integral, and genetic algorithm using an active filter to reduce current harmonics of inverter output has been studied by Renu et. al. The laxity of research is only done on a single phase PV and certain irradiance and temperature [3]. The dynamic analysis of power quality due to high penetration effect of distribution network connected to PV under variable irradiance has been studied by Massoud Farhoodnea, et. al. The result showed that high level penetration of grid connected PV will cause a number of power quality problems. However, the research was only analyzed on voltage harmonics and did not consider the ambient temperature condition [4]. Power quality characteristics in a number of three phase PV inverters at top roof PV has been performed by K.P. Kontogianis, et. al [5]. A comparative study of MPPT between FLC and conventional PI controller has been presented for interfacing PV array with utility grid through a three-phase line-commutated inverter by Omid Zhoulai Bakhoda, et.al. FLC was dominating PI in many important aspects like i.e., provided active power for grid, output current shape of inverter, grid current and current THD [6]. A grid interfaced solar PV (SPV) power generating system in a 3P4W system has been

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proposed by Arun Kumar Verma, et.al. This system was used for compensation of neutral current, harmonic currents, reactive power and to provide load balancing [7]. However, both of power quality analysis in both papers was only performed by using single PV. Power quality due to integration of multi units of PV generator connected to three phase grid under variable solar irradiation level has been implemented by Amirullah, et.al. At level of solar irradiation was fixed, the greater number of PV connected to three-phase grid, then average THD of grid voltage/current also increased. At level of solar irradiation increased, average THD of grid voltage/current also increased. The PV in this research was still using MPPT with P and O algorithm and not using intelligent control [8].

Adaptive Neuro-fuzzy Inference System (ANFIS)-based improvement of MPPT P and O for PV under different shading conditions has been investigated by Khaled Bataineh, et.al. The simulation show proposed algorithm efficiently reach MPP under uniform irradiation, sudden changes of irradiation, and partial shading [9]. The method for balancing line current and voltage, due to the presence of distributed generations (DGs) i.e. a number of single phase PV generation units in homes has been presented by Amirullah, et.al. This research shows that the combination of Battery Energy Storage (BES) and three single phase bi-directional inverter able to reduce unbalanced line current/voltage. Otherwise, the combination of both circuit able to inreases current/voltage harmonics [10]. Power quality enhancement on low voltage of three phase grid caused by different level of PV integration using MPPT Fuzzy under variabel solar irradiance level on constant temperature and load has been investigated by Amirullah, et.al. It was able to enhance profile of grid voltage and current THD due to different level of integration of PV to three phase grid corresponding with IEEE Standard 519. MPPT Fuzzy was also able to improve input power factor better than MPPT P and O [11]. Rachid Belaidi, et.al has proposed a combined system of 3P4W shunt active filter and PV with MPPT P and O, to solve power quality such as harmonic currents, poor power factor, and unbalanced load [12]. Salah Eddine Mankour, et al has investigated on modeling of a PV stand alone power system using two widely-adopted MPPT algorithms, P & O and incremental conductance [13]. Bambang Purwahyudi, et. al has researched design of electrical characteristics of solar PV cell model by using self constructing neural network (SCNN) [14]. Julián A.C.C., et. al has used a mathematical model implemented in Matlab/Simulink to evaluate the performance of building integrated photovoltaic systems (BIPVS) [15]. Ahmad Saudi Samosir, et. al has investigated on modeling and simulation of MPPT used in solar power systems with fuzzy logic [16]. But the researchs on enhancement of power quality and MPPT characteristics for PV were only analyzed in normal condition.

This paper presents comparative performance of power quality due to the multi PV integration at both fixed temperature and solar irradiation levels connected to 380 V and 50 Hz distribution network using MPPT P and O/MPPT Fuzzy controller. The research is performed during transient disturbances of short-circuit fault on PCC bus based on five of short circuit faults. An artificial intelligence method with FLC is used to set duty cycle (D) with step variable to control DC/DC boost converter, generate quick convergence calculation to determine MPPT value for controlling of PV generator output voltage. Futhermore the result is compared with MPPT P and O method. The parameters are voltage/current unbalanced, voltage/current THD on each phase, and voltage/current average THD on PCC bus of three phase grid.

This paper is organized as follow. Section 2 presents proposed method i.e. proposed model of single PV using MPPT Fuzzy, model multi PV connected three phase grid under short circuit fault, simulation parameters, equivalent circuit, mathematical, and characteristic curve of PV model, MPPT P and O method, MPPT Fuzzy method, voltage and current harmonics, voltage and current unbalance. Section 3 describes comparative performance of multi PV connected grid under short circuit fault during transient phase to current/voltage unbalance and current/voltage THD of three phase grid using MPPT P and O/MPPT Fuzzy method. In this section, example cases studied are presented and the results are verified with those of Matlab/Simulink. Finally, the paper in concluded in Section 4.

2. Research Method

2.1. Proposed Model

Figure 1 shows model of a single PV system connected to a three phase grid. The DC/DC converter circuit consists of a boost converter circuit that serves to raise the DC output voltage from the PV. The DC output voltage of the boost converter circuit is then changed by a three

phase DC/AC inverter into an AC voltage to three phase grid. The single PV model is then used as a reference to construct multiple PV models connected to grid through a three phase phase distribution transformer showed in Figure 2. This research uses three model group of PVs with an active power of 100 kW each. Besides connected three phase grid, multi PVs are also connected to three group of three phase loads with 20 kW of active power each. The aim of research is to compare performance of power quality due to the multi PV integration at both fixed temperature and solar irradiation levels connected to distribution network using MPPT P and O/MPPT Fuzzy. The research analysis includes transient disturbances of short-circuit fault on PCC bus based on a number of short circuit faults. An artificial intelligence with FLC is used to set duty cycle (D) with step variable to control DC/DC boost converter, generate quick convergence calculation to determine MPPT value for controlling of PV output voltage, and then its result is compared with MPPT P and O method. The DC/DC converter produces a constant DC voltage as an input for DC/AC inverter using pulse with modulation (PWM).

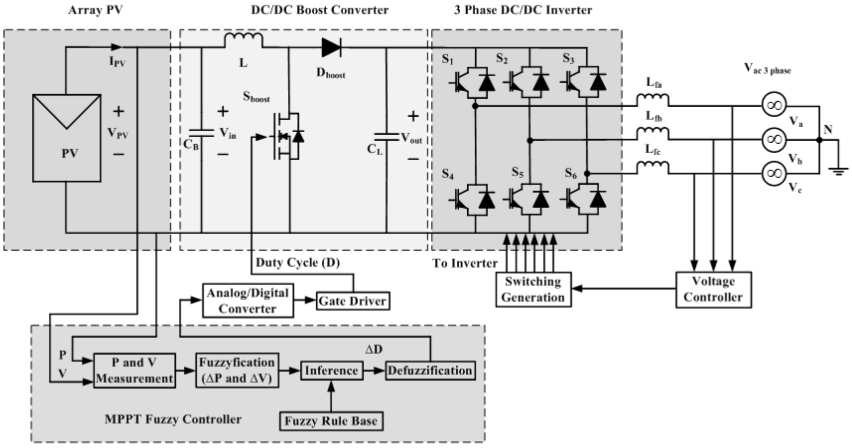


Figure 1. Proposed model of single PV using MPPT Fuzzy

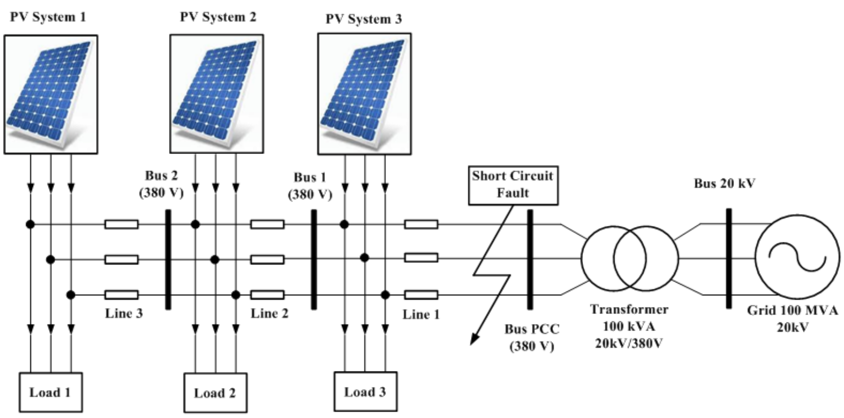


Figure 2. Proposed model of multi PV connected three phase grid under short circuit fault

There are two scenarios of multi PV connected three phase grids under fixed temperature and solar irradiation of 25^0 C and 1000 W/m^2, i.e. using MPPT P and O and MPPT Fuzzy methods respectively. The transient state in each of MPPT controllers are indicated by five short-circuit faults, resulting in a total of ten fault scenarios i.e. three phases to ground (3Ph-N), three phases (3Ph), two phases to ground (2Ph-N), two phases (2 Ph), and single phase to ground (1Ph-N). The 3ph-N and 3ph are classified as symmetrical faults. Futhermore 2ph-N, 2Ph, and 1Ph-N are classified as non-symmetrical faults. The next process is to determine voltage/current unbalanced, voltage/current harmonics (THD) on each phase, and voltage/current average harmonics on PCC bus of three-phase low voltage grid. The final step is to validate the results referring to the ANSI/IEEE 241-1990 standard about unbalanced voltage and current and IEEE Standard 519-1992 about average grid voltage and current harmonics. Simulation and analysis of this research use Matlab/Simulink. The simulation parameter values of proposed model are shown in Appendix Section.

2.2. Modelling of PV Array

Figure 3 shows the equivalent circuit of a solar panel. A solar panel is composed of several PV cells that have series, parallel, or series-parallel external connections [17].

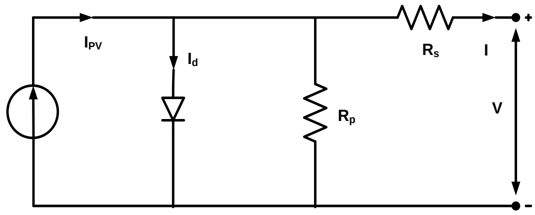


Figure 3. Equivalent circuit of solar panel

The V-I characteristic of a solar panel is showed in (1):

$$I = I_{PV} - I_o\left[\exp\left(\frac{V + R_S I}{aV_t}\right) - 1\right] - \frac{V + R_S I}{R_P} \tag{1}$$

where I_{PV} is the photovoltaic current, I_o is saturated reverse current, ‘a’ is the ideal diode constant, $V_t = N_S K T q^{-1}$ is the thermal voltage, N_S is the number of series cells, q is the electron charge, K is the Boltzmann constant, T is the temperature of p–n junction, R_S and R_P are series and parallel equivalent resistance of the solar panels. I_{PV} has a linear relation with light intensity and also varies with temperature variations. I_o is dependent on temperature variations.

2.3. MPPT P and O and MPPT Fuzzy

The initial research is to determine value of duty cycle (D) with a variable step to control DC/DC boost converter circuit with MPPT P and O. For PV converter, maximum power available is determined by PV cell characteristics, but this value often mismatches with the maximum power point (MPP) of the load. By implementing MPPT in PV systems, MPP can be maintained so that the number and size of PV panels can be reduced or energy yield can be optimized [18]. Because of moving of sun, PV panels angle, and variation of irradiance reaching the panels, energy generated from PV panels are absorbed does not constant over time. When this condition occurs, VI characteristics changes and MPP will move. To overcome these problems, MPPT has been developed. The system includes no moving parts. MPPT search for the maximum power independent based on environmental conditions (following changes in solar radiation and temperature) and maintain the PV terminal voltage remains constant at maximum value. The most used method of MPPT is P and O that algorithm is shown in Figure 4 [13] and its Matlab/Simulink model is presented in Figure 5.

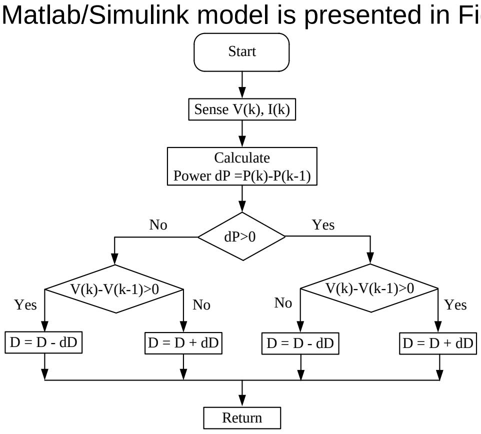


Figure 4. MPPT using P and O algorithm

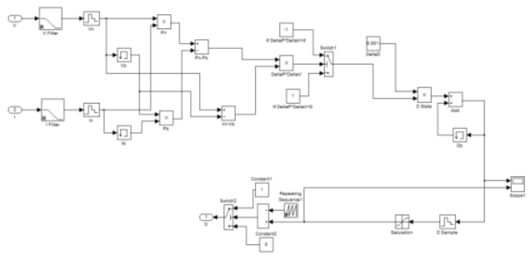


Figure 5. Matlab/Simulink for MPPT P and O

The same procedure for determining MPPT is using FLC. Fuzzy set theory is a new method of controlling the MPPT in obtaining the peak power point. The MPPT is implemented to obtain MPP operation voltage point faster with less overshoot and also it can minimize voltage fluctuation after MPP has been recognized. It also is capable to enhance power quality problem unbalance current/voltage and current/voltage harmonics. Typical fuzzy based MPPT controller reffered to MPPT Fuzzy includes three basic components i.e. fuzzification, inference engine, and defuzzification block as shown in Figure 6 and its Matlab/Simulink presented in Figure 7.

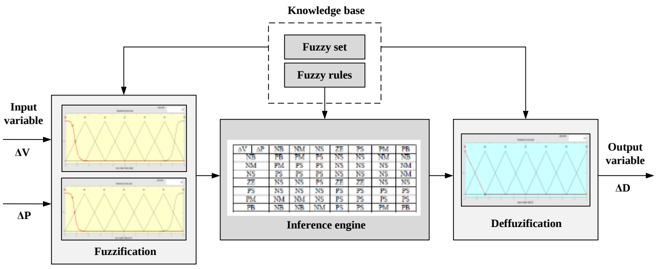


Figure 6. Structure of FLC

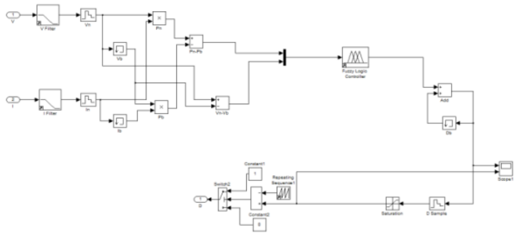


Figure 7. Matlab/Simulink for MPPT Fuzzy

Fuzzy MPPT method is done by determining input variables, namely fuzzy control output power (ΔP) and output voltage (ΔV) PV generator, seven linguistic variables fuzzy sets, fuzzy operating system block (fuzzification, fuzzy rules, and defuzzification), Function ΔP and Δ V during fuzzification, a table fuzzy rule base, crisp values to determine duty cycle (D) in defuzzification phase with variable step to control DC/DC boost converter. Figure 8 shows Matlab/Simulink model for MPPT Fuzzy. During fuzzification phase shown in Figure 7, a number of input variables is calculated and converted into a linguistic variable based on the subset called membership function (MF). To translate value of voltage change and power change in, input fuzzy "change of voltage" and "change of power" is designed to use seven fuzzy variable called PB (Positive Big), PM (Positive Medium), NS (Negative Small), PS (Positive Small) ZE (Zero), NM (Negative Medium), and Negative Big (NB). voltage change (ΔV) and power changes (ΔP) is a proposed system input variables and output variable FLC is duty cycle change (ΔD). The membership functions i.e. voltage changes, power changes, and duty cycle change, each are shown in Figure 8 into Figure 10.

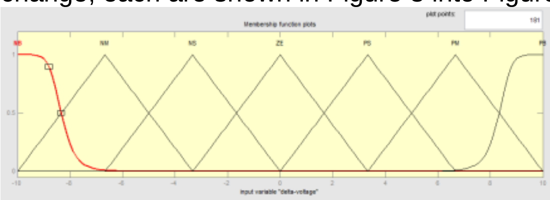


Figure 8. Input voltage change (delta voltage)

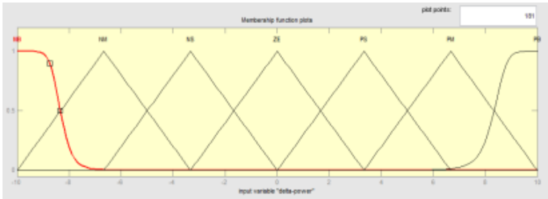


Figure 9. Input power change (delta power)

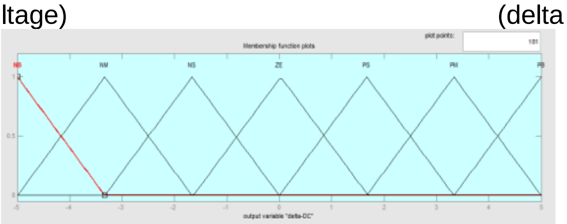


Figure 10. Output duty cyclechange (delta D)

The fuzzy inference using a method that relates to a composition Mamdani Max-Min. Fuzzy inference system consists of three parts, namely rule base, database, and reasoning mechanism. After determining ΔV and ΔP, these value are then converted into linguistic variables and use them as input functions for FLC. The output value is ΔD is generated using block inference and fuzzy rules as shown in Table 1. Finally defuzzification block operates to change value of ΔD is raised from linguistic variables into numeric variables back. Numeric variables that become inputs signal for the IGBT switch of DC/DC boost converter to be able to determine MPPT for each generation PV accurately at the same time also improve power quality as a result of integration of multi PV to low voltage three phase grid under short circuit.

Table 1. Fuzzy Rules

ΔV ΔP	NB	NM	NS	ZE	PS	PM	PB
NB	PB	PM	PS	NS	NS	NM	NB
NM	PM	PS	PS	NS	NS	NS	NM
NS	PS	PS	PS	NS	NS	NS	NM
ZE	NS	NS	PS	ZE	ZE	NS	NS
PS	NS	NS	NS	PS	PS	PS	PS
PM	NM	NM	NS	PS	PS	PS	PS
PB	NB	NB	NM	PS	PS	PM	PB

2.4. Voltage and Current Harmonics/Unbalance

Generally, current and voltage waveforms are pure sinusoidal. One problem that occurs is non sinusoida or distorted current and voltage waves generated by harmonics in power system [11]. Harmonic is distorted periodic steady state wave caused by the interaction between the shape of a sine wave at the fundamental frequency system with another wave component which is an integer multiples frequency of fundamental frequency. The most common harmonic index, which relates to voltage waveform is THD (2), which is defined as the root mean square (rms) of harmonics expressed as a percentage of fundamental component as showed in [19]. Second harmonic index is current THD means the ratio of rms harmonic current value to rms fundamental current which expressed in (3) [11].

$$THD_V = \frac{\sqrt{\sum_{n=2}^{N} V_n^2}}{V_1} \times 100\ \% \quad (2) \qquad THD_I = \frac{\sqrt{\sum_{n=2}^{N} I_n^2}}{I_1} \times 100\ \% \quad (3) \qquad V(\%) = \frac{\left| V_{a\,var\,age} - V_{a,b,c\,\min\,or\,\max} \right|}{V_{a\,var\,age}} \times 100\,\% \quad (4)$$

Where V_n and I_n (the rms voltage and current at harmonic n), V_1 and I_1 (the fundamental rms voltage and current), N (the maximum harmonic order to be considered). The allowable maximum THD value for each country is different depending on the standard used. THD standards most often used in electric power system is IEEE 519-1992. There are two criteria used in analysis of harmonics distortion i.e. voltage distortion and current distortion limit [20]. The value of unbalance voltage use (8) is based ANSI/IEEE 241-1990 is showed in (4) [21]. By using (4), value of unbalance voltage expressed in percent (%) and is defined as follows; $V_{avarage}$ is the average value of maximum voltage on phase a, b, c, in volt. $V_{a,b,c\ min}$ is minimum voltage on phase a, b, c in volt, $V_{a,b,c\ max}$ is maximum voltage on phase a, b, c in volt . By the same way, then unbalance current in % can be calculated by replacing voltage into current magnitude.

3. Results and Analysis

This research is started by determining the maximum and minimum of grid current in each phase, unbalanced current using (4), current THD on each phase (3), and average THD of three phase current grids on PCC bus using MPPT P and O/MPPT Fuzzy. By using the same procedure then obtained unbalanced voltage using (4), voltage THD on each phase using (3), and average voltage THD. Table 2 shows unbalanced current, THD grid current, and average THD of grid current of multi PV connected on a three phase low voltage grid using MPPT P and O/MPPT Fuzzy. Because, there are five short-circuit faults then there are three fault durations i.e. before, during (transient), and after fault phase with time durations are 0-0.02 sec, 0.02-0.04 sec, and 0.04-0.06 sec respectivelty. The simulation result of unbalanced current/voltage and average THD current/voltage is also presented as verification under five short circuit faults. The results analysis is conducted only on short circuit fault during transient phase.

Table 2. Unbalance Current and Average Current Harmonics Under Transient Phase

No.	Fault Types	Phase Current (V)			Unba Current (%)	THD_I (%)			Avg THD_I (%)
		A	B	C		A	B	C	
				MPPT P and O Method					
1	Normal	10.61	10.74	10.69	0.562	2.65	3.22	3.40	3,090
2	3Ph-N	1331	1359	1296	2.283	4.41	2.05	2.38	2.947
3	3Ph	1331	1359	1296	2.283	4.41	2.05	2.38	2.947
4	2Ph-N	1336	1350	7.671	50.353	4.70	1.76	3.91	3.457
5	2Ph	1179	1179	10.32	49.347	3.67	3.67	3.33	3.557
6	1Ph-N	1132	9.451	9.482	195.065	4.96	3.27	4.06	4.097
				MPPT Fuzzy Method					
1	Normal	10.72	10.76	10.80	0.372	3.32	3.76	4.28	3.787
2	3Ph-N	1331	1359	1296	2.283	4.41	2.05	2.38	2.947
3	3Ph	1331	1359	1296	2.283	4.41	2.05	2.38	2.947
4	2Ph-N	1336	1350	7.475	50.364	4.70	1.76	6.0	4.154
5	2Ph	1179	1179	10.09	49.361	3.69	3.66	5.10	4.150
6	1Ph-N	1332	9.203	9.319	195.886	4.97	4.88	5.28	5.044

Figure 11 shows current waveform of multi PV connected to three phase grid on a PCC bus using MPPT P and O/MPPT Fuzzy under normal condition, 3Ph-N, 2Ph-N, and 1Ph-N fault.

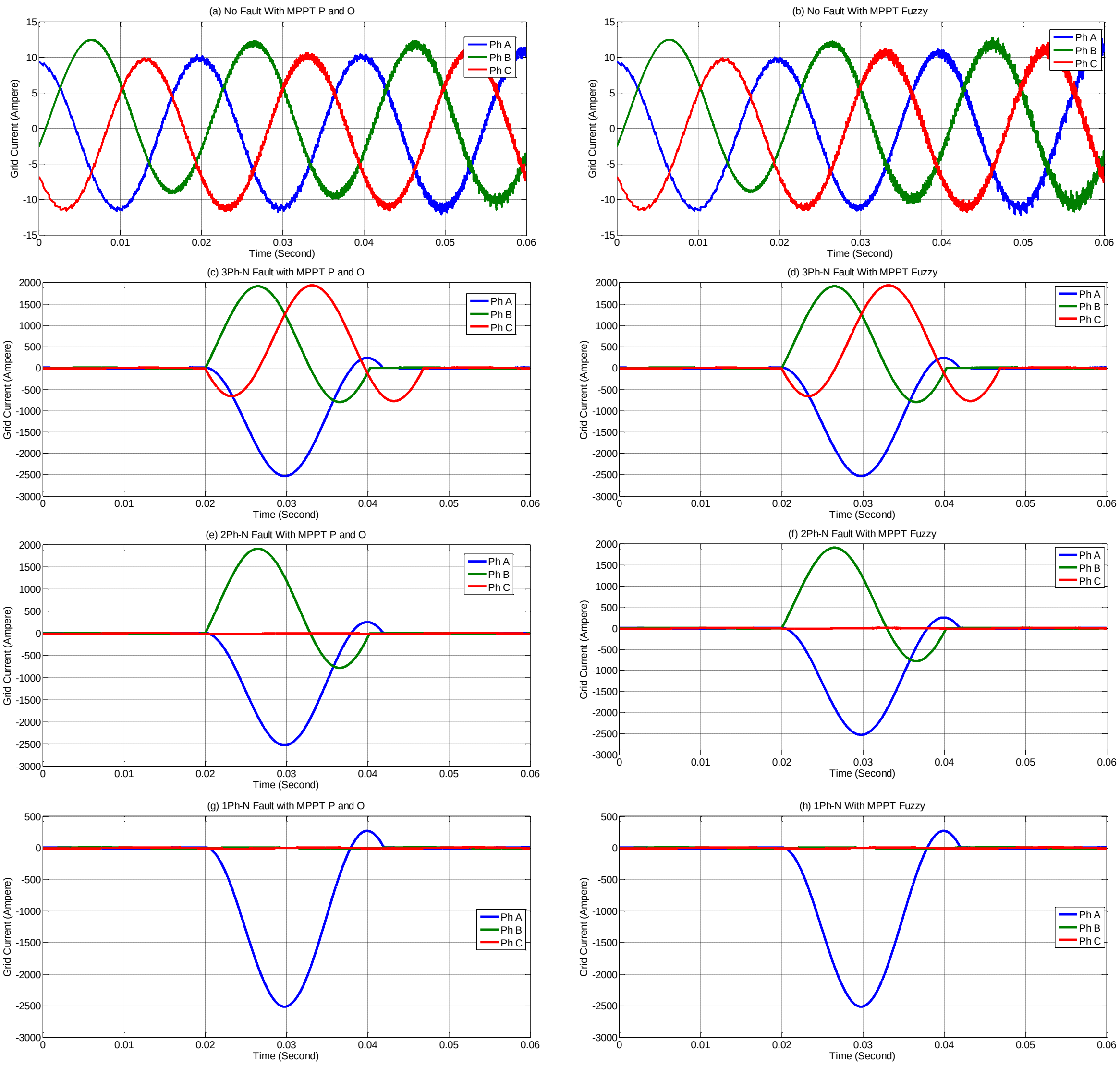


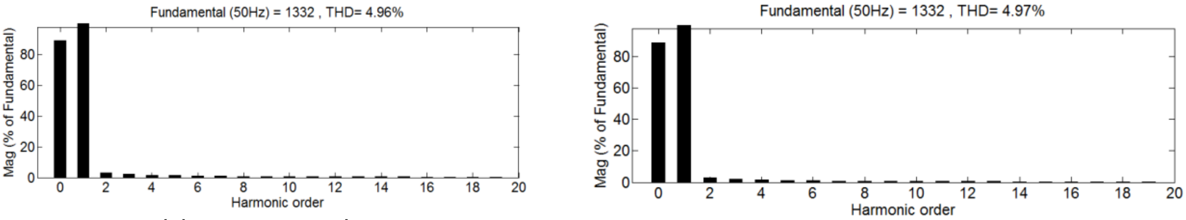
Figure 11. Current waveform of multi PV connected to a three phase grid on PCC bus

Table 3 shows unbalanced voltage, THD grid voltage, and average THD of grid voltage of multi PV connected on a three phase low voltage grid using MPPT P and O/ MPPT Fuzzy.

Table 3. Unbalance Voltage and Average Voltage Harmonics Under Transient Phase

No.	Fault Types	Phase Voltage (V)			Unba Voltage (%)	THD_V (%)			Avg THD_V (%)
		A	B	C		A	B	C	
				MPPT P and O Method					
1	Normal	308.8	308.7	307.8	0	6.74	7.06	7.14	6.980
2	3 Ph-N	1.332	1.350	1.307	1.523	6.50	179.32	189.46	125.094
3	3 Ph	1.347	1.325	1.318	1.279	275.94	336.34	341.31	317.864
4	2 Ph-N	2.242	2.268	308.4	195.677	5.36	106.86	7.83	39.017
5	2 Ph	155.0	152.7	307.8	50.025	7.96	8.09	7.72	7.924
6	1Ph-N	2.658	308.1	308.1	49.356	5.48	7.56	7.88	6.974
				MPPT Fuzzy Method					
1	Normal	307.7	307.7	307.7	0	8.23	9.74	9.79	9.254
2	3 Ph-N	1.332	1.351	1.306	1.605	5.38	172.84	181.97	120.064
3	3 Ph	1.339	1.343	1.307	1.003	223.47	283.53	294.43	267.144
4	2 Ph-N	2.242	2.269	308.4	195.676	4.90	102.82	11.16	39.627
5	2 Ph	155.0	152.7	307.8	50.025	10.12	10.28	9.98	10.127
6	1Ph-N	2.657	308.1	308.0	49.381	5.22	9.77	10.63	8,570

Figure 12 shows grid current harmonics spectra of phase A during transient phase due to the multi PV connected to three phase grid on PCC bus using MPPT P and O and MPPT Fuzzy method under 1Ph-N fault.

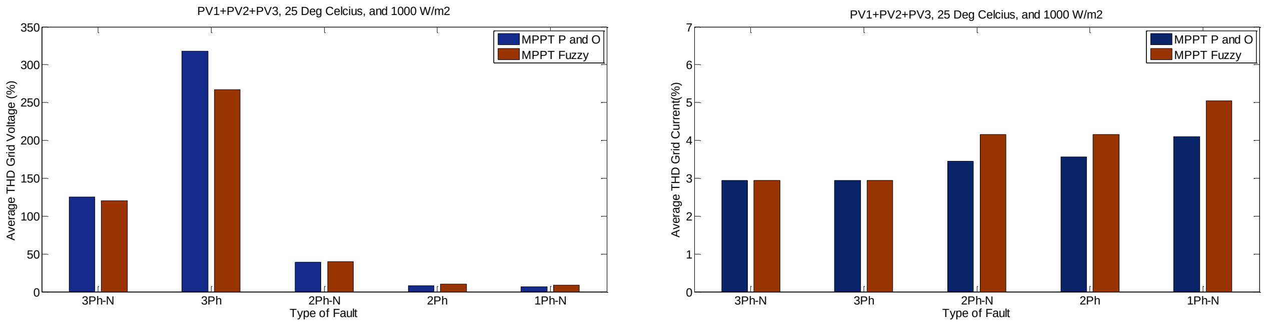


(a) MPPT P and O (b) MPPT Fuzzy

Figure 12. Current harmonics spectra of phase A under 1Ph-N fault

Table 2 presents that under normal condition, phase current of multi PV (PV1+PV2 + PV3) using MPPT P and O in transient phase are 10.61 A, 10.74 A, 10.69 A and able to result an unbalanced current of 0.562%. In short circuit faults, the highest unbalanced current of transient phase is generated by 1Ph-N fault of 195.886%. The 3Ph-N and 3Ph fault on transient phase are able equally produce an unbalanced current of 2,283%. The implementation of MPPT Fuzzy method under normal condition is able to generate an unbalanced current of 0.372%. If using MPPT Fuzzy under fault on transient phase, the highest unbalanced current is generated by 1Ph-N faults of 195.886%. At the same condition the smallest unbalanced current is equally generated by 3Ph-N and 3Ph fault of 2.282%. In non-symmetrical fault, the use of MPPT P and O is able to result an unbalanced current of transient phase slightly lower than MPPT Fuzzy. While in symmetrical faults, MPPT P and O/MPPT Fuzzy method for controlling of output power of multi PV gives same unbalanced current of transient phase of 2,283%. In normal condition, by using both MPPT P and O and MPPT Fuzzy method, the average THD current on transient phase are 3.090% and 3.787%, respectively. When using MPPT P and O, the highest average THD current is generated by 1Ph-N fault of 4,097%. In the same method, the smallest average THD voltage is equally generated by 3Ph-N and 3Ph of 2,947%. If using Fuzzy MPPT, the highest average THD current is generated by 1Ph-N fault of 5.044%. In the same method, the smallest average THD current is equally generated by 3Ph-N and 3Ph of 2,947%. In the symmetrical faults, both MPPT P and O and MPPT Fuzzy method is able equally result an average THD current during transient phase of 2,947%. In non-symmetrical fault, MPPT P and O is able to result an average THD current slightly smaller than MPPT Fuzzy method.

Table 3 presents that under normal condition, multi PV using MPPT P and O under transient phase is able to result an unbalanced voltage of 0%. In the short circuit faults, the highest unbalanced voltage during transient phase is generated by a 2Ph-N fault of 195.677% volt. The 3Ph fault during transient phase is able to result the smallest unbalanced voltage of 1.279%. MPPT Fuzzy under normal condition is also able to result an unbalanced voltage of 0%. When using the MPPT Fuzzy under short-circuit fault during transient phase, the highest unbalanced voltage is generated by a 2Ph-N fault of 195.676% and the lowest unbalanced voltage is generated by 3Ph fault of 1.003%. In non-symmetrical faults, the implemantation of MPPT P and O and MPPT Fuzzy method to control output power of multi PV produces nominal unbalanced voltage during transient phase results a close the same value. While in symmetrical fault, MPPT P and O and MPPT Fuzzy are able to result different unbalance voltage on transient phase. During 3Ph-N fault on transient phase, MPPT P and O method is able to result an unbalanced transient phase voltage of 1.523% slightly lower than MPPT Fuzzy of 1.605%. However during 3Ph fault on transient phase, MPPT Fuzzy is able to produce an unbalanced voltage of 1.003% slightly lower than MPPT P and O of 1.279%. In normal condition, the use of both MPPT P and O and MPPT Fuzzy method are able to result THD average voltages i.e. 6.980% and 9.254%, respectively. If using MPPT P and O, the largest average THD voltage is generated by a 3Ph fault of 317.864%. By using the same method, the lowest average THD voltage is produced by 1Ph-N fault of 6.974%. If using Fuzzy MPPT, the largest average THD voltage is also generated by a 3Ph fault of 267.144%. By using the same method, the lowest average THD voltage is generated by 1Ph-N fault of 8.570%. During symmetrical fault on transient phase, MPPT Fuzzy is able to result an average THD voltage smaller than MPPT P and O. Otherwise during non-symmetrical fault on transient phase, MPPT P and O is able to result an average THD voltage slightly lower than MPPT Fuzzy.



(a) Average THD voltage (b) Average THD current

Figure 13. Performance of (a) average voltage and (b) current harmonic during transient phase

Figure 13.a shows that on symmetrical faults during transient phase (3Ph-N and 3Ph), MPPT Fuzzy is able to result an average THD voltage smaller than MPPT P and O method. Otherwise on non-symmetrical faults during transient phase (2Ph-N, 2Ph, and 1Ph-N), MPPT P and O is able to result an average THD voltage slightly smaller than MPPT Fuzzy. Figure 14.b shows that on symmetrical faults during transient phase, MPPT Fuzzy and and MPPT P and O method are able to result the same average THD current. Furthermore on non-symmetrical faults during transient phase, MPPT P and O is able to result an average THD current slightly smaller than MPPT Fuzzy. The MPPT P and O and the MPPT Fuzzy on all short circuit fault during transient phase (3Ph-N, 3Ph, 2Ph-N, 2Ph, and 1Ph-N) are able to result smaller current average THD current significantly depend on average THD voltage.

4. Conclusion

Comparative performance of multi PVs connected grid under short circuit fault during transient phase to power quality using MPPT P and O/MPPT Fuzzy has been presented. During transient phase, non-symmetrical faults (2Ph-N, 2Ph, and 1Ph-N) is able to generate unbalance current/voltage greater depend on symmetrical faults (3Ph-N and 3Ph). On symmetrical faults, MPPT Fuzzy is able to result an average THD voltage/THD current smaller than MPPT P and O. Otherwise on non-symmetrical faults, MPPT P and O is able to result an average THD voltage/THD current slightly smaller than MPPT Fuzzy. The MPPT P and O/MPPT Fuzzy method on all short circuit faults during transient phase are able to results smaller current average THD than average THD voltage significantly. Futhermore the nominal of average THD current using both methods has also met THD limit prescribed in IEEE 519.

Appendix

PV generator 1, 2, and 3: active power = 100 kW, temperature = 25^0 C, irradiance = 1000 W/m^2; Three phase grid: short circuit power = 100 MVA, voltage = 380 volt (L-L), frequency = 50 Hz; Power transformer: rated power = 100 kVA, frequency = 50 Hz, voltage 380 Volt/20 kV (L-L), two winding type; Load 1, 2, and 3: active power = 20 kW, voltage = 380 volt (L-L), frequency = 50 Hz; Low Voltage Lines 1,2, and 3: resistance R = 0,1273 Ohm/km, inductance L = 93,37 mH/km, capasitance C = 1,274 μF/km; Length of Low Voltage Lines: Line 1, Line 2, Line 3 = 1 km; DC link capasitor: capacitance= 2000 μF, frequency = 4 kHz; PWM generator for DC/AC inverter: Sampling time= 5 x 10^{-6} Second; Fuzzy inference system = mamdani method; Fuzzy model composition = max-min; Input membership function: delta voltage=gbellmf, trimf, delta power: gbellmf, trimf; Output membership function: delta duty cycle = trimf.

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Transient Power Quality Performance of Multi Photovoltaics using MPPT P and O/MPPT Fuzzy

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Abstract

This paper presents comparative performance of transient power quality due to multi photovoltaic (PV) integration to grid at both fixed temperature and solar irradiation connected using Maximum Power Point Tracking Perturb and Observe (MPPT P and O)/MPPT Fuzzy. This research is performed as five transient of short-circuit faults on point common coupling (PCC) bus. An artificial intelligence with fuzzy logic controller (FLC) is used to set duty cycle with step variable to control DC/DC boost converter, generate quick convergence to determine MPPT for controlling of PV output voltage. Furthermore the result is compared with MPPT P and O. During transient phase, non-symmetrical faults are able to result an unbalance current/voltage greater than symmetrical faults. On symmetrical faults, MPPT Fuzzy is able to result an average THD voltage/THD current smaller than MPPT P and O. Otherwise on non-symmetrical faults, MPPT P and O is able to result an average THD voltage/THD current slightly smaller than MPPT Fuzzy. Both of MPPT P and O and MPPT Fuzzy on all short circuit faults during transient phase are able to result significantly smaller current average THD current than average THD voltage and limits of THD prescribed in IEEE 519. This research is simulated using Matlab/Simulink environment.

Keywords: *MPPT Fuzzy, MPPT P and O, Multi Photovoltaics, Power Quality, Short Circuit, Transient*

1. Introduction

The PV beside being able to generate power, it also results harmonics due to inverter as a medium to convert DC into AC voltage and is capable to decrease power quality. The short circuit fault can cause rise of current and voltage drop in certain phases depend on fault types, so it is able to generate unbalance voltage and current on low voltage distribution network (grid). The research on power quality of PV connected grid to power system using LCL filter has been done Kon Keng Weng et. al. A number of power quality problems i.e. over voltage, less voltage, power fluctuations, inrush currents, low power factor, and current harmonics or THD will appear on microgrid power system. This research is conducted only on constant solar irradiance and temperature condition (1000 W/m^2 and 25^0 C) as environmental input parameters for PV systems [1]. The study on effect of solar radiation on grid connected to PV generator to power quality has been investigated by Minas Patsalides, et.al. It considers two different scenarios of average and low radiation [2]. Investigation of grid connected a single phase PV inverter using a current proportional resonant, proportional resonant integral, and genetic algorithm using an active filter to reduce current harmonics of inverter output has been studied by Renu et. al. The laxity of research is only done on a single phase PV and certain irradiance and temperature [3]. The dynamic analysis of power quality due to high penetration effect of distribution network connected to PV under variable irradiance has been studied by Massoud Farhoodnea, et. al. The result showed that high level penetration of grid connected PV will cause a number of power quality problems. However, the research was only analyzed on voltage harmonics and did not consider the ambient temperature condition [4]. Power quality characteristics in a number of three phase PV inverters at top roof PV has been performed by K.P. Kontogianis, et. al [5]. A comparative study of MPPT between FLC and conventional PI controller has been presented for interfacing PV array with utility grid through a three-phase line-commutated inverter by Omid Zhoulai Bakhoda, et.al. FLC was dominating PI in many important aspects like i.e., provided active power for grid, output current shape of inverter, grid current and current THD [6]. A grid interfaced solar PV (SPV) power generating system in a 3P4W system has been

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proposed by Arun Kumar Verma, et.al. This system was used for compensation of neutral current, harmonic currents, reactive power and to provide load balancing [7]. However, both of power quality analysis in both papers was only performed by using single PV. Power quality due to integration of multi units of PV generator connected to three phase grid under variable solar irradiation level has been implemented by Amirullah, et.al. At level of solar irradiation was fixed, the greater number of PV connected to three-phase grid, then average THD of grid voltage/current also increased. At level of solar irradiation increased, average THD of grid voltage/current also increased. The PV in this research was still using MPPT with P and O algorithm and not using intelligent control [8].

Adaptive Neuro-fuzzy Inference System (ANFIS)-based improvement of MPPT P and O for PV under different shading conditions has been investigated by Khaled Bataineh, et.al. The simulation show proposed algorithm efficiently reach MPP under uniform irradiation, sudden changes of irradiation, and partial shading [9]. The method for balancing line current and voltage, due to the presence of distributed generations (DGs) i.e. a number of single phase PV generation units in homes has been presented by Amirullah, et.al. This research shows that the combination of Battery Energy Storage (BES) and three single phase bi-directional inverter able to reduce unbalanced line current/voltage. Otherwise, the combination of both circuit able to inreases current/voltage harmonics [10]. Power quality enhancement on low voltage of three phase grid caused by different level of PV integration using MPPT Fuzzy under variabel solar irradiance level on constant temperature and load has been investigated by Amirullah, et.al. It was able to enhance profile of grid voltage and current THD due to different level of integration of PV to three phase grid corresponding with IEEE Standard 519. MPPT Fuzzy was also able to improve input power factor better than MPPT P and O [11]. Rachid Belaidi, et.al has proposed a combined system of 3P4W shunt active filter and PV with MPPT P and O, to solve power quality such as harmonic currents, poor power factor, and unbalanced load [12]. Salah Eddine Mankour, et al has investigated on modeling of a PV stand alone power system using two widely-adopted MPPT algorithms, P & O and incremental conductance [13]. Bambang Purwahyudi, et. al has researched design of electrical characteristics of solar PV cell model by using self constructing neural network (SCNN) [14]. Julián A.C.C., et. al has used a mathematical model implemented in Matlab/Simulink to evaluate the performance of building integrated photovoltaic systems (BIPVS) [15]. Ahmad Saudi Samosir, et. al has investigated on modeling and simulation of MPPT used in solar power systems with fuzzy logic [16]. But the researchs on enhancement of power quality and MPPT characteristics for PV were only analyzed in normal condition.

This paper presents comparative performance of power quality due to the multi PV integration at both fixed temperature and solar irradiation levels connected to 380 V and 50 Hz distribution network using MPPT P and O/MPPT Fuzzy controller. The research is performed during transient disturbances of short-circuit fault on PCC bus based on five of short circuit faults. An artificial intelligence method with FLC is used to set duty cycle (D) with step variable to control DC/DC boost converter, generate quick convergence calculation to determine MPPT value for controlling of PV generator output voltage. Futhermore the result is compared with MPPT P and O method. The parameters are voltage/current unbalanced, voltage/current THD on each phase, and voltage/current average THD on PCC bus of three phase grid.

This paper is organized as follow. Section 2 presents proposed method i.e. proposed model of single PV using MPPT Fuzzy, model multi PV connected three phase grid under short circuit fault, simulation parameters, equivalent circuit, mathematical, and characteristic curve of PV model, MPPT P and O method, MPPT Fuzzy method, voltage and current harmonics, voltage and current unbalance. Section 3 describes comparative performance of multi PV connected grid under short circuit fault during transient phase to current/voltage unbalance and current/voltage THD of three phase grid using MPPT P and O/MPPT Fuzzy method. In this section, example cases studied are presented and the results are verified with those of Matlab/Simulink. Finally, the paper in concluded in Section 4.

2. Research Method

2.1. Proposed Model

Figure 1 shows model of a single PV system connected to a three phase grid. The DC/DC converter circuit consists of a boost converter circuit that serves to raise the DC output voltage from the PV. The DC output voltage of the boost converter circuit is then changed by a three

phase DC/AC inverter into an AC voltage to three phase grid. The single PV model is then used as a reference to construct multiple PV models connected to grid through a three phase phase distribution transformer showed in Figure 2. This research uses three model group of PVs with an active power of 100 kW each. Besides connected three phase grid, multi PVs are also connected to three group of three phase loads with 20 kW of active power each. The aim of research is to compare performance of power quality due to the multi PV integration at both fixed temperature and solar irradiation levels connected to distribution network using MPPT P and O/MPPT Fuzzy. The research analysis includes transient disturbances of short-circuit fault on PCC bus based on a number of short circuit faults. An artificial intelligence with FLC is used to set duty cycle (D) with step variable to control DC/DC boost converter, generate quick convergence calculation to determine MPPT value for controlling of PV output voltage, and then its result is compared with MPPT P and O method. The DC/DC converter produces a constant DC voltage as an input for DC/AC inverter using pulse with modulation (PWM).

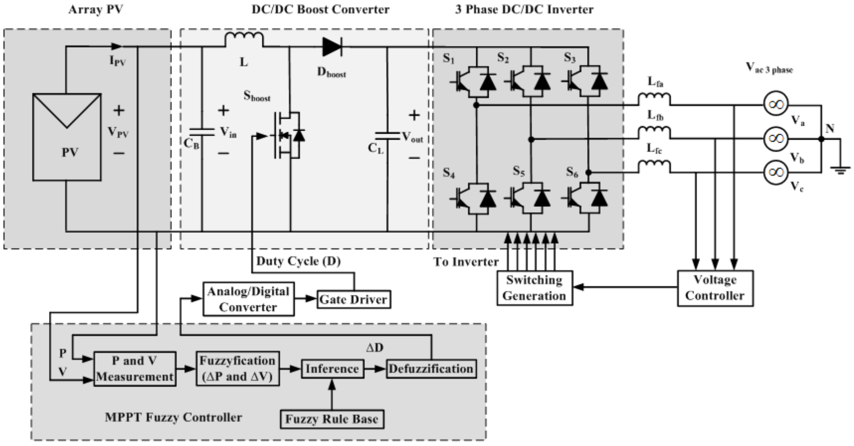


Figure 1. Proposed model of single PV using MPPT Fuzzy

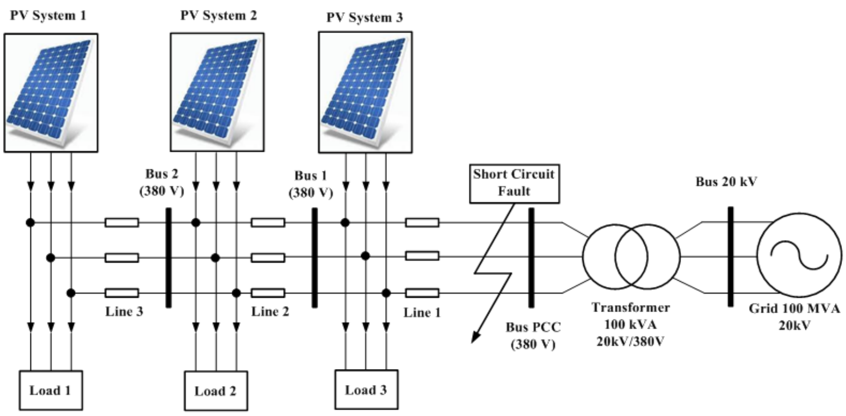


Figure 2. Proposed model of multi PV connected three phase grid under short circuit fault

There are two scenarios of multi PV connected three phase grids under fixed temperature and solar irradiation of 25^0 C and 1000 W/m^2, i.e. using MPPT P and O and MPPT Fuzzy methods respectively. The transient state in each of MPPT controllers are indicated by five short-circuit faults, resulting in a total of ten fault scenarios i.e. three phases to ground (3Ph-N), three phases (3Ph), two phases to ground (2Ph-N), two phases (2 Ph), and single phase to ground (1Ph-N). The 3ph-N and 3ph are classified as symmetrical faults. Futhermore 2ph-N, 2Ph, and 1Ph-N are classified as non-symmetrical faults. The next process is to determine voltage/current unbalanced, voltage/current harmonics (THD) on each phase, and voltage/current average harmonics on PCC bus of three-phase low voltage grid. The final step is to validate the results referring to the ANSI/IEEE 241-1990 standard about unbalanced voltage and current and IEEE Standard 519-1992 about average grid voltage and current harmonics. Simulation and analysis of this research use Matlab/Simulink. The simulation parameter values of proposed model are shown in Appendix Section.

2.2. Modelling of PV Array

Figure 3 shows the equivalent circuit of a solar panel. A solar panel is composed of several PV cells that have series, parallel, or series-parallel external connections [17].

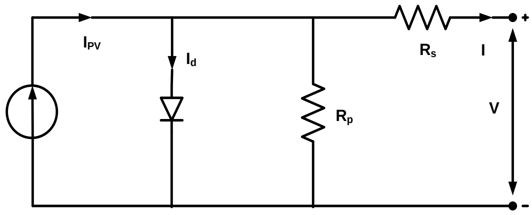


Figure 3. Equivalent circuit of solar panel

The V-I characteristic of a solar panel is showed in (1):

$$I = I_{PV} - I_o\left[\exp\left(\frac{V + R_S I}{aV_t}\right) - 1\right] - \frac{V + R_S I}{R_P} \tag{1}$$

where I_{PV} is the photovoltaic current, I_o is saturated reverse current, 'a' is the ideal diode constant, $V_t = N_S KTq^{-1}$ is the thermal voltage, N_S is the number of series cells, q is the electron charge, K is the Boltzmann constant, T is the temperature of p–n junction, R_S and R_P are series and parallel equivalent resistance of the solar panels. I_{PV} has a linear relation with light intensity and also varies with temperature variations. I_o is dependent on temperature variations.

2.3. MPPT P and O and MPPT Fuzzy

The initial research is to determine value of duty cycle (D) with a variable step to control DC/DC boost converter circuit with MPPT P and O. For PV converter, maximum power available is determined by PV cell characteristics, but this value often mismatches with the maximum power point (MPP) of the load. By implementing MPPT in PV systems, MPP can be maintained so that the number and size of PV panels can be reduced or energy yield can be optimized [18]. Because of moving of sun, PV panels angle, and variation of irradiance reaching the panels, energy generated from PV panels are absorbed does not constant over time. When this condition occurs, VI characteristics changes and MPP will move. To overcome these problems, MPPT has been developed. The system includes no moving parts. MPPT search for the maximum power independent based on environmental conditions (following changes in solar radiation and temperature) and maintain the PV terminal voltage remains constant at maximum value. The most used method of MPPT is P and O that algorithm is shown in Figure 4 [13] and its Matlab/Simulink model is presented in Figure 5.

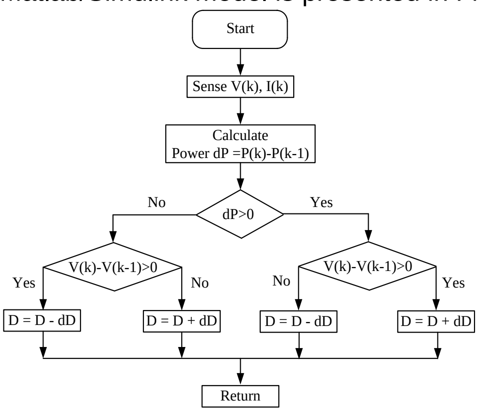


Figure 4. MPPT using P and O algorithm

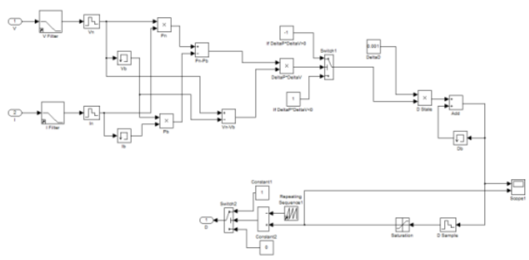


Figure 5. Matlab/Simulink for MPPT P and O

The same procedure for determining MPPT is using FLC. Fuzzy set theory is a new method of controlling the MPPT in obtaining the peak power point. The MPPT is implemented to obtain MPP operation voltage point faster with less overshoot and also it can minimize voltage fluctuation after MPP has been recognized. It also is capable to enhance power quality problem unbalance current/voltage and current/voltage harmonics. Typical fuzzy based MPPT controller reffered to MPPT Fuzzy includes three basic components i.e. fuzzification, inference engine, and defuzzification block as shown in Figure 6 and its Matlab/Simulink presented in Figure 7.

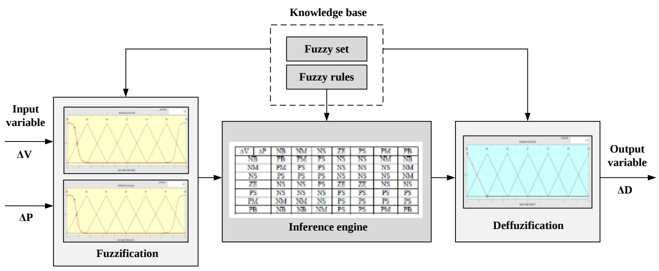


Figure 6. Structure of FLC

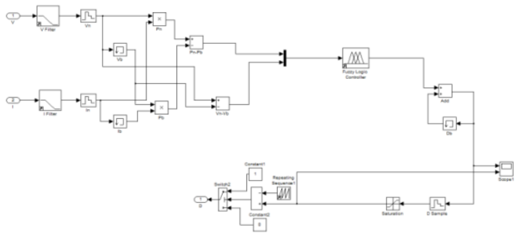


Figure 7. Matlab/Simulink for MPPT Fuzzy

Fuzzy MPPT method is done by determining input variables, namely fuzzy control output power (ΔP) and output voltage (ΔV) PV generator, seven linguistic variables fuzzy sets, fuzzy operating system block (fuzzification, fuzzy rules, and defuzzification), Function ΔP and Δ V during fuzzification, a table fuzzy rule base, crisp values to determine duty cycle (D) in defuzzification phase with variable step to control DC/DC boost converter. Figure 8 shows Matlab/Simulink model for MPPT Fuzzy. During fuzzification phase shown in Figure 7, a number of input variables is calculated and converted into a linguistic variable based on the subset called membership function (MF). To translate value of voltage change and power change in, input fuzzy "change of voltage" and "change of power" is designed to use seven fuzzy variable called PB (Positive Big), PM (Positive Medium), NS (Negative Small), PS (Positive Small) ZE (Zero), NM (Negative Medium), and Negative Big (NB). voltage change (ΔV) and power changes (ΔP) is a proposed system input variables and output variable FLC is duty cycle change (ΔD). The membership functions i.e. voltage changes, power changes, and duty cycle change, each are shown in Figure 8 into Figure 10.

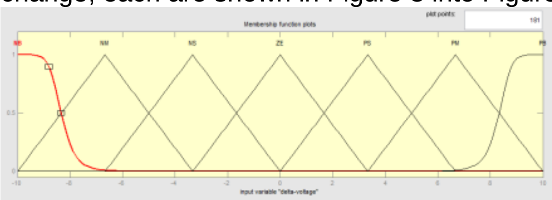


Figure 8. Input voltage change (delta voltage)

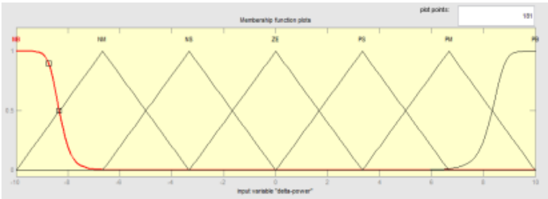


Figure 9. Input power change (delta power)

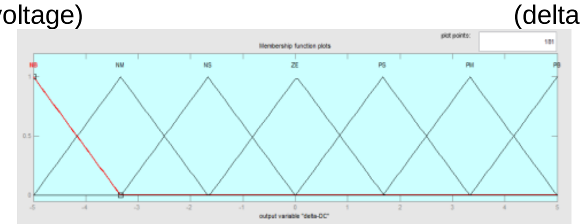


Figure 10. Output duty cyclechange (delta D)

The fuzzy inference using a method that relates to a composition Mamdani Max-Min. Fuzzy inference system consists of three parts, namely rule base, database, and reasoning mechanism. After determining ΔV and ΔP, these value are then converted into linguistic variables and use them as input functions for FLC. The output value is ΔD is generated using block inference and fuzzy rules as shown in Table 1. Finally defuzzification block operates to change value of ΔD is raised from linguistic variables into numeric variables back. Numeric variables that become inputs signal for the IGBT switch of DC/DC boost converter to be able to determine MPPT for each generation PV accurately at the same time also improve power quality as a result of integration of multi PV to low voltage three phase grid under short circuit.

Table 1. Fuzzy Rules

ΔV ΔP	NB	NM	NS	ZE	PS	PM	PB
NB	PB	PM	PS	NS	NS	NM	NB
NM	PM	PS	PS	NS	NS	NS	NM
NS	PS	PS	PS	NS	NS	NS	NM
ZE	NS	NS	PS	ZE	ZE	NS	NS
PS	NS	NS	NS	PS	PS	PS	PS
PM	NM	NM	NS	PS	PS	PS	PS
PB	NB	NB	NM	PS	PS	PM	PB

2.4. Voltage and Current Harmonics/Unbalance

Generally, current and voltage waveforms are pure sinusoidal. One problem that occurs is non sinusoida or distorted current and voltage waves generated by harmonics in power system [11]. Harmonic is distorted periodic steady state wave caused by the interaction between the shape of a sine wave at the fundamental frequency system with another wave component which is an integer multiples frequency of fundamental frequency. The most common harmonic index, which relates to voltage waveform is THD (2), which is defined as the root mean square (rms) of harmonics expressed as a percentage of fundamental component as showed in [19]. Second harmonic index is current THD means the ratio of rms harmonic current value to rms fundamental current which expressed in (3) [11].

$$THD_V = \frac{\sqrt{\sum_{n=2}^{N} V_n^2}}{V_1} \times 100\ \% \quad (2) \qquad THD_I = \frac{\sqrt{\sum_{n=2}^{N} I_n^2}}{I_1} \times 100\ \% \quad (3) \qquad V(\%) = \frac{\left|V_{a\,var\,age} - V_{a,b,c\,\min\,or\,\max}\right|}{V_{a\,var\,age}} \times 100\ \% \quad (4)$$

Where V_n and I_n (the rms voltage and current at harmonic n), V_1 and I_1 (the fundamental rms voltage and current), N (the maximum harmonic order to be considered). The allowable maximum THD value for each country is different depending on the standard used. THD standards most often used in electric power system is IEEE 519-1992. There are two criteria used in analysis of harmonics distortion i.e. voltage distortion and current distortion limit [20]. The value of unbalance voltage use (8) is based ANSI/IEEE 241-1990 is showed in (4) [21]. By using (4), value of unbalance voltage expressed in percent (%) and is defined as follows; $V_{avarage}$ is the average value of maximum voltage on phase a, b, c, in volt. $V_{a,b,c\ min}$ is minimum voltage on phase a, b, c in volt, $V_{a,b,c\ max}$ is maximum voltage on phase a, b, c in volt . By the same way, then unbalance current in % can be calculated by replacing voltage into current magnitude.

3. Results and Analysis

This research is started by determining the maximum and minimum of grid current in each phase, unbalanced current using (4), current THD on each phase (3), and average THD of three phase current grids on PCC bus using MPPT P and O/MPPT Fuzzy. By using the same procedure then obtained unbalanced voltage using (4), voltage THD on each phase using (3), and average voltage THD. Table 2 shows unbalanced current, THD grid current, and average THD of grid current of multi PV connected on a three phase low voltage grid using MPPT P and O/MPPT Fuzzy. Because, there are five short-circuit faults then there are three fault durations i.e. before, during (transient), and after fault phase with time durations are 0-0.02 sec, 0.02-0.04 sec, and 0.04-0.06 sec respectivelty. The simulation result of unbalanced current/voltage and average THD current/voltage is also presented as verification under five short circuit faults. The results analysis is conducted only on short circuit fault during transient phase.

Table 2. Unbalance Current and Average Current Harmonics Under Transient Phase

No.	Fault Types	Phase Current (V) A	B	C	Unba Current (%)	THD_I (%) A	B	C	Avg THD_I (%)
				MPPT P and O Method					
1	Normal	10.61	10.74	10.69	0.562	2.65	3.22	3.40	3,090
2	3Ph-N	1331	1359	1296	2.283	4.41	2.05	2.38	2.947
3	3Ph	1331	1359	1296	2.283	4.41	2.05	2.38	2.947
4	2Ph-N	1336	1350	7.671	50.353	4.70	1.76	3.91	3.457
5	2Ph	1179	1179	10.32	49.347	3.67	3.67	3.33	3.557
6	1Ph-N	1132	9.451	9.482	195.065	4.96	3.27	4.06	4.097
				MPPT Fuzzy Method					
1	Normal	10.72	10.76	10.80	0.372	3.32	3.76	4.28	3.787
2	3Ph-N	1331	1359	1296	2.283	4.41	2.05	2.38	2.947
3	3Ph	1331	1359	1296	2.283	4.41	2.05	2.38	2.947
4	2Ph-N	1336	1350	7.475	50.364	4.70	1.76	6.0	4.154
5	2Ph	1179	1179	10.09	49.361	3.69	3.66	5.10	4.150
6	1Ph-N	1332	9.203	9.319	195.886	4.97	4.88	5.28	5.044

Figure 11 shows current waveform of multi PV connected to three phase grid on a PCC bus using MPPT P and O/MPPT Fuzzy under normal condition, 3Ph-N, 2Ph-N, and 1Ph-N fault.

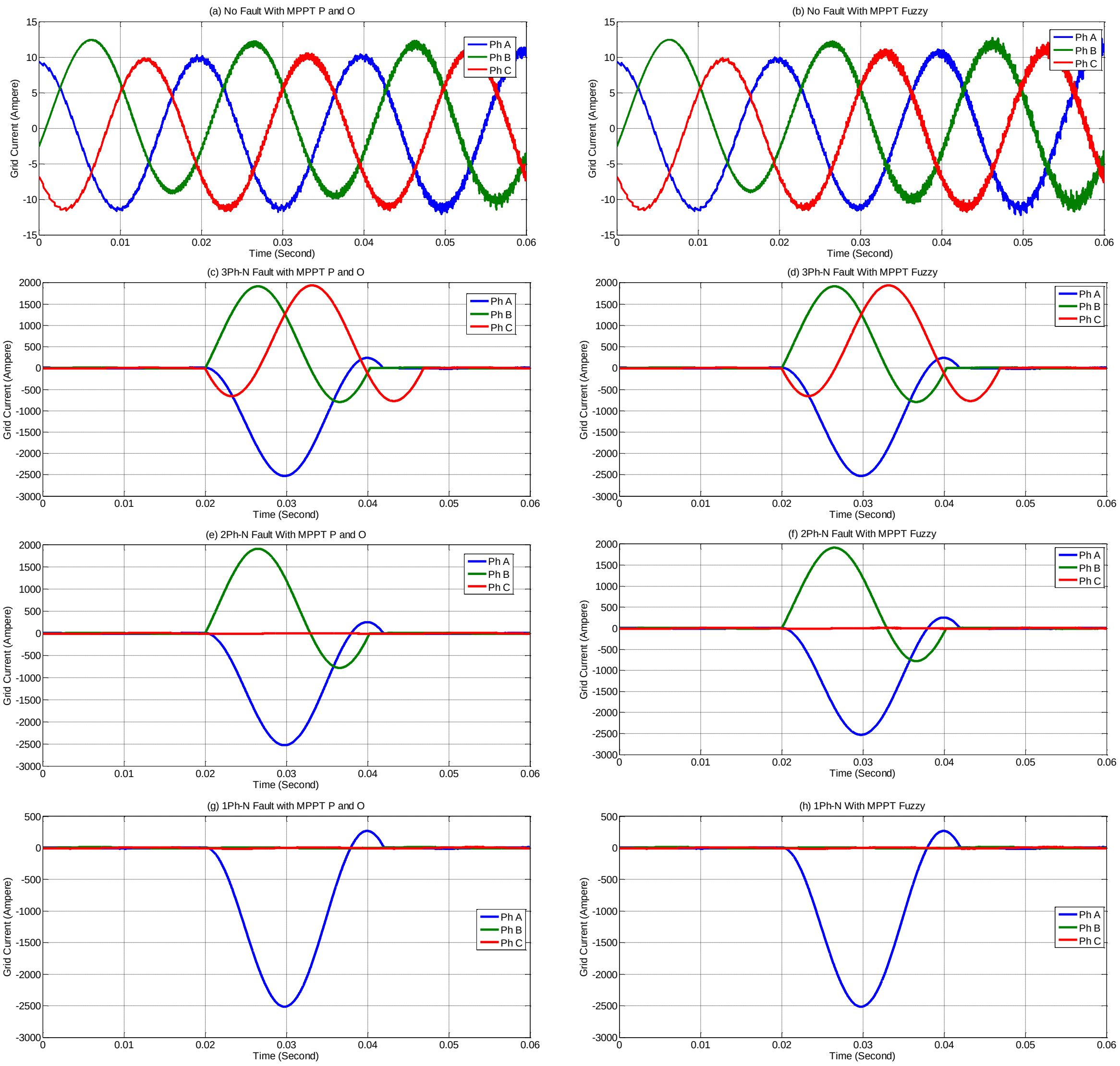


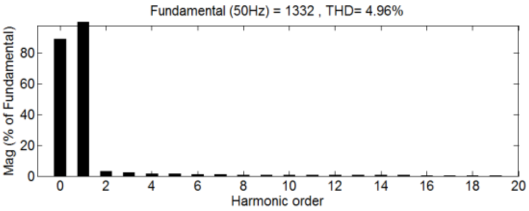
Figure 11. Current waveform of multi PV connected to a three phase grid on PCC bus

Table 3 shows unbalanced voltage, THD grid voltage, and average THD of grid voltage of multi PV connected on a three phase low voltage grid using MPPT P and O/ MPPT Fuzzy.

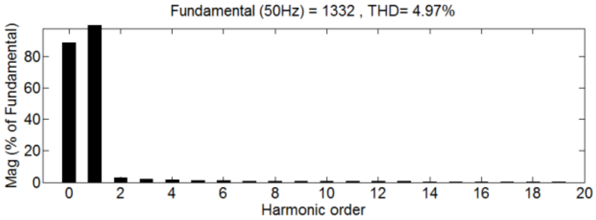
Table 3. Unbalance Voltage and Average Voltage Harmonics Under Transient Phase

No.	Fault Types	Phase Voltage (V)			Unba Voltage (%)	THD_V (%)			Avg THD_V (%)
		A	B	C		A	B	C	
					MPPT P and O Method				
1	Normal	308.8	308.7	307.8	0	6.74	7.06	7.14	6.980
2	3 Ph-N	1.332	1.350	1.307	1.523	6.50	179.32	189.46	125.094
3	3 Ph	1.347	1.325	1.318	1.279	275.94	336.34	341.31	317.864
4	2 Ph-N	2.242	2.268	308.4	195.677	5.36	106.86	7.83	39.017
5	2 Ph	155.0	152.7	307.8	50.025	7.96	8.09	7.72	7.924
6	1Ph-N	2.658	308.1	308.1	49.356	5.48	7.56	7.88	6.974
					MPPT Fuzzy Method				
1	Normal	307.7	307.7	307.7	0	8.23	9.74	9.79	9.254
2	3 Ph-N	1.332	1.351	1.306	1.605	5.38	172.84	181.97	120.064
3	3 Ph	1.339	1.343	1.307	1.003	223.47	283.53	294.43	267.144
4	2 Ph-N	2.242	2.269	308.4	195.676	4.90	102.82	11.16	39.627
5	2 Ph	155.0	152.7	307.8	50.025	10.12	10.28	9.98	10.127
6	1Ph-N	2.657	308.1	308.0	49.381	5.22	9.77	10.63	8,570

Figure 12 shows grid current harmonics spectra of phase A during transient phase due to the multi PV connected to three phase grid on PCC bus using MPPT P and O and MPPT Fuzzy method under 1Ph-N fault.



(a) MPPT P and O

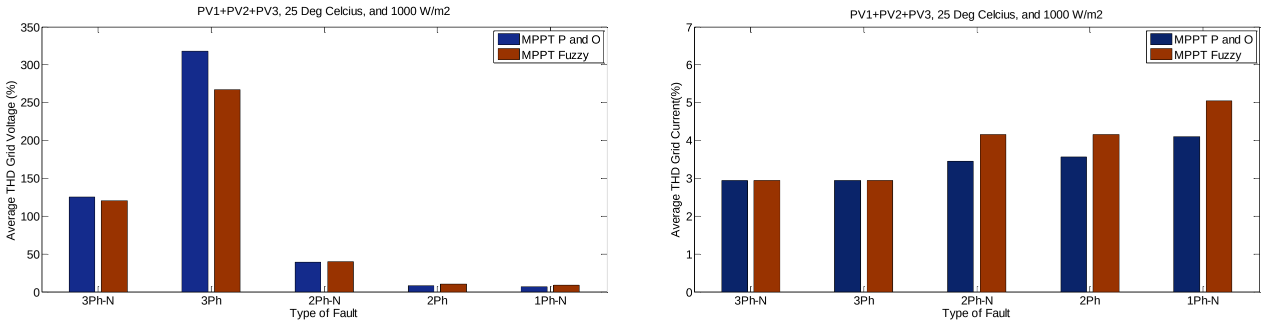


(b) MPPT Fuzzy

Figure 12. Current harmonics spectra of phase A under 1Ph-N fault

Table 2 presents that under normal condition, phase current of multi PV (PV1+PV2 + PV3) using MPPT P and O in transient phase are 10.61 A, 10.74 A, 10.69 A and able to result an unbalanced current of 0.562%. In short circuit faults, the highest unbalanced current of transient phase is generated by 1Ph-N fault of 195.886%. The 3Ph-N and 3Ph fault on transient phase are able equally produce an unbalanced current of 2,283%. The implementation of MPPT Fuzzy method under normal condition is able to generate an unbalanced current of 0.372%. If using MPPT Fuzzy under fault on transient phase, the highest unbalanced current is generated by 1Ph-N faults of 195.886%. At the same condition the smallest unbalanced current is equally generated by 3Ph-N and 3Ph fault of 2.282%. In non-symmetrical fault, the use of MPPT P and O is able to result an unbalanced current of transient phase slightly lower than MPPT Fuzzy. While in symmetrical faults, MPPT P and O/MPPT Fuzzy method for controlling of output power of multi PV gives same unbalanced current of transient phase of 2,283%. In normal condition, by using both MPPT P and O and MPPT Fuzzy method, the average THD current on transient phase are 3.090% and 3.787%, respectively. When using MPPT P and O, the highest average THD current is generated by 1Ph-N fault of 4,097%. In the same method, the smallest average THD voltage is equally generated by 3Ph-N and 3Ph of 2,947%. If using Fuzzy MPPT, the highest average THD current is generated by 1Ph-N fault of 5.044%. In the same method, the smallest average THD current is equally generated by 3Ph-N and 3Ph of 2,947%. In the symmetrical faults, both MPPT P and O and MPPT Fuzzy method is able equally result an average THD current during transient phase of 2,947%. In non-symmetrical fault, MPPT P and O is able to result an average THD current slightly smaller than MPPT Fuzzy method.

Table 3 presents that under normal condition, multi PV using MPPT P and O under transient phase is able to result an unbalanced voltage of 0%. In the short circuit faults, the highest unbalanced voltage during transient phase is generated by a 2Ph-N fault of 195.677% volt. The 3Ph fault during transient phase is able to result the smallest unbalanced voltage of 1.279%. MPPT Fuzzy under normal condition is also able to result an unbalanced voltage of 0%. When using the MPPT Fuzzy under short-circuit fault during transient phase, the highest unbalanced voltage is generated by a 2Ph-N fault of 195.676% and the lowest unbalanced voltage is generated by 3Ph fault of 1.003%. In non-symmetrical faults, the implemantation of MPPT P and O and MPPT Fuzzy method to control output power of multi PV produces nominal unbalanced voltage during transient phase results a close the same value. While in symmetrical fault, MPPT P and O and MPPT Fuzzy are able to result different unbalance voltage on transient phase. During 3Ph-N fault on transient phase, MPPT P and O method is able to result an unbalanced transient phase voltage of 1.523% slightly lower than MPPT Fuzzy of 1.605%. However during 3Ph fault on transient phase, MPPT Fuzzy is able to produce an unbalanced voltage of 1.003% slightly lower than MPPT P and O of 1.279%. In normal condition, the use of both MPPT P and O and MPPT Fuzzy method are able to result THD average voltages i.e. 6.980% and 9.254%, respectively. If using MPPT P and O, the largest average THD voltage is generated by a 3Ph fault of 317.864%. By using the same method, the lowest average THD voltage is produced by 1Ph-N fault of 6.974%. If using Fuzzy MPPT, the largest average THD voltage is also generated by a 3Ph fault of 267.144%. By using the same method, the lowest average THD voltage is generated by 1Ph-N fault of 8.570%. During symmetrical fault on transient phase, MPPT Fuzzy is able to result an average THD voltage smaller than MPPT P and O. Otherwise during non-symmetrical fault on transient phase, MPPT P and O is able to result an average THD voltage slightly lower than MPPT Fuzzy.



(a) Average THD voltage (b) Average THD current

Figure 13. Performance of (a) average voltage and (b) current harmonic during transient phase

Figure 13.a shows that on symmetrical faults during transient phase (3Ph-N and 3Ph), MPPT Fuzzy is able to result an average THD voltage smaller than MPPT P and O method. Otherwise on non-symmetrical faults during transient phase (2Ph-N, 2Ph, and 1Ph-N), MPPT P and O is able to result an average THD voltage slightly smaller than MPPT Fuzzy. Figure 14.b shows that on symmetrical faults during transient phase, MPPT Fuzzy and and MPPT P and O method are able to result the same average THD current. Furthermore on non-symmetrical faults during transient phase, MPPT P and O is able to result an average THD current slightly smaller than MPPT Fuzzy. The MPPT P and O and the MPPT Fuzzy on all short circuit fault during transient phase (3Ph-N, 3Ph, 2Ph-N, 2Ph, and 1Ph-N) are able to result smaller current average THD current significantly depend on average THD voltage.

4. Conclusion

Comparative performance of multi PVs connected grid under short circuit fault during transient phase to power quality using MPPT P and O/MPPT Fuzzy has been presented. During transient phase, non-symmetrical faults (2Ph-N, 2Ph, and 1Ph-N) is able to generate unbalance current/voltage greater depend on symmetrical faults (3Ph-N and 3Ph). On symmetrical faults, MPPT Fuzzy is able to result an average THD voltage/THD current smaller than MPPT P and O. Otherwise on non-symmetrical faults, MPPT P and O is able to result an average THD voltage/THD current slightly smaller than MPPT Fuzzy. The MPPT P and O/MPPT Fuzzy method on all short circuit faults during transient phase are able to results smaller current average THD than average THD voltage significantly. Futhermore the nominal of average THD current using both methods has also met THD limit prescribed in IEEE 519.

Appendix

PV generator 1, 2, and 3: active power = 100 kW, temperature = 25^0 C, irradiance = 1000 W/m^2; Three phase grid: short circuit power = 100 MVA, voltage = 380 volt (L-L), frequency = 50 Hz; Power transformer: rated power = 100 kVA, frequency = 50 Hz, voltage 380 Volt/20 kV (L-L), two winding type; Load 1, 2, and 3: active power = 20 kW, voltage = 380 volt (L-L), frequency = 50 Hz; Low Voltage Lines 1,2, and 3: resistance R = 0,1273 Ohm/km, inductance L = 93,37 mH/km, capasitance C = 1,274 μF/km; Length of Low Voltage Lines: Line 1, Line 2, Line 3 = 1 km; DC link capasitor: capacitance= 2000 μF, frequency = 4 kHz; PWM generator for DC/AC inverter: Sampling time= 5 x 10^{-6} Second; Fuzzy inference system = mamdani method; Fuzzy model composition = max-min; Input membership function: delta voltage=gbellmf, trimf, delta power: gbellmf, trimf; Output membership function: delta duty cycle = trimf.

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Transient Power Quality Performance of Multi Photovoltaics using MPPT P and O/MPPT Fuzzy

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Abstract

This paper presents comparative performance of transient power quality due to multi photovoltaic (PV) integration to grid at both fixed temperature and solar irradiation connected using Maximum Power Point Tracking Perturb and Observe (MPPT P and O)/MPPT Fuzzy. This research is performed as five transient of short-circuit faults on point common coupling (PCC) bus. An artificial intelligence with fuzzy logic controller (FLC) is used to set duty cycle with step variable to control DC/DC boost converter, generate quick convergence to determine MPPT for controlling of PV output voltage. Furthermore the result is compared with MPPT P and O. During transient phase, non-symmetrical faults are able to result an unbalance current/voltage greater than symmetrical faults. On symmetrical faults, MPPT Fuzzy is able to result an average THD voltage/THD current smaller than MPPT P and O. Otherwise on non-symmetrical faults, MPPT P and O is able to result an average THD voltage/THD current slightly smaller than MPPT Fuzzy. Both of MPPT P and O and MPPT Fuzzy on all short circuit faults during transient phase are able to result significantly smaller current average THD current than average THD voltage and limits of THD prescribed in IEEE 519. This research is simulated using Matlab/Simulink environment.

Keywords: *MPPT Fuzzy, MPPT P and O, Multi Photovoltaics, Power Quality, Short Circuit, Transient*

1. Introduction

The PV beside being able to generate power, it also results harmonics due to inverter as a medium to convert DC into AC voltage and is capable to decrease power quality. The short circuit fault can cause rise of current and voltage drop in certain phases depend on fault types, so it is able to generate unbalance voltage and current on low voltage distribution network (grid). The research on power quality of PV connected grid to power system using LCL filter has been done Kon Keng Weng et. al. A number of power quality problems i.e. over voltage, less voltage, power fluctuations, inrush currents, low power factor, and current harmonics or THD will appear on microgrid power system. This research is conducted only on constant solar irradiance and temperature condition (1000 W/m^2 and 25^0 C) as environmental input parameters for PV systems [1]. The study on effect of solar radiation on grid connected to PV generator to power quality has been investigated by Minas Patsalides, et.al. It considers two different scenarios of average and low radiation [2]. Investigation of grid connected a single phase PV inverter using a current proportional resonant, proportional resonant integral, and genetic algorithm using an active filter to reduce current harmonics of inverter output has been studied by Renu et. al. The laxity of research is only done on a single phase PV and certain irradiance and temperature [3]. The dynamic analysis of power quality due to high penetration effect of distribution network connected to PV under variable irradiance has been studied by Massoud Farhoodnea, et. al. The result showed that high level penetration of grid connected PV will cause a number of power quality problems. However, the research was only analyzed on voltage harmonics and did not consider the ambient temperature condition [4]. Power quality characteristics in a number of three phase PV inverters at top roof PV has been performed by K.P. Kontogianis, et. al [5]. A comparative study of MPPT between FLC and conventional PI controller has been presented for interfacing PV array with utility grid through a three-phase line-commutated inverter by Omid Zhoulai Bakhoda, et.al. FLC was dominating PI in many important aspects like i.e., provided active power for grid, output current shape of inverter, grid current and current THD [6]. A grid interfaced solar PV (SPV) power generating system in a 3P4W system has been

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proposed by Arun Kumar Verma, et.al. This system was used for compensation of neutral current, harmonic currents, reactive power and to provide load balancing [7]. However, both of power quality analysis in both papers was only performed by using single PV. Power quality due to integration of multi units of PV generator connected to three phase grid under variable solar irradiation level has been implemented by Amirullah, et.al. At level of solar irradiation was fixed, the greater number of PV connected to three-phase grid, then average THD of grid voltage/current also increased. At level of solar irradiation increased, average THD of grid voltage/current also increased. The PV in this research was still using MPPT with P and O algorithm and not using intelligent control [8].

Adaptive Neuro-fuzzy Inference System (ANFIS)-based improvement of MPPT P and O for PV under different shading conditions has been investigated by Khaled Bataineh, et.al. The simulation show proposed algorithm efficiently reach MPP under uniform irradiation, sudden changes of irradiation, and partial shading [9]. The method for balancing line current and voltage, due to the presence of distributed generations (DGs) i.e. a number of single phase PV generation units in homes has been presented by Amirullah, et.al. This research shows that the combination of Battery Energy Storage (BES) and three single phase bi-directional inverter able to reduce unbalanced line current/voltage. Otherwise, the combination of both circuit able to inreases current/voltage harmonics [10]. Power quality enhancement on low voltage of three phase grid caused by different level of PV integration using MPPT Fuzzy under variabel solar irradiance level on constant temperature and load has been investigated by Amirullah, et.al. It was able to enhance profile of grid voltage and current THD due to different level of integration of PV to three phase grid corresponding with IEEE Standard 519. MPPT Fuzzy was also able to improve input power factor better than MPPT P and O [11]. Rachid Belaidi, et.al has proposed a combined system of 3P4W shunt active filter and PV with MPPT P and O, to solve power quality such as harmonic currents, poor power factor, and unbalanced load [12]. Salah Eddine Mankour, et al has investigated on modeling of a PV stand alone power system using two widely-adopted MPPT algorithms, P & O and incremental conductance [13]. Bambang Purwahyudi, et. al has researched design of electrical characteristics of solar PV cell model by using self constructing neural network (SCNN) [14]. Julián A.C.C., et. al has used a mathematical model implemented in Matlab/Simulink to evaluate the performance of building integrated photovoltaic systems (BIPVS) [15]. Ahmad Saudi Samosir, et. al has investigated on modeling and simulation of MPPT used in solar power systems with fuzzy logic [16]. But the researchs on enhancement of power quality and MPPT characteristics for PV were only analyzed in normal condition.

This paper presents comparative performance of power quality due to the multi PV integration at both fixed temperature and solar irradiation levels connected to 380 V and 50 Hz distribution network using MPPT P and O/MPPT Fuzzy controller. The research is performed during transient disturbances of short-circuit fault on PCC bus based on five of short circuit faults. An artificial intelligence method with FLC is used to set duty cycle (D) with step variable to control DC/DC boost converter, generate quick convergence calculation to determine MPPT value for controlling of PV generator output voltage. Futhermore the result is compared with MPPT P and O method. The parameters are voltage/current unbalanced, voltage/current THD on each phase, and voltage/current average THD on PCC bus of three phase grid.

This paper is organized as follow. Section 2 presents proposed method i.e. proposed model of single PV using MPPT Fuzzy, model multi PV connected three phase grid under short circuit fault, simulation parameters, equivalent circuit, mathematical, and characteristic curve of PV model, MPPT P and O method, MPPT Fuzzy method, voltage and current harmonics, voltage and current unbalance. Section 3 describes comparative performance of multi PV connected grid under short circuit fault during transient phase to current/voltage unbalance and current/voltage THD of three phase grid using MPPT P and O/MPPT Fuzzy method. In this section, example cases studied are presented and the results are verified with those of Matlab/Simulink. Finally, the paper in concluded in Section 4.

2. Research Method

2.1. Proposed Model

Figure 1 shows model of a single PV system connected to a three phase grid. The DC/DC converter circuit consists of a boost converter circuit that serves to raise the DC output voltage from the PV. The DC output voltage of the boost converter circuit is then changed by a three

phase DC/AC inverter into an AC voltage to three phase grid. The single PV model is then used as a reference to construct multiple PV models connected to grid through a three phase phase distribution transformer showed in Figure 2. This research uses three model group of PVs with an active power of 100 kW each. Besides connected three phase grid, multi PVs are also connected to three group of three phase loads with 20 kW of active power each. The aim of research is to compare performance of power quality due to the multi PV integration at both fixed temperature and solar irradiation levels connected to distribution network using MPPT P and O/MPPT Fuzzy. The research analysis includes transient disturbances of short-circuit fault on PCC bus based on a number of short circuit faults. An artificial intelligence with FLC is used to set duty cycle (D) with step variable to control DC/DC boost converter, generate quick convergence calculation to determine MPPT value for controlling of PV output voltage, and then its result is compared with MPPT P and O method. The DC/DC converter produces a constant DC voltage as an input for DC/AC inverter using pulse with modulation (PWM).

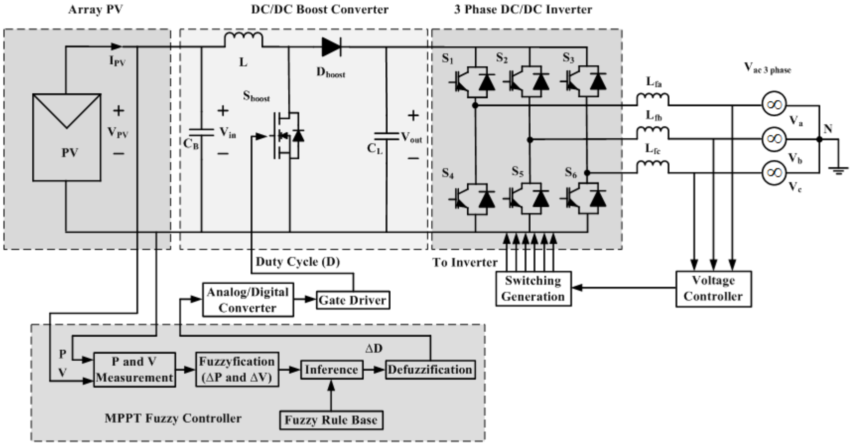


Figure 1. Proposed model of single PV using MPPT Fuzzy

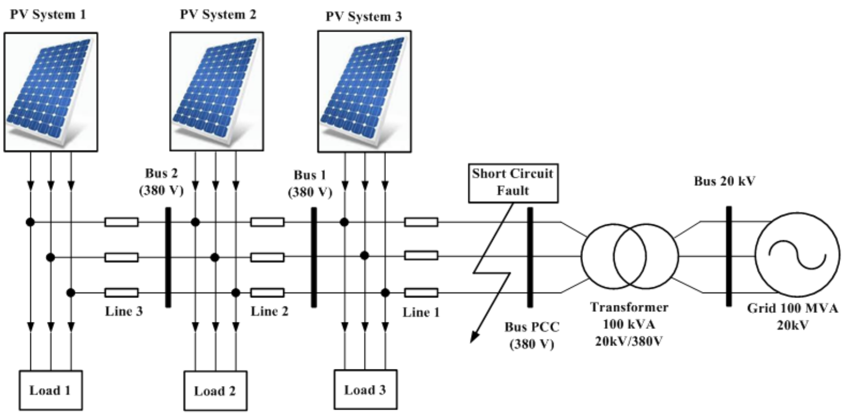


Figure 2. Proposed model of multi PV connected three phase grid under short circuit fault

There are two scenarios of multi PV connected three phase grids under fixed temperature and solar irradiation of 25^0 C and 1000 W/m^2, i.e. using MPPT P and O and MPPT Fuzzy methods respectively. The transient state in each of MPPT controllers are indicated by five short-circuit faults, resulting in a total of ten fault scenarios i.e. three phases to ground (3Ph-N), three phases (3Ph), two phases to ground (2Ph-N), two phases (2 Ph), and single phase to ground (1Ph-N). The 3ph-N and 3ph are classified as symmetrical faults. Futhermore 2ph-N, 2Ph, and 1Ph-N are classified as non-symmetrical faults. The next process is to determine voltage/current unbalanced, voltage/current harmonics (THD) on each phase, and voltage/current average harmonics on PCC bus of three-phase low voltage grid. The final step is to validate the results referring to the ANSI/IEEE 241-1990 standard about unbalanced voltage and current and IEEE Standard 519-1992 about average grid voltage and current harmonics. Simulation and analysis of this research use Matlab/Simulink. The simulation parameter values of proposed model are shown in Appendix Section.

2.2. Modelling of PV Array

Figure 3 shows the equivalent circuit of a solar panel. A solar panel is composed of several PV cells that have series, parallel, or series-parallel external connections [17].

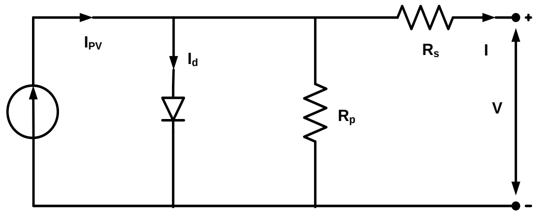


Figure 3. Equivalent circuit of solar panel

The V-I characteristic of a solar panel is showed in (1):

$$I = I_{PV} - I_o\left[\exp\left(\frac{V + R_S I}{aV_t}\right) - 1\right] - \frac{V + R_S I}{R_P} \tag{1}$$

where I_{PV} is the photovoltaic current, I_o is saturated reverse current, ‘a’ is the ideal diode constant, $V_t = N_S K T q^{-1}$ is the thermal voltage, N_S is the number of series cells, q is the electron charge, K is the Boltzmann constant, T is the temperature of p–n junction, R_S and R_P are series and parallel equivalent resistance of the solar panels. I_{PV} has a linear relation with light intensity and also varies with temperature variations. I_o is dependent on temperature variations.

2.3. MPPT P and O and MPPT Fuzzy

The initial research is to determine value of duty cycle (D) with a variable step to control DC/DC boost converter circuit with MPPT P and O. For PV converter, maximum power available is determined by PV cell characteristics, but this value often mismatches with the maximum power point (MPP) of the load. By implementing MPPT in PV systems, MPP can be maintained so that the number and size of PV panels can be reduced or energy yield can be optimized [18]. Because of moving of sun, PV panels angle, and variation of irradiance reaching the panels, energy generated from PV panels are absorbed does not constant over time. When this condition occurs, VI characteristics changes and MPP will move. To overcome these problems, MPPT has been developed. The system includes no moving parts. MPPT search for the maximum power independent based on environmental conditions (following changes in solar radiation and temperature) and maintain the PV terminal voltage remains constant at maximum value. The most used method of MPPT is P and O that algorithm is shown in Figure 4 [13] and its Matlab/Simulink model is presented in Figure 5.

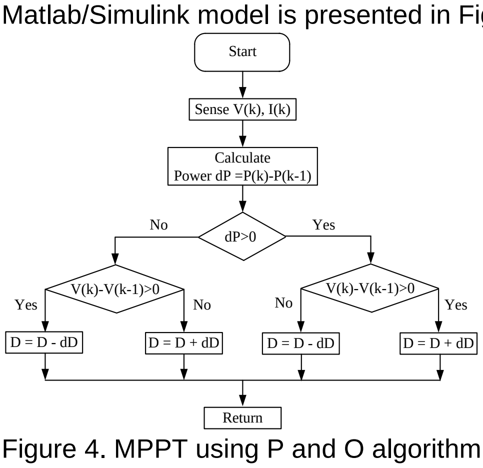


Figure 4. MPPT using P and O algorithm

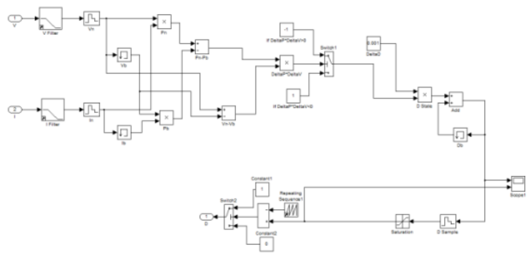


Figure 5. Matlab/Simulink for MPPT P and O

The same procedure for determining MPPT is using FLC. Fuzzy set theory is a new method of controlling the MPPT in obtaining the peak power point. The MPPT is implemented to obtain MPP operation voltage point faster with less overshoot and also it can minimize voltage fluctuation after MPP has been recognized. It also is capable to enhance power quality problem unbalance current/voltage and current/voltage harmonics. Typical fuzzy based MPPT controller reffered to MPPT Fuzzy includes three basic components i.e. fuzzification, inference engine, and defuzzification block as shown in Figure 6 and its Matlab/Simulink presented in Figure 7.

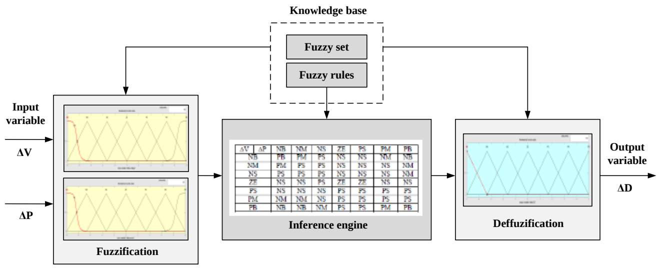


Figure 6. Structure of FLC

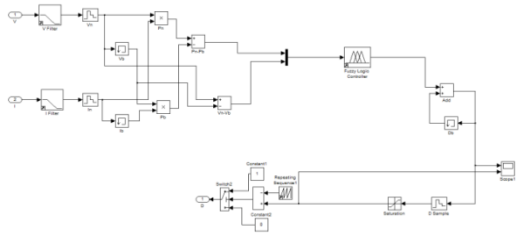


Figure 7. Matlab/Simulink for MPPT Fuzzy

Fuzzy MPPT method is done by determining input variables, namely fuzzy control output power (ΔP) and output voltage (ΔV) PV generator, seven linguistic variables fuzzy sets, fuzzy operating system block (fuzzification, fuzzy rules, and defuzzification), Function ΔP and Δ V during fuzzification, a table fuzzy rule base, crisp values to determine duty cycle (D) in defuzzification phase with variable step to control DC/DC boost converter. Figure 8 shows Matlab/Simulink model for MPPT Fuzzy. During fuzzification phase shown in Figure 7, a number of input variables is calculated and converted into a linguistic variable based on the subset called membership function (MF). To translate value of voltage change and power change in, input fuzzy "change of voltage" and "change of power" is designed to use seven fuzzy variable called PB (Positive Big), PM (Positive Medium), NS (Negative Small), PS (Positive Small) ZE (Zero), NM (Negative Medium), and Negative Big (NB). voltage change (ΔV) and power changes (ΔP) is a proposed system input variables and output variable FLC is duty cycle change (ΔD). The membership functions i.e. voltage changes, power changes, and duty cycle change, each are shown in Figure 8 into Figure 10.

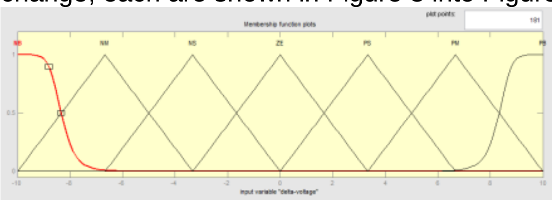


Figure 8. Input voltage change (delta voltage)

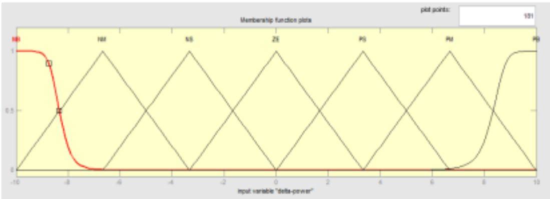


Figure 9. Input power change (delta power)

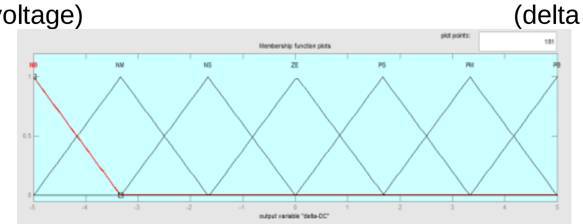


Figure 10. Output duty cyclechange (delta D)

The fuzzy inference using a method that relates to a composition Mamdani Max-Min. Fuzzy inference system consists of three parts, namely rule base, database, and reasoning mechanism. After determining ΔV and ΔP, these value are then converted into linguistic variables and use them as input functions for FLC. The output value is ΔD is generated using block inference and fuzzy rules as shown in Table 1. Finally defuzzification block operates to change value of ΔD is raised from linguistic variables into numeric variables back. Numeric variables that become inputs signal for the IGBT switch of DC/DC boost converter to be able to determine MPPT for each generation PV accurately at the same time also improve power quality as a result of integration of multi PV to low voltage three phase grid under short circuit.

Table 1. Fuzzy Rules

ΔV ΔP	NB	NM	NS	ZE	PS	PM	PB
NB	PB	PM	PS	NS	NS	NM	NB
NM	PM	PS	PS	NS	NS	NS	NM
NS	PS	PS	PS	NS	NS	NS	NM
ZE	NS	NS	PS	ZE	ZE	NS	NS
PS	NS	NS	NS	PS	PS	PS	PS
PM	NM	NM	NS	PS	PS	PS	PS
PB	NB	NB	NM	PS	PS	PM	PB

2.4. Voltage and Current Harmonics/Unbalance

Generally, current and voltage waveforms are pure sinusoidal. One problem that occurs is non sinusoida or distorted current and voltage waves generated by harmonics in power system [11]. Harmonic is distorted periodic steady state wave caused by the interaction between the shape of a sine wave at the fundamental frequency system with another wave component which is an integer multiples frequency of fundamental frequency. The most common harmonic index, which relates to voltage waveform is THD (2), which is defined as the root mean square (rms) of harmonics expressed as a percentage of fundamental component as showed in [19]. Second harmonic index is current THD means the ratio of rms harmonic current value to rms fundamental current which expressed in (3) [11].

$$THD_V = \frac{\sqrt{\sum_{n=2}^{N} V_n^2}}{V_1} \times 100\ \% \quad (2) \qquad THD_I = \frac{\sqrt{\sum_{n=2}^{N} I_n^2}}{I_1} \times 100\ \% \quad (3) \qquad V(\%) = \frac{\left|V_{a\,var\,age} - V_{a,b,c\,\min\,or\,\max}\right|}{V_{a\,var\,age}} \times 100\,\% \quad (4)$$

Where V_n and I_n (the rms voltage and current at harmonic n), V_1 and I_1 (the fundamental rms voltage and current), N (the maximum harmonic order to be considered). The allowable maximum THD value for each country is different depending on the standard used. THD standards most often used in electric power system is IEEE 519-1992. There are two criteria used in analysis of harmonics distortion i.e. voltage distortion and current distortion limit [20]. The value of unbalance voltage use (8) is based ANSI/IEEE 241-1990 is showed in (4) [21]. By using (4), value of unbalance voltage expressed in percent (%) and is defined as follows; $V_{avarage}$ is the average value of maximum voltage on phase a, b, c, in volt. $V_{a,b,c\ min}$ is minimum voltage on phase a, b, c in volt, $V_{a,b,c\ max}$ is maximum voltage on phase a, b, c in volt . By the same way, then unbalance current in % can be calculated by replacing voltage into current magnitude.

3. Results and Analysis

This research is started by determining the maximum and minimum of grid current in each phase, unbalanced current using (4), current THD on each phase (3), and average THD of three phase current grids on PCC bus using MPPT P and O/MPPT Fuzzy. By using the same procedure then obtained unbalanced voltage using (4), voltage THD on each phase using (3), and average voltage THD. Table 2 shows unbalanced current, THD grid current, and average THD of grid current of multi PV connected on a three phase low voltage grid using MPPT P and O/MPPT Fuzzy. Because, there are five short-circuit faults then there are three fault durations i.e. before, during (transient), and after fault phase with time durations are 0-0.02 sec, 0.02-0.04 sec, and 0.04-0.06 sec respectivelty. The simulation result of unbalanced current/voltage and average THD current/voltage is also presented as verification under five short circuit faults. The results analysis is conducted only on short circuit fault during transient phase.

Table 2. Unbalance Current and Average Current Harmonics Under Transient Phase

No.	Fault Types	Phase Current (V) A	B	C	Unba Current (%)	THD_I (%) A	B	C	Avg THD_I (%)
					MPPT P and O Method				
1	Normal	10.61	10.74	10.69	0.562	2.65	3.22	3.40	3,090
2	3Ph-N	1331	1359	1296	2.283	4.41	2.05	2.38	2.947
3	3Ph	1331	1359	1296	2.283	4.41	2.05	2.38	2.947
4	2Ph-N	1336	1350	7.671	50.353	4.70	1.76	3.91	3.457
5	2Ph	1179	1179	10.32	49.347	3.67	3.67	3.33	3.557
6	1Ph-N	1132	9.451	9.482	195.065	4.96	3.27	4.06	4.097
					MPPT Fuzzy Method				
1	Normal	10.72	10.76	10.80	0.372	3.32	3.76	4.28	3.787
2	3Ph-N	1331	1359	1296	2.283	4.41	2.05	2.38	2.947
3	3Ph	1331	1359	1296	2.283	4.41	2.05	2.38	2.947
4	2Ph-N	1336	1350	7.475	50.364	4.70	1.76	6.0	4.154
5	2Ph	1179	1179	10.09	49.361	3.69	3.66	5.10	4.150
6	1Ph-N	1332	9.203	9.319	195.886	4.97	4.88	5.28	5.044

Figure 11 shows current waveform of multi PV connected to three phase grid on a PCC bus using MPPT P and O/MPPT Fuzzy under normal condition, 3Ph-N, 2Ph-N, and 1Ph-N fault.

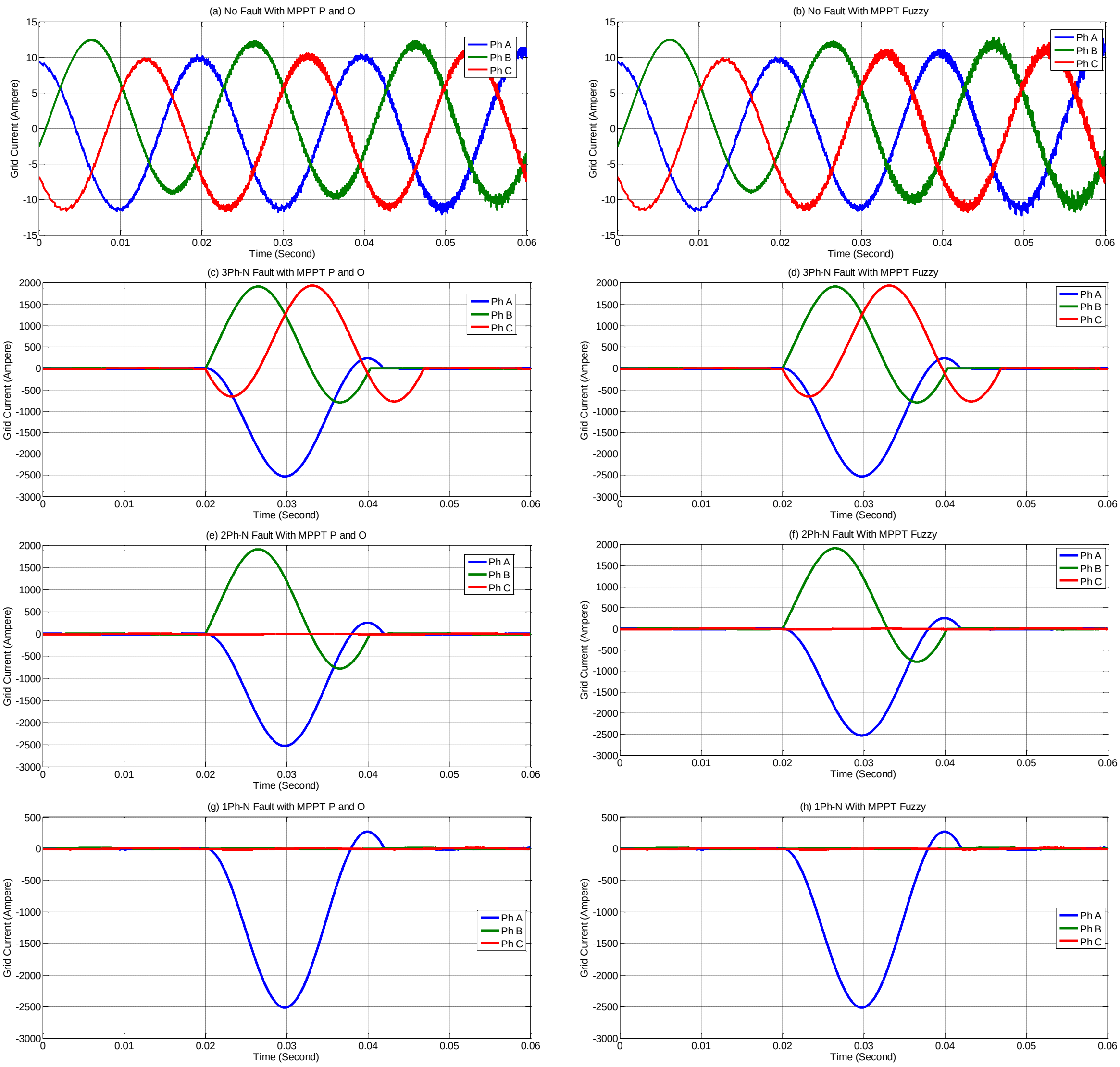


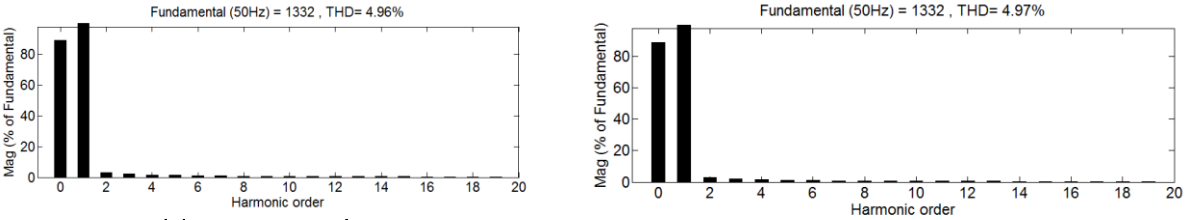
Figure 11. Current waveform of multi PV connected to a three phase grid on PCC bus

Table 3 shows unbalanced voltage, THD grid voltage, and average THD of grid voltage of multi PV connected on a three phase low voltage grid using MPPT P and O/ MPPT Fuzzy.

Table 3. Unbalance Voltage and Average Voltage Harmonics Under Transient Phase

No.	Fault Types	Phase Voltage (V) A	Phase Voltage (V) B	Phase Voltage (V) C	Unba Voltage (%)	THD_V (%) A	THD_V (%) B	THD_V (%) C	Avg THD_V (%)
				MPPT P and O Method					
1	Normal	308.8	308.7	307.8	0	6.74	7.06	7.14	6.980
2	3 Ph-N	1.332	1.350	1.307	1.523	6.50	179.32	189.46	125.094
3	3 Ph	1.347	1.325	1.318	1.279	275.94	336.34	341.31	317.864
4	2 Ph-N	2.242	2.268	308.4	195.677	5.36	106.86	7.83	39.017
5	2 Ph	155.0	152.7	307.8	50.025	7.96	8.09	7.72	7.924
6	1Ph-N	2.658	308.1	308.1	49.356	5.48	7.56	7.88	6.974
				MPPT Fuzzy Method					
1	Normal	307.7	307.7	307.7	0	8.23	9.74	9.79	9.254
2	3 Ph-N	1.332	1.351	1.306	1.605	5.38	172.84	181.97	120.064
3	3 Ph	1.339	1.343	1.307	1.003	223.47	283.53	294.43	267.144
4	2 Ph-N	2.242	2.269	308.4	195.676	4.90	102.82	11.16	39.627
5	2 Ph	155.0	152.7	307.8	50.025	10.12	10.28	9.98	10.127
6	1Ph-N	2.657	308.1	308.0	49.381	5.22	9.77	10.63	8,570

Figure 12 shows grid current harmonics spectra of phase A during transient phase due to the multi PV connected to three phase grid on PCC bus using MPPT P and O and MPPT Fuzzy method under 1Ph-N fault.

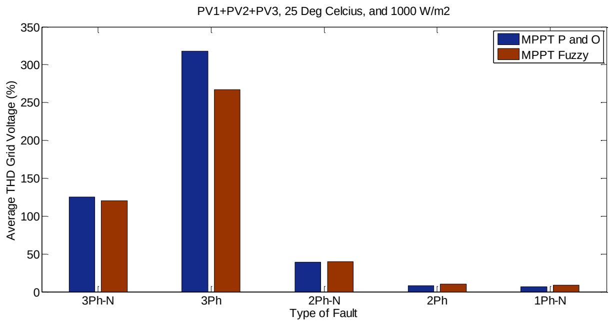


(a) MPPT P and O (b) MPPT Fuzzy

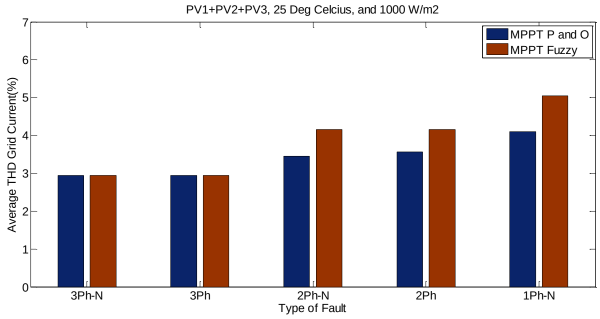
Figure 12. Current harmonics spectra of phase A under 1Ph-N fault

Table 2 presents that under normal condition, phase current of multi PV (PV1+PV2 + PV3) using MPPT P and O in transient phase are 10.61 A, 10.74 A, 10.69 A and able to result an unbalanced current of 0.562%. In short circuit faults, the highest unbalanced current of transient phase is generated by 1Ph-N fault of 195.886%. The 3Ph-N and 3Ph fault on transient phase are able equally produce an unbalanced current of 2,283%. The implementation of MPPT Fuzzy method under normal condition is able to generate an unbalanced current of 0.372%. If using MPPT Fuzzy under fault on transient phase, the highest unbalanced current is generated by 1Ph-N faults of 195.886%. At the same condition the smallest unbalanced current is equally generated by 3Ph-N and 3Ph fault of 2.282%. In non-symmetrical fault, the use of MPPT P and O is able to result an unbalanced current of transient phase slightly lower than MPPT Fuzzy. While in symmetrical faults, MPPT P and O/MPPT Fuzzy method for controlling of output power of multi PV gives same unbalanced current of transient phase of 2,283%. In normal condition, by using both MPPT P and O and MPPT Fuzzy method, the average THD current on transient phase are 3.090% and 3.787%, respectively. When using MPPT P and O, the highest average THD current is generated by 1Ph-N fault of 4,097%. In the same method, the smallest average THD voltage is equally generated by 3Ph-N and 3Ph of 2,947%. If using Fuzzy MPPT, the highest average THD current is generated by 1Ph-N fault of 5.044%. In the same method, the smallest average THD current is equally generated by 3Ph-N and 3Ph of 2,947%. In the symmetrical faults, both MPPT P and O and MPPT Fuzzy method is able equally result an average THD current during transient phase of 2,947%. In non-symmetrical fault, MPPT P and O is able to result an average THD current slightly smaller than MPPT Fuzzy method.

Table 3 presents that under normal condition, multi PV using MPPT P and O under transient phase is able to result an unbalanced voltage of 0%. In the short circuit faults, the highest unbalanced voltage during transient phase is generated by a 2Ph-N fault of 195.677% volt. The 3Ph fault during transient phase is able to result the smallest unbalanced voltage of 1.279%. MPPT Fuzzy under normal condition is also able to result an unbalanced voltage of 0%. When using the MPPT Fuzzy under short-circuit fault during transient phase, the highest unbalanced voltage is generated by a 2Ph-N fault of 195.676% and the lowest unbalanced voltage is generated by 3Ph fault of 1.003%. In non-symmetrical faults, the implemantation of MPPT P and O and MPPT Fuzzy method to control output power of multi PV produces nominal unbalanced voltage during transient phase results a close the same value. While in symmetrical fault, MPPT P and O and MPPT Fuzzy are able to result different unbalance voltage on transient phase. During 3Ph-N fault on transient phase, MPPT P and O method is able to result an unbalanced transient phase voltage of 1.523% slightly lower than MPPT Fuzzy of 1.605%. However during 3Ph fault on transient phase, MPPT Fuzzy is able to produce an unbalanced voltage of 1.003% slightly lower than MPPT P and O of 1.279%. In normal condition, the use of both MPPT P and O and MPPT Fuzzy method are able to result THD average voltages i.e. 6.980% and 9.254%, respectively. If using MPPT P and O, the largest average THD voltage is generated by a 3Ph fault of 317.864%. By using the same method, the lowest average THD voltage is produced by 1Ph-N fault of 6.974%. If using Fuzzy MPPT, the largest average THD voltage is also generated by a 3Ph fault of 267.144%. By using the same method, the lowest average THD voltage is generated by 1Ph-N fault of 8.570%. During symmetrical fault on transient phase, MPPT Fuzzy is able to result an average THD voltage smaller than MPPT P and O. Otherwise during non-symmetrical fault on transient phase, MPPT P and O is able to result an average THD voltage slightly lower than MPPT Fuzzy.



(a) Average THD voltage



(b) Average THD current

Figure 13. Performance of (a) average voltage and (b) current harmonic during transient phase

Figure 13.a shows that on symmetrical faults during transient phase (3Ph-N and 3Ph), MPPT Fuzzy is able to result an average THD voltage smaller than MPPT P and O method. Otherwise on non-symmetrical faults during transient phase (2Ph-N, 2Ph, and 1Ph-N), MPPT P and O is able to result an average THD voltage slightly smaller than MPPT Fuzzy. Figure 14.b shows that on symmetrical faults during transient phase, MPPT Fuzzy and and MPPT P and O method are able to result the same average THD current. Furthermore on non-symmetrical faults during transient phase, MPPT P and O is able to result an average THD current slightly smaller than MPPT Fuzzy. The MPPT P and O and the MPPT Fuzzy on all short circuit fault during transient phase (3Ph-N, 3Ph, 2Ph-N, 2Ph, and 1Ph-N) are able to result smaller current average THD current significantly depend on average THD voltage.

4. Conclusion

Comparative performance of multi PVs connected grid under short circuit fault during transient phase to power quality using MPPT P and O/MPPT Fuzzy has been presented. During transient phase, non-symmetrical faults (2Ph-N, 2Ph, and 1Ph-N) is able to generate unbalance current/voltage greater depend on symmetrical faults (3Ph-N and 3Ph). On symmetrical faults, MPPT Fuzzy is able to result an average THD voltage/THD current smaller than MPPT P and O. Otherwise on non-symmetrical faults, MPPT P and O is able to result an average THD voltage/THD current slightly smaller than MPPT Fuzzy. The MPPT P and O/MPPT Fuzzy method on all short circuit faults during transient phase are able to results smaller current average THD than average THD voltage significantly. Futhermore the nominal of average THD current using both methods has also met THD limit prescribed in IEEE 519.

Appendix

PV generator 1, 2, and 3: active power = 100 kW, temperature = 25^0 C, irradiance = 1000 W/m^2; Three phase grid: short circuit power = 100 MVA, voltage = 380 volt (L-L), frequency = 50 Hz; Power transformer: rated power = 100 kVA, frequency = 50 Hz, voltage 380 Volt/20 kV (L-L), two winding type; Load 1, 2, and 3: active power = 20 kW, voltage = 380 volt (L-L), frequency = 50 Hz; Low Voltage Lines 1,2, and 3: resistance R = 0,1273 Ohm/km, inductance L = 93,37 mH/km, capasitance C = 1,274 μF/km; Length of Low Voltage Lines: Line 1, Line 2, Line 3 = 1 km; DC link capasitor: capacitance= 2000 μF, frequency = 4 kHz; PWM generator for DC/AC inverter: Sampling time= 5 x 10^{-6} Second; Fuzzy inference system = mamdani method; Fuzzy model composition = max-min; Input membership function: delta voltage=gbellmf, trimf, delta power: gbellmf, trimf; Output membership function: delta duty cycle = trimf.

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Transient Power Quality Performance of Multi Photovoltaics using MPPT P and O/MPPT Fuzzy

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Abstract

This paper presents comparative performance of transient power quality due to multi photovoltaic (PV) integration to grid at both fixed temperature and solar irradiation connected using Maximum Power Point Tracking Perturb and Observe (MPPT P and O)/MPPT Fuzzy. This research is performed as five transient of short-circuit faults on point common coupling (PCC) bus. An artificial intelligence with fuzzy logic controller (FLC) is used to set duty cycle with step variable to control DC/DC boost converter, generate quick convergence to determine MPPT for controlling of PV output voltage. Furthermore the result is compared with MPPT P and O. During transient phase, non-symmetrical faults are able to result an unbalance current/voltage greater than symmetrical faults. On symmetrical faults, MPPT Fuzzy is able to result an average THD voltage/THD current smaller than MPPT P and O. Otherwise on non-symmetrical faults, MPPT P and O is able to result an average THD voltage/THD current slightly smaller than MPPT Fuzzy. Both of MPPT P and O and MPPT Fuzzy on all short circuit faults during transient phase are able to result significantly smaller current average THD current than average THD voltage and limits of THD prescribed in IEEE 519. This research is simulated using Matlab/Simulink environment.

Keywords*: MPPT Fuzzy, MPPT P and O, Multi Photovoltaics, Power Quality, Short Circuit, Transient*

1. Introduction

The PV beside being able to generate power, it also results harmonics due to inverter as a medium to convert DC into AC voltage and is capable to decrease power quality. The short circuit fault can cause rise of current and voltage drop in certain phases depend on fault types, so it is able to generate unbalance voltage and current on low voltage distribution network (grid). The research on power quality of PV connected grid to power system using LCL filter has been done Kon Keng Weng et. al. A number of power quality problems i.e. over voltage, less voltage, power fluctuations, inrush currents, low power factor, and current harmonics or THD will appear on microgrid power system. This research is conducted only on constant solar irradiance and temperature condition (1000 W/m^2 and 25^0 C) as environmental input parameters for PV systems [1]. The study on effect of solar radiation on grid connected to PV generator to power quality has been investigated by Minas Patsalides, et.al. It considers two different scenarios of average and low radiation [2]. Investigation of grid connected a single phase PV inverter using a current proportional resonant, proportional resonant integral, and genetic algorithm using an active filter to reduce current harmonics of inverter output has been studied by Renu et. al. The laxity of research is only done on a single phase PV and certain irradiance and temperature [3]. The dynamic analysis of power quality due to high penetration effect of distribution network connected to PV under variable irradiance has been studied by Massoud Farhoodnea, et. al. The result showed that high level penetration of grid connected PV will cause a number of power quality problems. However, the research was only analyzed on voltage harmonics and did not consider the ambient temperature condition [4]. Power quality characteristics in a number of three phase PV inverters at top roof PV has been performed by K.P. Kontogianis, et. al [5]. A comparative study of MPPT between FLC and conventional PI controller has been presented for interfacing PV array with utility grid through a three-phase line-commutated inverter by Omid Zhoulai Bakhoda, et.al. FLC was dominating PI in many important aspects like i.e., provided active power for grid, output current shape of inverter, grid current and current THD [6]. A grid interfaced solar PV (SPV) power generating system in a 3P4W system has been

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proposed by Arun Kumar Verma, et.al. This system was used for compensation of neutral current, harmonic currents, reactive power and to provide load balancing [7]. However, both of power quality analysis in both papers was only performed by using single PV. Power quality due to integration of multi units of PV generator connected to three phase grid under variable solar irradiation level has been implemented by Amirullah, et.al. At level of solar irradiation was fixed, the greater number of PV connected to three-phase grid, then average THD of grid voltage/current also increased. At level of solar irradiation increased, average THD of grid voltage/current also increased. The PV in this research was still using MPPT with P and O algorithm and not using intelligent control [8].

Adaptive Neuro-fuzzy Inference System (ANFIS)-based improvement of MPPT P and O for PV under different shading conditions has been investigated by Khaled Bataineh, et.al. The simulation show proposed algorithm efficiently reach MPP under uniform irradiation, sudden changes of irradiation, and partial shading [9]. The method for balancing line current and voltage, due to the presence of distributed generations (DGs) i.e. a number of single phase PV generation units in homes has been presented by Amirullah, et.al. This research shows that the combination of Battery Energy Storage (BES) and three single phase bi-directional inverter able to reduce unbalanced line current/voltage. Otherwise, the combination of both circuit able to inreases current/voltage harmonics [10]. Power quality enhancement on low voltage of three phase grid caused by different level of PV integration using MPPT Fuzzy under variabel solar irradiance level on constant temperature and load has been investigated by Amirullah, et.al. It was able to enhance profile of grid voltage and current THD due to different level of integration of PV to three phase grid corresponding with IEEE Standard 519. MPPT Fuzzy was also able to improve input power factor better than MPPT P and O [11]. Rachid Belaidi, et.al has proposed a combined system of 3P4W shunt active filter and PV with MPPT P and O, to solve power quality such as harmonic currents, poor power factor, and unbalanced load [12]. Salah Eddine Mankour, et al has investigated on modeling of a PV stand alone power system using two widely-adopted MPPT algorithms, P & O and incremental conductance [13]. Bambang Purwahyudi, et. al has researched design of electrical characteristics of solar PV cell model by using self constructing neural network (SCNN) [14]. Julián A.C.C., et. al has used a mathematical model implemented in Matlab/Simulink to evaluate the performance of building integrated photovoltaic systems (BIPVS) [15]. Ahmad Saudi Samosir, et. al has investigated on modeling and simulation of MPPT used in solar power systems with fuzzy logic [16]. But the researchs on enhancement of power quality and MPPT characteristics for PV were only analyzed in normal condition.

This paper presents comparative performance of power quality due to the multi PV integration at both fixed temperature and solar irradiation levels connected to 380 V and 50 Hz distribution network using MPPT P and O/MPPT Fuzzy controller. The research is performed during transient disturbances of short-circuit fault on PCC bus based on five of short circuit faults. An artificial intelligence method with FLC is used to set duty cycle (D) with step variable to control DC/DC boost converter, generate quick convergence calculation to determine MPPT value for controlling of PV generator output voltage. Futhermore the result is compared with MPPT P and O method. The parameters are voltage/current unbalanced, voltage/current THD on each phase, and voltage/current average THD on PCC bus of three phase grid.

This paper is organized as follow. Section 2 presents proposed method i.e. proposed model of single PV using MPPT Fuzzy, model multi PV connected three phase grid under short circuit fault, simulation parameters, equivalent circuit, mathematical, and characteristic curve of PV model, MPPT P and O method, MPPT Fuzzy method, voltage and current harmonics, voltage and current unbalance. Section 3 describes comparative performance of multi PV connected grid under short circuit fault during transient phase to current/voltage unbalance and current/voltage THD of three phase grid using MPPT P and O/MPPT Fuzzy method. In this section, example cases studied are presented and the results are verified with those of Matlab/Simulink. Finally, the paper in concluded in Section 4.

2. Research Method

2.1. Proposed Model

Figure 1 shows model of a single PV system connected to a three phase grid. The DC/DC converter circuit consists of a boost converter circuit that serves to raise the DC output voltage from the PV. The DC output voltage of the boost converter circuit is then changed by a three

phase DC/AC inverter into an AC voltage to three phase grid. The single PV model is then used as a reference to construct multiple PV models connected to grid through a three phase phase distribution transformer showed in Figure 2. This research uses three model group of PVs with an active power of 100 kW each. Besides connected three phase grid, multi PVs are also connected to three group of three phase loads with 20 kW of active power each. The aim of research is to compare performance of power quality due to the multi PV integration at both fixed temperature and solar irradiation levels connected to distribution network using MPPT P and O/MPPT Fuzzy. The research analysis includes transient disturbances of short-circuit fault on PCC bus based on a number of short circuit faults. An artificial intelligence with FLC is used to set duty cycle (D) with step variable to control DC/DC boost converter, generate quick convergence calculation to determine MPPT value for controlling of PV output voltage, and then its result is compared with MPPT P and O method. The DC/DC converter produces a constant DC voltage as an input for DC/AC inverter using pulse with modulation (PWM).

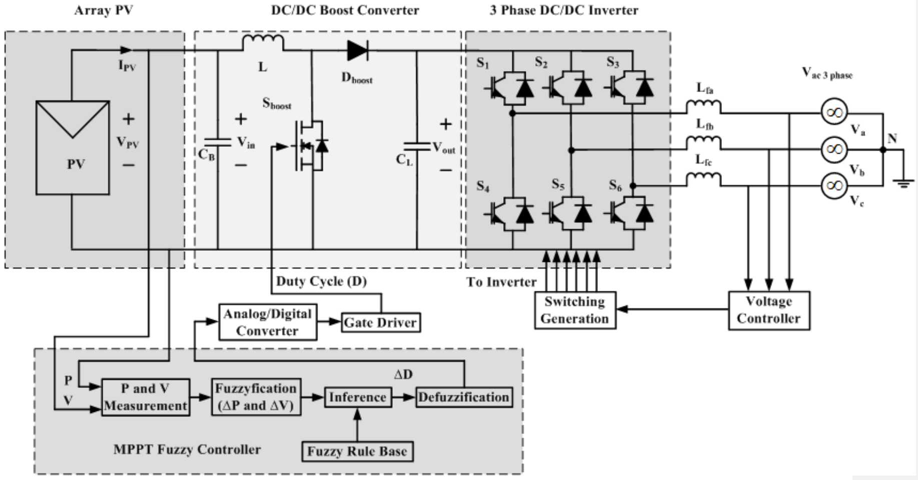


Figure 1. Proposed model of single PV using MPPT Fuzzy

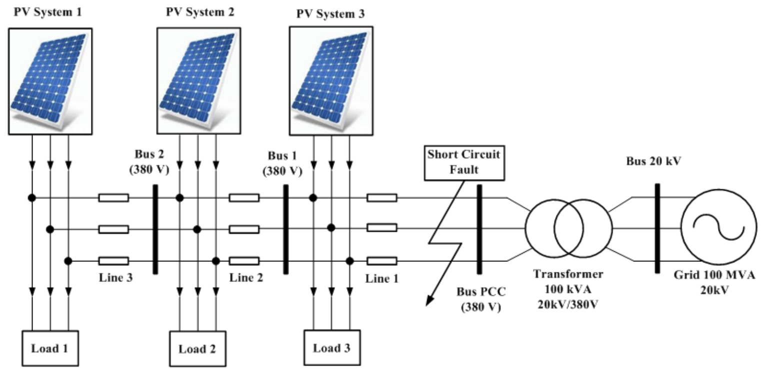


Figure 2. Proposed model of multi PV connected three phase grid under short circuit fault

There are two scenarios of multi PV connected three phase grids under fixed temperature and solar irradiation of 25^0 C and 1000 W/m^2, i.e. using MPPT P and O and MPPT Fuzzy methods respectively. The transient state in each of MPPT controllers are indicated by five short-circuit faults, resulting in a total of ten fault scenarios i.e. three phases to ground (3Ph-N), three phases (3Ph), two phases to ground (2Ph-N), two phases (2 Ph), and single phase to ground (1Ph-N). The 3ph-N and 3ph are classified as symmetrical faults. Futhermore 2ph-N, 2Ph, and 1Ph-N are classified as non-symmetrical faults. The next process is to determine voltage/current unbalanced, voltage/current harmonics (THD) on each phase, and voltage/current average harmonics on PCC bus of three-phase low voltage grid. The final step is to validate the results referring to the ANSI/IEEE 241-1990 standard about unbalanced voltage and current and IEEE Standard 519-1992 about average grid voltage and current harmonics. Simulation and analysis of this research use Matlab/Simulink. The simulation parameter values of proposed model are shown in Appendix Section.

2.2. Modelling of PV Array

Figure 3 shows the equivalent circuit of a solar panel. A solar panel is composed of several PV cells that have series, parallel, or series-parallel external connections [17].

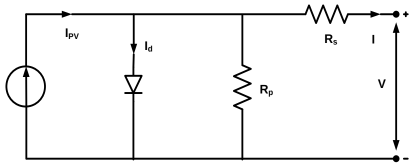


Figure 3. Equivalent circuit of solar panel

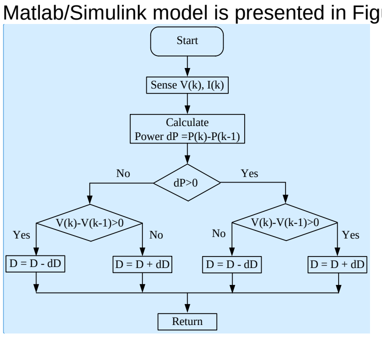
The V-I characteristic of a solar panel is showed in (1):

$$I = I_{PV} - I_o\left[\exp\left(\frac{V + R_S I}{aV_t}\right) - 1\right] - \frac{V + R_S I}{R_P} \quad (1)$$

where I_{PV} is the photovoltaic current, I_o is saturated reverse current, 'a' is the ideal diode constant, $V_t = N_S K T q^{-1}$ is the thermal voltage, N_S is the number of series cells, q is the electron charge, K is the Boltzmann constant, T is the temperature of p–n junction, R_S and R_P are series and parallel equivalent resistance of the solar panels. I_{PV} has a linear relation with light intensity and also varies with temperature variations. I_o is dependent on temperature variations.

2.3. MPPT P and O and MPPT Fuzzy

The initial research is to determine value of duty cycle (D) with a variable step to control DC/DC boost converter circuit with MPPT P and O. For PV converter, maximum power available is determined by PV cell characteristics, but this value often mismatches with the maximum power point (MPP) of the load. By implementing MPPT in PV systems, MPP can be maintained so that the number and size of PV panels can be reduced or energy yield can be optimized [18]. Because of moving of sun, PV panels angle, and variation of irradiance reaching the panels, energy generated from PV panels are absorbed does not constant over time. When this condition occurs, VI characteristics changes and MPP will move. To overcome these problems, MPPT has been developed. The system includes no moving parts. MPPT search for the maximum power independent based on environmental conditions (following changes in solar radiation and temperature) and maintain the PV terminal voltage remains constant at maximum value. The most used method of MPPT is P and O that algorithm is shown in Figure 4 [13] and its Matlab/Simulink model is presented in Figure 5.



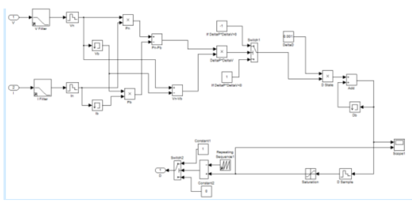


Figure 4. MPPT using P and O algorithm

Figure 5. Matlab/Simulink for MPPT P and O

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The same procedure for determining MPPT is using FLC. Fuzzy set theory is a new method of controlling the MPPT in obtaining the peak power point. The MPPT is implemented to obtain MPP operation voltage point faster with less overshoot and also it can minimize voltage fluctuation after MPP has been recognized. It also is capable to enhance power quality problem unbalance current/voltage and current/voltage harmonics. Typical fuzzy based MPPT controller reffered to MPPT Fuzzy includes three basic components i.e. fuzzification, inference engine, and defuzzification block as shown in Figure 6 and its Matlab/Simulink presented in Figure 7.

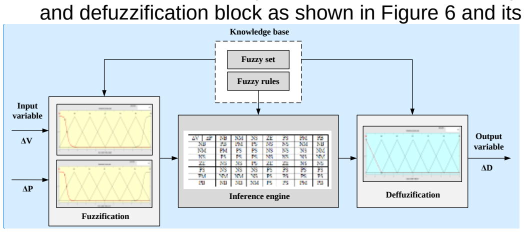

Figure 6. Structure of FLC

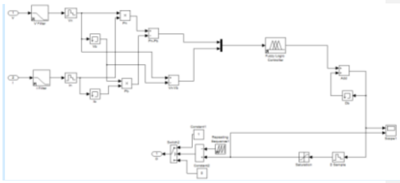

Figure 7. Matlab/Simulink for MPPT Fuzzy

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Fuzzy MPPT method is done by determining input variables, namely fuzzy control output power (ΔP) and output voltage (ΔV) PV generator, seven linguistic variables fuzzy sets, fuzzy operating system block (fuzzification, fuzzy rules, and defuzzification), Function ΔP and Δ V during fuzzification, a table fuzzy rule base, crisp values to determine duty cycle (D) in defuzzification phase with variable step to control DC/DC boost converter. Figure 8 shows Matlab/Simulink model for MPPT Fuzzy. During fuzzification phase shown in Figure 7, a number of input variables is calculated and converted into a linguistic variable based on the subset called membership function (MF). To translate value of voltage change and power change in, input fuzzy "change of voltage" and "change of power" is designed to use seven fuzzy variable called PB (Positive Big), PM (Positive Medium), NS (Negative Small), PS (Positive Small) ZE (Zero), NM (Negative Medium), and Negative Big (NB). voltage change (ΔV) and power changes (ΔP) is a proposed system input variables and output variable FLC is duty cycle change (ΔD). The membership functions i.e. voltage changes, power changes, and duty cycle change, each are shown in Figure 8 into Figure 10.

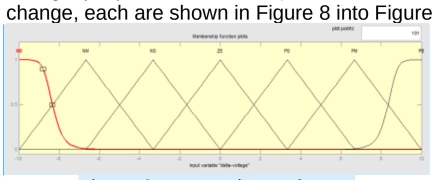

Figure 8. Input voltage change (delta voltage)

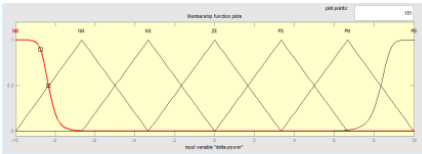

Figure 9. Input power change (delta power)

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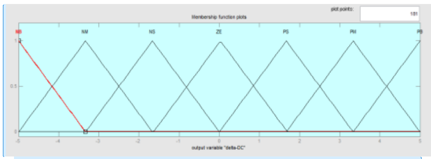

Figure 10. Output duty cyclechange (delta D)

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The fuzzy inference using a method that relates to a composition Mamdani Max-Min. Fuzzy inference system consists of three parts, namely rule base, database, and reasoning mechanism. After determining ΔV and ΔP, these value are then converted into linguistic variables and use them as input functions for FLC. The output value is ΔD is generated using block inference and fuzzy rules as shown in Table 1. Finally defuzzification block operates to change value of ΔD is raised from linguistic variables into numeric variables back. Numeric variables that become inputs signal for the IGBT switch of DC/DC boost converter to be able to determine MPPT for each generation PV accurately at the same time also improve power quality as a result of integration of multi PV to low voltage three phase grid under short circuit.

Table 1. Fuzzy Rules

ΔV ΔP	NB	NM	NS	ZE	PS	PM	PB
NB	PB	PM	PS	NS	NS	NM	NB
NM	PM	PS	PS	NS	NS	NS	NM
NS	PS	PS	PS	NS	NS	NS	NM
ZE	NS	NS	PS	ZE	ZE	NS	NS
PS	NS	NS	NS	PS	PS	PS	PS
PM	NM	NM	NS	PS	PS	PS	PS
PB	NB	NB	NM	PS	PS	PM	PB

2.4. Voltage and Current Harmonics/Unbalance

Generally, current and voltage waveforms are pure sinusoidal. One problem that occurs is non sinusoida or distorted current and voltage waves generated by harmonics in power system [11]. Harmonic is distorted periodic steady state wave caused by the interaction between the shape of a sine wave at the fundamental frequency system with another wave component which is an integer multiples frequency of fundamental frequency. The most common harmonic index, which relates to voltage waveform is THD (2), which is defined as the root mean square (rms) of harmonics expressed as a percentage of fundamental component as showed in [19]. Second harmonic index is current THD means the ratio of rms harmonic current value to rms fundamental current which expressed in (3) [11].

$$THD_V = \frac{\sqrt{\sum_{n=2}^{N} V_n^2}}{V_1} \times 100\ \% \quad (2) \qquad THD_I = \frac{\sqrt{\sum_{n=2}^{N} I_n^2}}{I_1} \times 100\ \% \quad (3) \qquad V(\%) = \frac{\left|V_{a\,var\,age} - V_{a,b,c\,\min\,or\,\max}\right|}{V_{a\,var\,age}} \times 100\,\% \quad (4)$$

Where V_n and I_n (the rms voltage and current at harmonic n), V_1 and I_1 (the fundamental rms voltage and current), N (the maximum harmonic order to be considered). The allowable maximum THD value for each country is different depending on the standard used. THD standards most often used in electric power system is IEEE 519-1992. There are two criteria used in analysis of harmonics distortion i.e. voltage distortion and current distortion limit [20]. The value of unbalance voltage use (8) is based ANSI/IEEE 241-1990 is showed in (4) [21]. By using (4), value of unbalance voltage expressed in percent (%) and is defined as follows; $V_{avarage}$ is the average value of maximum voltage on phase a, b, c, in volt. $V_{a,b,c\ min}$ is minimum voltage on phase a, b, c in volt, $V_{a,b,c\ max}$ is maximum voltage on phase a, b, c in volt . By the same way, then unbalance current in % can be calculated by replacing voltage into current magnitude.

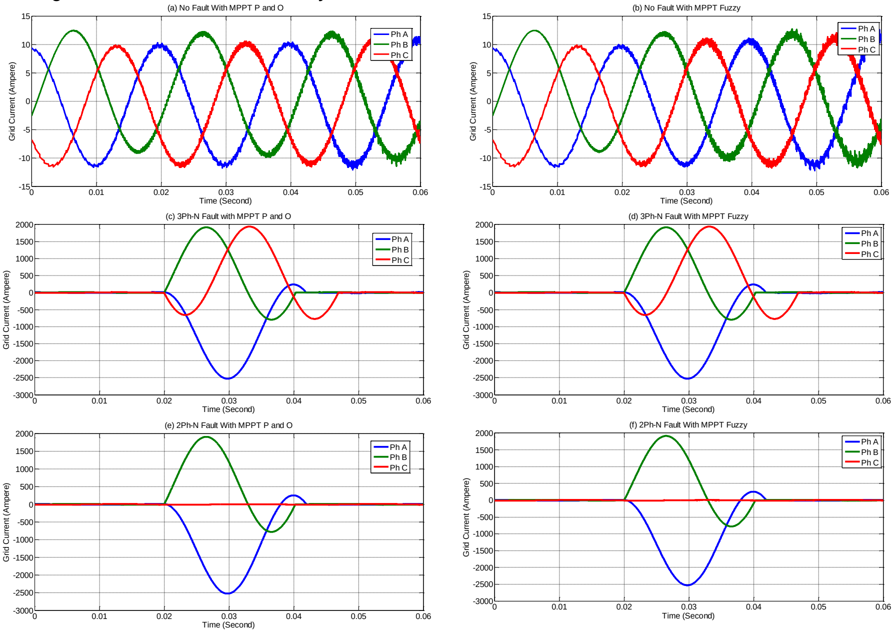
3. Results and Analysis

This research is started by determining the maximum and minimum of grid current in each phase, unbalanced current using (4), current THD on each phase (3), and average THD of three phase current grids on PCC bus using MPPT P and O/MPPT Fuzzy. By using the same procedure then obtained unbalanced voltage using (4), voltage THD on each phase using (3), and average voltage THD. Table 2 shows unbalanced current, THD grid current, and average THD of grid current of multi PV connected on a three phase low voltage grid using MPPT P and O/MPPT Fuzzy. Because, there are five short-circuit faults then there are three fault durations i.e. before, during (transient), and after fault phase with time durations are 0-0.02 sec, 0.02-0.04 sec, and 0.04-0.06 sec respectivelty. The simulation result of unbalanced current/voltage and average THD current/voltage is also presented as verification under five short circuit faults. The results analysis is conducted only on short circuit fault during transient phase.

Table 2. Unbalance Current and Average Current Harmonics Under Transient Phase

No.	Fault Types	Phase Current (V)			Unba Current (%)	THD_I (%)			Avg THD_I (%)
		A	B	C		A	B	C	
MPPT P and O Method									
1	Normal	10.61	10.74	10.69	0.562	2.65	3.22	3.40	3,090
2	3Ph-N	1331	1359	1296	2.283	4.41	2.05	2.38	2.947
3	3Ph	1331	1359	1296	2.283	4.41	2.05	2.38	2.947
4	2Ph-N	1336	1350	7.671	50.353	4.70	1.76	3.91	3.457
5	2Ph	1179	1179	10.32	49.347	3.67	3.67	3.33	3.557
6	1Ph-N	1132	9.451	9.482	195.065	4.96	3.27	4.06	4.097
MPPT Fuzzy Method									
1	Normal	10.72	10.76	10.80	0.372	3.32	3.76	4.28	3.787
2	3Ph-N	1331	1359	1296	2.283	4.41	2.05	2.38	2.947
3	3Ph	1331	1359	1296	2.283	4.41	2.05	2.38	2.947
4	2Ph-N	1336	1350	7.475	50.364	4.70	1.76	6.0	4.154
5	2Ph	1179	1179	10.09	49.361	3.69	3.66	5.10	4.150
6	1Ph-N	1332	9.203	9.319	195.886	4.97	4.88	5.28	5.044

Figure 11 shows current waveform of multi PV connected to three phase grid on a PCC bus using MPPT P and O/MPPT Fuzzy under normal condition, 3Ph-N, 2Ph-N, and 1Ph-N fault.



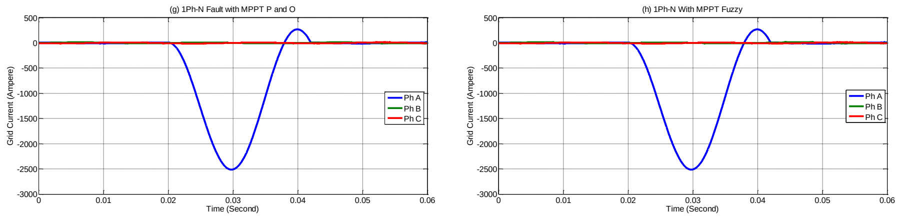


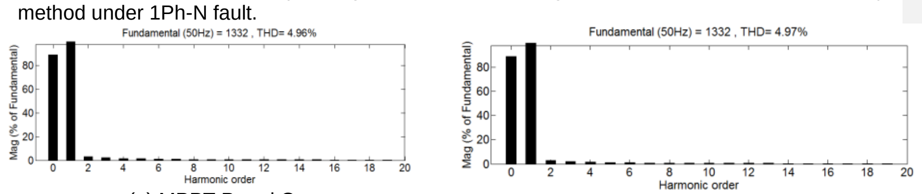
Figure 11. Current waveform of multi PV connected to a three phase grid on PCC bus

Table 3 shows unbalanced voltage, THD grid voltage, and average THD of grid voltage of multi PV connected on a three phase low voltage grid using MPPT P and O/ MPPT Fuzzy.

Table 3. Unbalance Voltage and Average Voltage Harmonics Under Transient Phase

No.	Fault Types	Phase Voltage (V)			Unba Voltage (%)	THD_V (%)			Avg THD_V (%)
		A	B	C		A	B	C	
					MPPT P and O Method				
1	Normal	308.8	308.7	307.8	0	6.74	7.06	7.14	6.980
2	3 Ph-N	1.332	1.350	1.307	1.523	6.50	179.32	189.46	125.094
3	3 Ph	1.347	1.325	1.318	1.279	275.94	336.34	341.31	317.864
4	2 Ph-N	2.242	2.268	308.4	195.677	5.36	106.86	7.83	39.017
5	2 Ph	155.0	152.7	307.8	50.025	7.96	8.09	7.72	7.924
6	1Ph-N	2.658	308.1	308.1	49.356	5.48	7.56	7.88	6.974
					MPPT Fuzzy Method				
1	Normal	307.7	307.7	307.7	0	8.23	9.74	9.79	9.254
2	3 Ph-N	1.332	1.351	1.306	1.605	5.38	172.84	181.97	120.064
3	3 Ph	1.339	1.343	1.307	1.003	223.47	283.53	294.43	267.144
4	2 Ph-N	2.242	2.269	308.4	195.676	4.90	102.82	11.16	39.627
5	2 Ph	155.0	152.7	307.8	50.025	10.12	10.28	9.98	10.127
6	1Ph-N	2.657	308.1	308.0	49.381	5.22	9.77	10.63	8,570

Figure 12 shows grid current harmonics spectra of phase A during transient phase due to the multi PV connected to three phase grid on PCC bus using MPPT P and O and MPPT Fuzzy method under 1Ph-N fault.



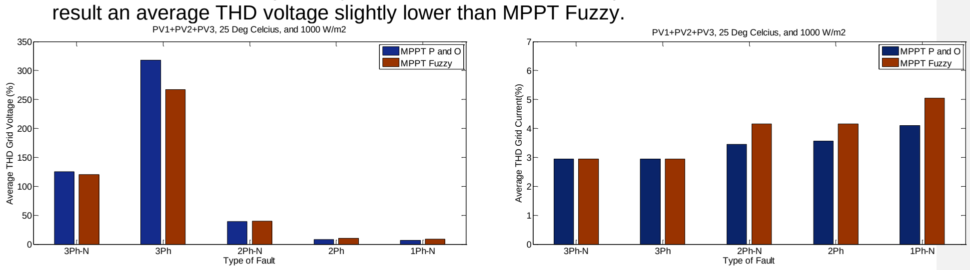
(a) MPPT P and O (b) MPPT Fuzzy

Figure 12. Current harmonics spectra of phase A under 1Ph-N fault

Table 2 presents that under normal condition, phase current of multi PV (PV1+PV2 + PV3) using MPPT P and O in transient phase are 10.61 A, 10.74 A, 10.69 A and able to result an unbalanced current of 0.562%. In short circuit faults, the highest unbalanced current of transient phase is generated by 1Ph-N fault of 195.886%. The 3Ph-N and 3Ph fault on transient phase are able equally produce an unbalanced current of 2,283%. The implementation of MPPT Fuzzy method under normal condition is able to generate an unbalanced current of 0.372%. If using MPPT Fuzzy under fault on transient phase, the highest unbalanced current is generated by 1Ph-N faults of 195.886%. At the same condition the smallest unbalanced current is equally generated by 3Ph-N and 3Ph fault of 2.282%. In non-symmetrical fault, the use of MPPT P and O is able to result an unbalanced current of transient phase slightly lower than MPPT Fuzzy. While in symmetrical faults, MPPT P and O/MPPT Fuzzy method for controlling of output power of multi PV gives same unbalanced current of transient phase of 2,283%. In normal condition, by using both MPPT P and O and MPPT Fuzzy method, the average THD current on transient phase are 3.090% and 3.787%, respectively. When using MPPT P and O, the highest average THD current is generated by 1Ph-N fault of 4,097%. In the same method, the smallest average

THD voltage is equally generated by 3Ph-N and 3Ph of 2,947%. If using Fuzzy MPPT, the highest average THD current is generated by 1Ph-N fault of 5.044%. In the same method, the smallest average THD current is equally generated by 3Ph-N and 3Ph of 2,947%. In the symmetrical faults, both MPPT P and O and MPPT Fuzzy method is able equally result an average THD current during transient phase of 2,947%. In non-symmetrical fault, MPPT P and O is able to result an average THD current slightly smaller than MPPT Fuzzy method.

Table 3 presents that under normal condition, multi PV using MPPT P and O under transient phase is able to result an unbalanced voltage of 0%. In the short circuit faults, the highest unbalanced voltage during transient phase is generated by a 2Ph-N fault of 195.677% volt. The 3Ph fault during transient phase is able to result the smallest unbalanced voltage of 1.279%. MPPT Fuzzy under normal condition is also able to result an unbalanced voltage of 0%. When using the MPPT Fuzzy under short-circuit fault during transient phase, the highest unbalanced voltage is generated by a 2Ph-N fault of 195.676% and the lowest unbalanced voltage is generated by 3Ph fault of 1.003%. In non-symmetrical faults, the implemantation of MPPT P and O and MPPT Fuzzy method to control output power of multi PV produces nominal unbalanced voltage during transient phase results a close the same value. While in symmetrical fault, MPPT P and O and MPPT Fuzzy are able to result different unbalance voltage on transient phase. During 3Ph-N fault on transient phase, MPPT P and O method is able to result an unbalanced transient phase voltage of 1.523% slightly lower than MPPT Fuzzy of 1.605%. However during 3Ph fault on transient phase, MPPT Fuzzy is able to produce an unbalanced voltage of 1.003% slightly lower than MPPT P and O of 1.279%. In normal condition, the use of both MPPT P and O and MPPT Fuzzy method are able to result THD average voltages i.e. 6.980% and 9.254%, respectively. If using MPPT P and O, the largest average THD voltage is generated by a 3Ph fault of 317.864%. By using the same method, the lowest average THD voltage is produced by 1Ph-N fault of 6.974%. If using Fuzzy MPPT, the largest average THD voltage is also generated by a 3Ph fault of 267.144%. By using the same method, the lowest average THD voltage is generated by 1Ph-N fault of 8.570%. During symmetrical fault on transient phase, MPPT Fuzzy is able to result an average THD voltage smaller than MPPT P and O. Otherwise during non-symmetrical fault on transient phase, MPPT P and O is able to result an average THD voltage slightly lower than MPPT Fuzzy.



(a) Average THD voltage (b) Average THD current

Figure 13. Performance of (a) average voltage and (b) current harmonic during transient phase

Figure 13.a shows that on symmetrical faults during transient phase (3Ph-N and 3Ph), MPPT Fuzzy is able to result an average THD voltage smaller than MPPT P and O method. Otherwise on non-symmetrical faults during transient phase (2Ph-N, 2Ph, and 1Ph-N), MPPT P and O is able to result an average THD voltage slightly smaller than MPPT Fuzzy. Figure 14.b shows that on symmetrical faults during transient phase, MPPT Fuzzy and and MPPT P and O method are able to result the same average THD current. Furthermore on non-symmetrical faults during transient phase, MPPT P and O is able to result an average THD current slightly smaller than MPPT Fuzzy. The MPPT P and O and the MPPT Fuzzy on all short circuit fault during transient phase (3Ph-N, 3Ph, 2Ph-N, 2Ph, and 1Ph-N) are able to result smaller current average THD current significantly depend on average THD voltage.

4. Conclusion

Comparative performance of multi PVs connected grid under short circuit fault during transient phase to power quality using MPPT P and O/MPPT Fuzzy has been presented. During transient phase, non-symmetrical faults (2Ph-N, 2Ph, and 1Ph-N) is able to generate unbalance current/voltage greater depend on symmetrical faults (3Ph-N and 3Ph). On symmetrical faults, MPPT Fuzzy is able to result an average THD voltage/THD current smaller than MPPT P and O. Otherwise on non-symmetrical faults, MPPT P and O is able to result an average THD voltage/THD current slightly smaller than MPPT Fuzzy. The MPPT P and O/MPPT Fuzzy method on all short circuit faults during transient phase are able to results smaller current average THD than average THD voltage significantly. Futhermore the nominal of average THD current using both methods has also met THD limit prescribed in IEEE 519.

Appendix

PV generator 1, 2, and 3: active power = 100 kW, temperature = 25^0 C, irradiance = 1000 W/m^2; Three phase grid: short circuit power = 100 MVA, voltage = 380 volt (L-L), frequency = 50 Hz; Power transformer: rated power = 100 kVA, frequency = 50 Hz, voltage 380 Volt/20 kV (L-L), two winding type; Load 1, 2, and 3: active power = 20 kW, voltage = 380 volt (L-L), frequency = 50 Hz; Low Voltage Lines 1,2, and 3: resistance R = 0,1273 Ohm/km, inductance L = 93,37 mH/km, capasitance C = 1,274 μF/km; Length of Low Voltage Lines: Line 1, Line 2, Line 3 = 1 km; DC link capasitor: capacitance= 2000 μF, frequency = 4 kHz; PWM generator for DC/AC inverter: Sampling time= 5 x 10^{-6} Second; Fuzzy inference system = mamdani method; Fuzzy model composition = max-min; Input membership function: delta voltage=gbellmf, trimf, delta power: gbellmf, trimf; Output membership function: delta duty cycle = trimf.

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Lampiran 2.17

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Transient Power Quality Performance of Multi Photovoltaics using MPPT P and O/MPPT Fuzzy

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Abstract

This paper presents comparative performance of transient power quality due to multi photovoltaic (PV) integration to grid at both fixed temperature and solar irradiation connected using Maximum Power Point Tracking Perturb and Observe (MPPT P and O)/MPPT Fuzzy. This research is performed as five transient of short-circuit faults on point common coupling (PCC) bus. An artificial intelligence with fuzzy logic controller (FLC) is used to set duty cycle with step variable to control DC/DC boost converter, generate quick convergence to determine MPPT for controlling of PV output voltage. Furthermore the result is compared with MPPT P and O. During transient phase, non-symmetrical faults are able to result an unbalance current/voltage greater than symmetrical faults. On symmetrical faults, MPPT Fuzzy is able to resultan average THD voltage/THD current smaller than MPPT P and O. Otherwise on non-symmetrical faults, MPPT P and O is able to resultan average THD voltage/THD current slightly smaller than MPPT Fuzzy. Both of MPPT P and O and MPPT Fuzzy on all short circuit faults during transient phase are able to result significantly smaller current average THD current than average THD voltage and limits of THD prescribed in IEEE 519. This research is simulated using Matlab/Simulink environment.

Keywords*: MPPT Fuzzy, MPPT P and O, Multi Photovoltaics, Power Quality, Short Circuit, Transient*

1. Introduction

The PV beside being able to generate power, it also results harmonics due to inverter as a medium to convert DC into AC voltage andis capable to decrease power quality. The short circuit fault can cause rise of current and voltage drop in certain phases depend on fault types, so it is able to generate unbalance voltage and current on low voltage distribution network (grid). The research on power quality of PV connected grid to power system using LCL filter has been done KonKengWenget. al. A number of power quality problems i.e. over voltage, less voltage, power fluctuations, inrush currents, low power factor, and current harmonics or THD will appear on microgrid power system. This research is conducted only on constant solar irradiance and temperature condition (1000 W/m^2 and 25^0 C) as environmental input parameters for PV systems [1]. The study on effect of solar radiation on grid connected to PV generator to power quality has been investigated by Minas Patsalides, et.al. It considers two different scenarios of average and low radiation [2]. Investigation of grid connected a single phase PV inverter using a current proportional resonant, proportional resonant integral, and genetic algorithm using an active filter to reduce current harmonics of inverter output has been studied by Renuet. al. The laxity of research is only done on a single phase PV and certain irradiance and temperature [3]. The dynamic analysis of power quality due to high penetration effect of distribution network connected to PV under variable irradiance has been studied by MassoudFarhoodnea, et. al. The result showed that high level penetration of grid connected PV will cause a number of power quality problems. However, the research was only analyzed on voltage harmonics and did not consider the ambient temperature condition [4]. Power quality characteristics in a number of three phase PV inverters at top roof PV has been performed by K.P. Kontogianis, et. al [5]. A comparative study of MPPT between FLC and conventional PI controller has been presented for interfacing PV array with utility grid through a three-phase line-commutated inverter by Omid ZhoulaiBakhoda, et.al. FLC was dominating PI in many important aspects like i.e., provided active power for grid, output current shape of inverter, grid current and current THD [6]. A grid interfaced solar PV (SPV) power generating system in a 3P4W system has been

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proposed by Arun Kumar Verma, et.al. This system was used for compensation of neutral current, harmonic currents, reactive power and to provide load balancing [7]. However, both of power quality analysis in both papers was only performed by using single PV. Power quality due to integration of multi units of PV generator connected to three phase grid under variable solar irradiation level has been implemented by Amirullah, et.al. At level of solar irradiation was fixed, the greater number of PV connected to three-phase grid, then average THD of grid voltage/current also increased. At level of solar irradiation increased, average THD of grid voltage/current also increased. The PV in this research was still using MPPT with P and O algorithm and not using intelligent control [8].

Adaptive Neuro-fuzzy Inference System (ANFIS)-based improvement of MPPT P and O for PV under different shading conditions has been investigated by Khaled Bataineh, et.al. The simulation show proposed algorithm efficiently reach MPP under uniform irradiation, sudden changes of irradiation, and partial shading [9]. The method for balancing line current and voltage, due to the presence of distributed generations (DGs) i.e. a number of single phase PV generation units in homes has been presented by Amirullah, et.al. This research shows that the combination of Battery Energy Storage (BES) and three single phase bi-directional inverter able to reduce unbalanced line current/voltage. Otherwise, the combination of both circuit able to inreases current/voltage harmonics [10]. Power quality enhancement on low voltage of three phase grid caused by different level of PV integration using MPPT Fuzzy under variabel solar irradiance level on constant temperature and load has been investigated by Amirullah, et.al. It was able to enhance profile of grid voltage and current THD due to different level of integration of PV to three phase grid corresponding with IEEE Standard 519. MPPT Fuzzy was also able to improve input power factor better than MPPT P and O [11]. RachidBelaidi, et.al has proposed a combined system of 3P4W shunt active filter and PV with MPPT P and O, to solve power quality such as harmonic currents, poor power factor, and unbalanced load [12]. Salah EddineMankour, et al has investigated on modeling of a PV stand alone power system using two widely-adopted MPPT algorithms, P & O and incremental conductance [13]. BambangPurwahyudi, et. al has researched design of electrical characteristics of solar PV cell model by using self constructing neural network (SCNN) [14]. Julián A.C.C., et. al has used a mathematical model implemented in Matlab/Simulink to evaluate the performance of building integrated photovoltaic systems (BIPVS) [15]. Ahmad Saudi Samosir, et. al has investigated on modeling and simulation of MPPT used in solar power systems with fuzzy logic [16]. But the researchs on enhancement of power quality and MPPT characteristics for PV were only analyzed in normal condition.

This paper presents comparative performance of power quality due to the multi PV integration at both fixed temperature and solar irradiation levels connected to 380 V and 50 Hz distribution network using MPPT P and O/MPPT Fuzzy controller. The research is performed during transient disturbances of short-circuit fault on PCC bus based on five of short circuit faults. An artificial intelligence method with FLC is used to set duty cycle (D) with step variable to control DC/DC boost converter, generate quick convergence calculation to determine MPPT value for controlling of PV generator output voltage. Futhermore the result is compared with MPPT P and O method. The parameters are voltage/current unbalanced, voltage/current THD on each phase, and voltage/current average THD on PCC bus of three phase grid.

This paper is organized as follow. Section 2 presents proposed method i.e. proposed model of single PV using MPPT Fuzzy, model multi PV connected three phase grid under short circuit fault, simulation parameters, equivalent circuit, mathematical, and characteristic curve of PV model, MPPT P and O method, MPPT Fuzzy method, voltage and current harmonics, voltage and current unbalance. Section 3 describes comparative performance of multi PV connected grid under short circuit fault during transient phase to current/voltage unbalance and current/voltage THD of three phase grid using MPPT P and O/MPPT Fuzzy method. In this section, example cases studied are presented and the results are verified with those of Matlab/Simulink. Finally, the paper in concluded in Section 4.

2. Research Method

2.1. Proposed Model

Figure 1 shows model of a single PV system connected to a three phase grid. The DC/DC converter circuit consists of a boost converter circuit that serves to raise the DC output voltage from the PV. The DC output voltage of the boost converter circuit is then changed by a three phase DC/AC inverter into an AC voltage to three phase grid. The single PV model is then used as a reference to construct multiple PV models connected to grid through a three phase phase distribution transformer showed in Figure 2. This research uses three model group of PVs with an active power of 100 kW each. Besides connected three phase grid, multi PVs are also connected to three group of three phase loads with 20 kW of active power each. The aim of research is to compare performance of power quality due to the multi PV integration at both fixed temperature and solar irradiation levels connected to distribution network using MPPT P and O/MPPT Fuzzy. The research analysis includes transient disturbances of short-circuit fault on PCC bus based on a number of short circuit faults. An artificial intelligence with FLC is used to set duty cycle (D) with step variable to control DC/DC boost converter, generate quick convergence calculation to determine MPPT value for controlling of PV output voltage, and then its result is compared with MPPT P and O method. The DC/DC converter produces a constant DC voltage as an input for DC/AC inverter using pulse with modulation (PWM).

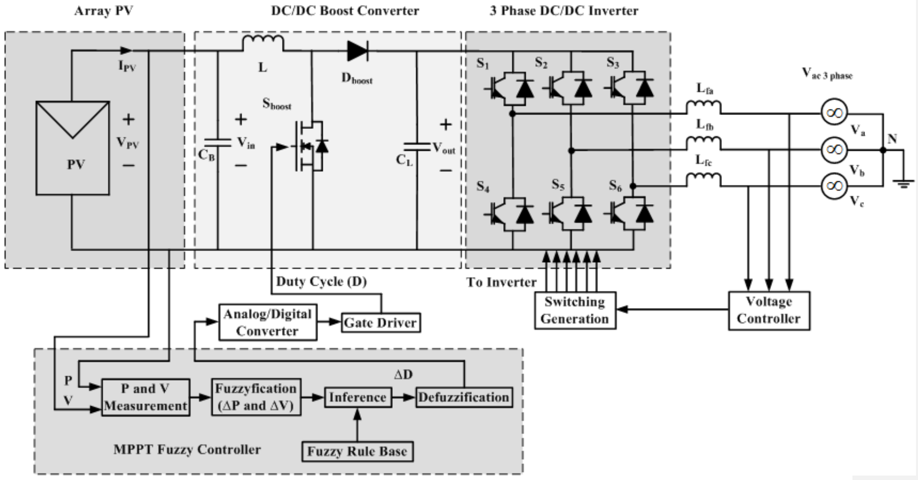

Figure 1. Proposed model of single PV using MPPT Fuzzy

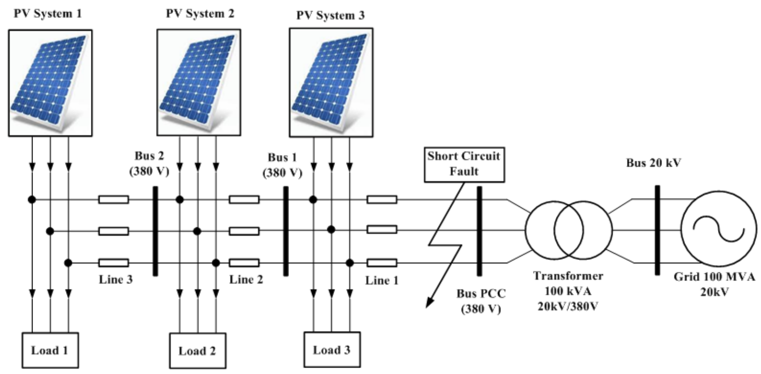

Figure 2. Proposed model of multi PV connected three phase grid under short circuit fault

There are two scenarios of multi PV connected three phase grids under fixed temperature and solar irradiation of 25^0 C and 1000 W/m^2, i.e. using MPPT P and O and MPPT Fuzzy methods respectively. The transient state in each of MPPT controllers are indicated by five short-circuit faults, resulting in a total of ten fault scenarios i.e. three phases to ground (3Ph-N), three phases (3Ph), two phases to ground (2Ph-N), two phases (2 Ph), and single phase to ground (1Ph-N). The 3ph-N and 3ph are classified as symmetrical faults. Futhermore 2ph-N, 2Ph, and 1Ph-N are classified as non-symmetrical faults. The next process is to determine voltage/current unbalanced, voltage/current harmonics (THD) on each phase, and voltage/current average harmonics on PCC bus of three-phase low voltage grid. The final step is to validate the results referring to the ANSI/IEEE 241-1990 standard about unbalanced voltage and current and IEEE Standard 519-1992 about average grid voltage and current harmonics. Simulation and analysis of this research use Matlab/Simulink. The simulation parameter values of proposed model are shown in Appendix Section.

2.2. Modelling of PV Array

Figure 3 shows the equivalent circuit of a solar panel. A solar panel is composed of several PV cells that have series, parallel, or series-parallel external connections [17].

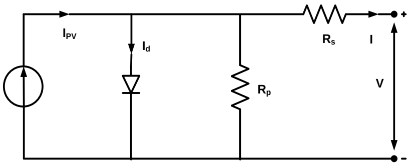

Figure 3. Equivalent circuit of solar panel

The V-I characteristic of a solar panel is showed in (1):

$$I = I_{PV} - I_o\left[\exp\left(\frac{V + R_S I}{aV_t}\right) - 1\right] - \frac{V + R_S I}{R_P} \quad (1)$$

where I_{PV} is the photovoltaic current, I_o is saturated reverse current, 'a' is the ideal diode constant, $V_t = N_S KTq^{-1}$ is the thermal voltage, N_S is the number of series cells, q is the electron charge, K is the Boltzmann constant, T is the temperature of p–n junction, R_S and R_P are series and parallel equivalent resistance of the solar panels. I_{PV} has a linear relation with light intensity and also varies with temperature variations. I_o is dependent on temperature variations.

2.3. MPPT P and O and MPPT Fuzzy

The initial research is to determine value of duty cycle (D) with a variable step to control DC/DC boost converter circuit with MPPT P and O. For PV converter, maximum power available is determined by PV cell characteristics, but this value often mismatches with the maximum power point (MPP) of the load. By implementing MPPT in PV systems, MPP can be maintained so that the number and size of PV panels can be reduced or energy yield can be optimized [18]. Because of moving of sun, PV panels angle, and variation of irradiance reaching the panels, energy generated from PV panels are absorbed does not constant over time. When this condition occurs, VI characteristics changes and MPP will move. To overcome these problems, MPPT has been developed. The system includes no moving parts. MPPT search for the maximum power independent based on environmental conditions (following changes in solar radiation and temperature) and maintain the PV terminal voltage remains constant at maximum value. The most used method of MPPT is P and O that algorithm is shown in Figure 4 [13] and its Matlab/Simulink model is presented in Figure 5.

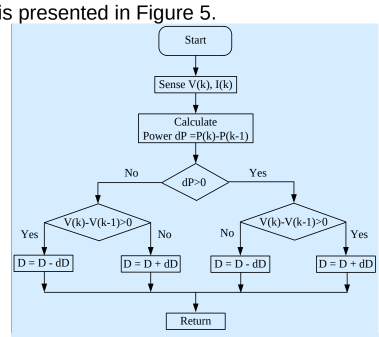

Figure 4. MPPT using P and O algorithm

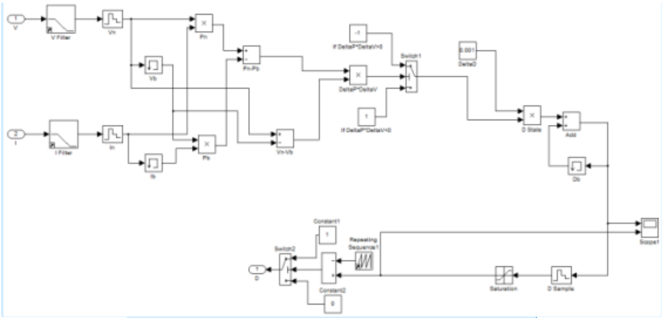

Figure 5. Matlab/Simulink for MPPT P and O

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The same procedure for determining MPPT is using FLC. Fuzzy set theory is a new method of controlling the MPPT in obtaining the peak power point. The MPPT is implemented to obtain MPP operation voltage point faster with less overshoot and also it can minimize voltage fluctuation after MPP has been recognized. It also is capable to enhance power quality problem unbalance current/voltage and current/voltage harmonics. Typical fuzzy based MPPT controller reffered to MPPT Fuzzy includes three basic components i.e. fuzzification, inference engine, and defuzzification block as shown in Figure 6 and its Matlab/Simulink presented in Figure 7.

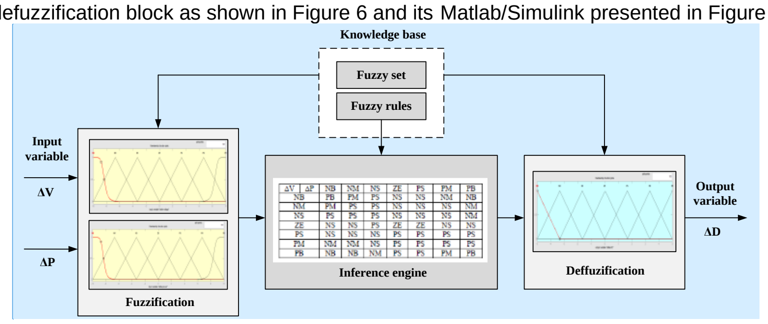

Figure 6. Structure of FLC

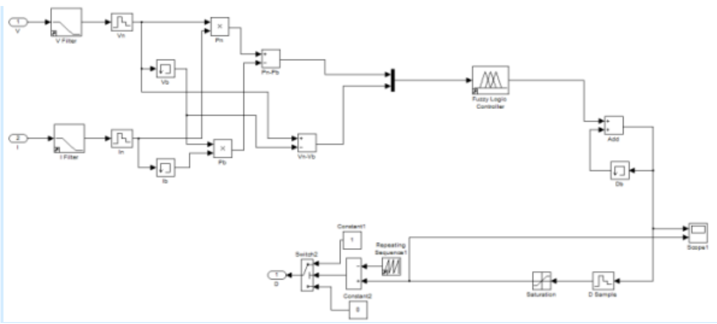

Figure 7. Matlab/Simulink for MPPT Fuzzy

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Fuzzy MPPT method is done by determining input variables, namely fuzzy control output power (ΔP) and output voltage (ΔV) PV generator, seven linguistic variables fuzzy sets, fuzzy operating system block (fuzzification, fuzzy rules, and defuzzification), Function ΔP and Δ V during fuzzification, a table fuzzy rule base, crisp values to determine duty cycle (D) in defuzzification phase with variable step to control DC/DC boost converter. Figure 8 shows Matlab/Simulink model for MPPT Fuzzy.During fuzzification phase shown in Figure 7, a number of input variables is calculated and converted into a linguistic variable based on the subset called membership function (MF). To translate value of voltage change and power change in, input fuzzy "change of voltage" and "change of power" is designed to use seven fuzzy variable called PB (Positive Big), PM (Positive Medium), NS (Negative Small), PS (Positive Small) ZE (Zero), NM (Negative Medium), and Negative Big (NB). voltage change (ΔV) and power changes (ΔP) is a proposed system input variables and output variable FLC is duty cycle change (ΔD). The membership functions i.e. voltage changes, power changes, and duty cycle change, each are shown in Figure 8 into Figure 10.

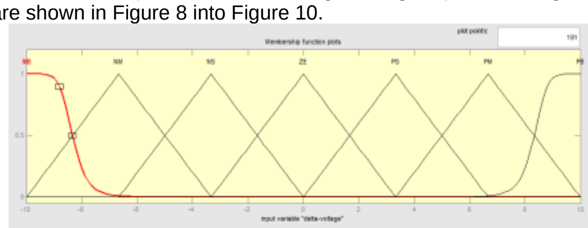

Figure 8. Input voltage change (delta voltage)

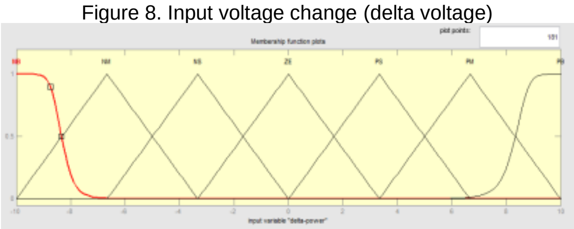

Figure 9. Input power change (delta power)

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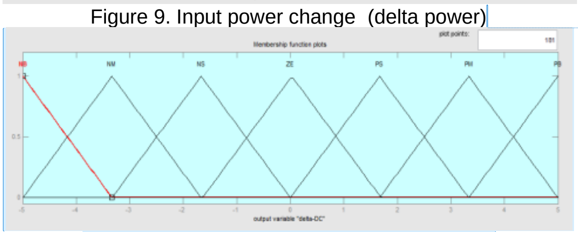

Figure 10. Output duty cycle change (delta D)

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The fuzzy inference using a method that relates to a composition Mamdani Max-Min. Fuzzy inference system consists of three parts, namely rule base, database, and reasoning mechanism. After determining ΔV and ΔP, these value are then converted into linguistic variables and use them as input functions for FLC. The output value is ΔD is generated using block inference and fuzzy rules as shown in Table 1. Finally defuzzification block operates to change value of ΔD is raised from linguistic variables into numeric variables back. Numeric variables that become inputs signal for the IGBT switch of DC/DC boost converter to be able to determine MPPT for each generation PV accurately at the same time also improve power quality as a result of integration of multi PV to low voltage three phase grid under short circuit.

Table 1. Fuzzy Rules

ΔV ΔP	NB	NM	NS	ZE	PS	PM	PB
NB	PB	PM	PS	NS	NS	NM	NB
NM	PM	PS	PS	NS	NS	NS	NM
NS	PS	PS	PS	NS	NS	NS	NM
ZE	NS	NS	PS	ZE	ZE	NS	NS
PS	NS	NS	NS	PS	PS	PS	PS
PM	NM	NM	NS	PS	PS	PS	PS
PB	NB	NB	NM	PS	PS	PM	PB

2.4 Voltage and Current Harmonics/Unbalance

Generally, current and voltage waveforms are pure sinusoidal. One problem that occurs is non sinusoida or distorted current and voltage waves generated by harmonics in power system [11]. Harmonic is distorted periodic steady state wave caused by the interaction between the shape of a sine wave at the fundamental frequency system with another wave component which is an integer multiples frequency of fundamental frequency. The most common harmonic index, which relates to voltage waveform is THD (2), which is defined as the root mean square (rms) of harmonics expressed as a percentage of fundamental component as showed in [19]. Second harmonic index is current THD means the ratio of rms harmonic current value to rms fundamental current which expressed in (3) [11].

$$THD_V = \frac{\sqrt{\sum_{n=2}^{N} V_n^2}}{V_1} \times 100\,\% \quad (2) \qquad THD_I = \frac{\sqrt{\sum_{n=2}^{N} I_n^2}}{I_1} \times 100\,\% \quad (3) \qquad V(\%) = \frac{\left|V_{a\,var\,age} - V_{a,b,c\,\min\,or\,\max}\right|}{V_{a\,var\,age}} \times 100\,\% \quad (4)$$

Where $V_n$and I_n (the rms voltage and current at harmonic n), V_1 and I_1 (the fundamental rms voltageand current), N (the maximum harmonic order to be considered). The allowable maximum THD value for each country is different depending on the standard used. THD standards most often used in electric power system is IEEE 519-1992. There are two criteria used in analysis of harmonics distortion i.e. voltage distortion and current distortion limit [20]. The value of unbalance voltage use (8) is based ANSI/IEEE 241-1990 is showed in (4) [21].By using (4), value of unbalance voltage expressed in percent (%) and is defined as follows; $V_{avarage}$ is the average value of maximum voltage on phase a, b, c, in volt. $V_{a,b,c\ min}$ is minimum voltage on phase a, b, c in volt, $V_{a,b,c\ max}$ is maximum voltage on phase a, b, c in volt . By the same way, then unbalance current in % can be calculated by replacing voltage into current magnitude.

3. Results and Analysis

This research is started by determining the maximum and minimum of grid current in each phase, unbalanced current using (4), current THD on each phase (3), and average THD of three phase current grids on PCC bus using MPPT P and O/MPPT Fuzzy. By using the same procedure then obtained unbalanced voltage using (4), voltage THD on each phase using (3), and average voltage THD. Table 2 shows unbalanced current, THD grid current, and average THD of grid current of multi PV connected on a three phase low voltage grid using MPPT P and O/MPPT Fuzzy. Because, there are five short-circuit faults then there are three fault durations i.e. before, during (transient), and after fault phase with time durations are 0-0.02 sec, 0.02-0.04 sec, and 0.04-0.06 sec respectivelty. The simulation result of unbalanced current/voltage and average THD current/voltage is also presented as verification under five short circuit faults. The results analysis is conducted only on short circuit fault during transient phase.

Table 2. Unbalance Current and Average Current Harmonics Under Transient Phase

No.	Fault Types	Phase Current (V)			Unba Current (%)	THD_I (%)			Avg THD_I (%)
		A	B	C		A	B	C	
					MPPT P and O Method				
1	Normal	10.61	10.74	10.69	0.562	2.65	3.22	3.40	3,090
2	3Ph-N	1331	1359	1296	2.283	4.41	2.05	2.38	2.947
3	3Ph	1331	1359	1296	2.283	4.41	2.05	2.38	2.947
4	2Ph-N	1336	1350	7.671	50.353	4.70	1.76	3.91	3.457
5	2Ph	1179	1179	10.32	49.347	3.67	3.67	3.33	3.557
6	1Ph-N	1132	9.451	9.482	195.065	4.96	3.27	4.06	4.097
					MPPT Fuzzy Method				
1	Normal	10.72	10.76	10.80	0.372	3.32	3.76	4.28	3.787
2	3Ph-N	1331	1359	1296	2.283	4.41	2.05	2.38	2.947
3	3Ph	1331	1359	1296	2.283	4.41	2.05	2.38	2.947
4	2Ph-N	1336	1350	7.475	50.364	4.70	1.76	6.0	4.154
5	2Ph	1179	1179	10.09	49.361	3.69	3.66	5.10	4.150
6	1Ph-N	1332	9.203	9.319	195.886	4.97	4.88	5.28	5.044

Figure 11 shows current waveform of multi PV connected to three phase grid on a PCC bus using MPPT P and O/MPPT Fuzzy under normal condition, 3Ph-N, 2Ph-N, and 1Ph-N fault.

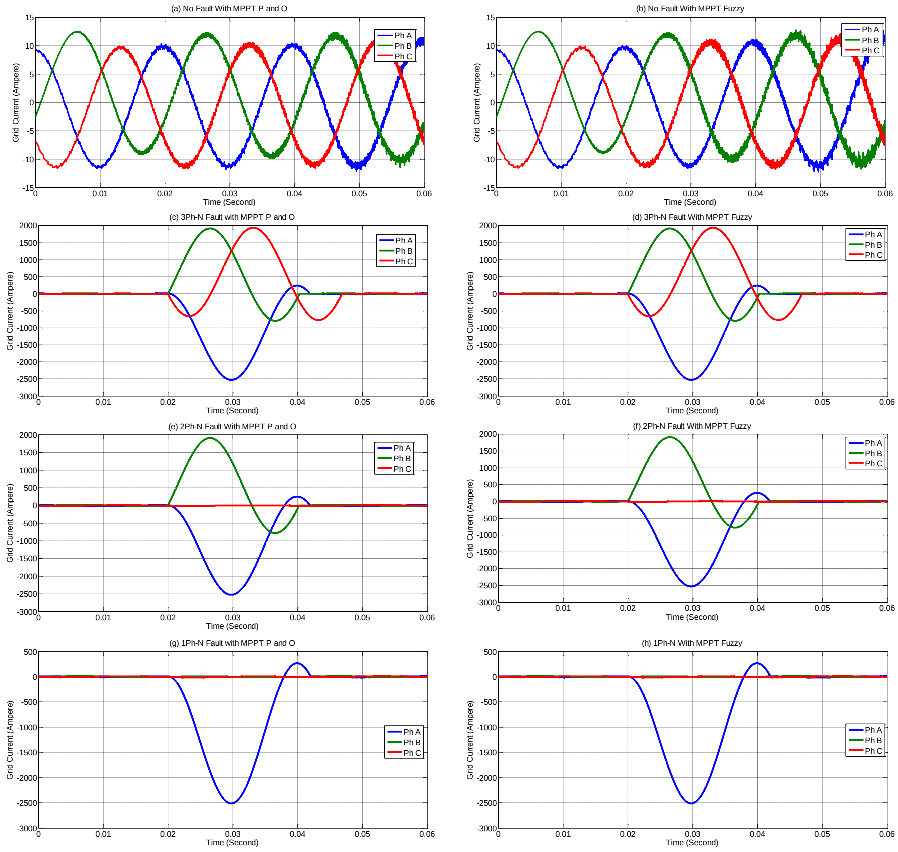


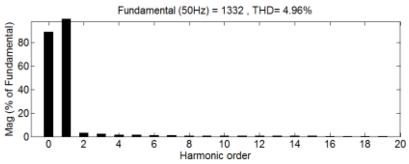
Figure 11. Current waveform of multi PV connected to a three phase grid on PCC bus

Table 3 shows unbalanced voltage, THD grid voltage, and average THD of grid voltage of multi PV connected on a three phase low voltage grid using MPPT P and O/ MPPT Fuzzy.

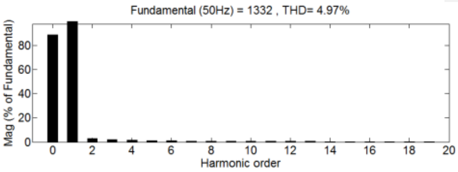
Table 3. Unbalance Voltage and Average Voltage Harmonics Under Transient Phase

No.	Fault Types	Phase Voltage (V)			Unba Voltage (%)	THD_V (%)			Avg THD_V (%)
		A	B	C		A	B	C	
					MPPT P and O Method				
1	Normal	308.8	308.7	307.8	0	6.74	7.06	7.14	6.980
2	3 Ph-N	1.332	1.350	1.307	1.523	6.50	179.32	189.46	125.094
3	3 Ph	1.347	1.325	1.318	1.279	275.94	336.34	341.31	317.864
4	2 Ph-N	2.242	2.268	308.4	195.677	5.36	106.86	7.83	39.017
5	2 Ph	155.0	152.7	307.8	50.025	7.96	8.09	7.72	7.924
6	1Ph-N	2.658	308.1	308.1	49.356	5.48	7.56	7.88	6.974
					MPPT Fuzzy Method				
1	Normal	307.7	307.7	307.7	0	8.23	9.74	9.79	9.254
2	3 Ph-N	1.332	1.351	1.306	1.605	5.38	172.84	181.97	120.064
3	3 Ph	1.339	1.343	1.307	1.003	223.47	283.53	294.43	267.144
4	2 Ph-N	2.242	2.269	308.4	195.676	4.90	102.82	11.16	39.627
5	2 Ph	155.0	152.7	307.8	50.025	10.12	10.28	9.98	10.127
6	1Ph-N	2.657	308.1	308.0	49.381	5.22	9.77	10.63	8,570

Figure 12 shows grid current harmonics spectra of phase A during transient phase due to the multi PV connected to three phase grid on PCC bus using MPPT P and O and MPPT Fuzzy method under 1Ph-N fault.



(a) MPPT P and O

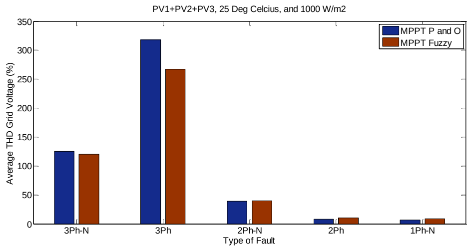


(b) MPPT Fuzzy

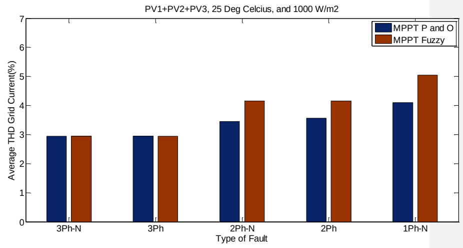
Figure 12. Current harmonics spectra of phase A under 1Ph-N fault

Table 2 presents that under normal condition, phase current of multi PV (PV1+PV2 + PV3) using MPPT P and O in transient phase are 10.61 A, 10.74 A, 10.69 A and able to result an unbalanced current of 0.562%. In short circuit faults, the highest unbalanced current of transient phase is generated by 1Ph-N fault of 195.886%. The 3Ph-N and 3Ph fault on transient phase are able equally produce an unbalanced current of 2,283%. The implementation of MPPT Fuzzy method under normal condition is able to generate an unbalanced current of 0.372%. If using MPPT Fuzzy under fault on transient phase, the highest unbalanced current is generated by 1Ph-N faults of 195.886%. At the same condition the smallest unbalanced current is equally generated by 3Ph-N and 3Ph fault of 2.282%. In non-symmetrical fault, the use of MPPT P and O is able to result an unbalanced current of transient phase slightly lower than MPPT Fuzzy. While in symmetrical faults, MPPT P and O/MPPT Fuzzy method for controlling of output power of multi PV gives same unbalanced current of transient phase of 2,283%.In normal condition, by using both MPPT P and O and MPPT Fuzzy method, the average THD current on transient phase are 3.090% and 3.787%, respectively. When using MPPT P and O, the highest average THD current is generated by 1Ph-N fault of 4,097%. In the same method, the smallest average THD voltage is equally generated by 3Ph-N and 3Ph of 2,947%. If using Fuzzy MPPT, the highest average THD current is generated by 1Ph-N fault of 5.044%. In the same method, the smallest average THD current is equally generated by 3Ph-N and 3Ph of 2,947%. In the symmetrical faults, both MPPT P and O and MPPT Fuzzy method is able equally resultan average THD current during transient phase of 2,947%. In non-symmetrical fault, MPPT P and O is able to result an average THD current slightly smaller than MPPT Fuzzy method.

Table 3 presents that under normal condition, multi PV using MPPT P and O under transient phase is able to result an unbalanced voltage of 0%. In the short circuit faults, the highest unbalanced voltage during transient phase is generated by a 2Ph-N fault of 195.677% volt. The 3Ph fault during transient phase is able to result the smallest unbalanced voltage of 1.279%. MPPT Fuzzy under normal condition is also able to result an unbalanced voltage of 0%. When using the MPPT Fuzzy under short-circuit fault during transient phase, the highest unbalanced voltage is generated by a 2Ph-N fault of 195.676% and the lowest unbalanced voltage is generated by 3Ph fault of 1.003%. In non-symmetrical faults, the implemantation of MPPT P and O and MPPT Fuzzy method to control output power of multi PV produces nominal unbalanced voltage during transient phase results a close the same value. While in symmetrical fault, MPPT P and O and MPPT Fuzzy are able to result different unbalance voltage on transient phase. During 3Ph-N fault on transient phase, MPPT P and O method is able to result an unbalanced transient phase voltage of 1.523% slightly lower than MPPT Fuzzy of 1.605%. However during 3Ph fault on transient phase, MPPT Fuzzy is able to produce an unbalanced voltage of 1.003% slightly lower than MPPT P and O of 1.279%.In normal condition,the use of both MPPT P and O and MPPT Fuzzy method are able to result THD average voltages i.e. 6.980% and 9.254%, respectively. If using MPPT P and O, the largest average THD voltage is generated by a 3Ph fault of 317.864%. By using the same method, the lowest average THD voltage is produced by 1Ph-N fault of 6.974%. If using Fuzzy MPPT, the largest average THD voltage is also generated by a 3Ph fault of 267.144%. By using the same method, the lowest average THD voltage is generated by 1Ph-N fault of 8.570%. During symmetrical fault on transient phase, MPPT Fuzzyis able to result an average THD voltage smaller than MPPT P and O. Otherwise during non-symmetrical fault on transient phase, MPPT P and O is able to result an average THD voltage slightly lower than MPPT Fuzzy.



(a) Average THD voltage



(b) Average THD current

Figure 13. Performance of (a) average voltage and (b) current harmonic during transient phase

Figure 13.a shows that on symmetrical faults during transient phase (3Ph-N and 3Ph), MPPT Fuzzyis able to resultan average THD voltage smaller than MPPT P and O method. Otherwise on non-symmetrical faults during transient phase (2Ph-N, 2Ph, and 1Ph-N), MPPT P and Ois able to result an average THD voltage slightly smaller than MPPT Fuzzy. Figure 14.b shows that on symmetrical faults during transient phase, MPPT Fuzzy and and MPPT P and O method are able to resultthe same average THD current. Furthermore on non-symmetrical faults during transient phase, MPPT P and O is able to resultan average THD current slightly smaller than MPPT Fuzzy. The MPPT P and O and the MPPT Fuzzy on all short circuit fault during transient phase (3Ph-N, 3Ph, 2Ph-N, 2Ph, and 1Ph-N) are able to result smaller current average THD current significantly depend on average THD voltage.

4. Conclusion

Comparative performance of multi PVs connected grid under short circuit fault during transient phase to power quality using MPPT P and O/MPPT Fuzzy has been presented. During transient phase, non-symmetrical faults (2Ph-N, 2Ph, and 1Ph-N) is able to generate unbalance current/voltage greater depend on symmetrical faults (3Ph-N and 3Ph). On symmetrical faults, MPPT Fuzzy is able to resultan average THD voltage/THD current smaller than MPPT P and O. Otherwise on non-symmetrical faults, MPPT P and O is able to result an average THD voltage/THD current slightly smaller than MPPT Fuzzy.The MPPT P and O/MPPT Fuzzy method on all short circuit faults during transient phase are able to results smaller current average THD than average THD voltage significantly. Futhermore the nominal of average THD current using both methods has also met THD limit prescribed in IEEE 519.

Appendix

PV generator 1, 2, and 3: active power = 100 kW, temperature = 25^0 C, irradiance = 1000 W/m^2; Three phase grid: short circuit power = 100 MVA, voltage = 380 volt (L-L), frequency = 50 Hz; Power transformer: rated power = 100 kVA, frequency = 50 Hz, voltage 380 Volt/20 kV (L-L), two winding type; Load 1, 2, and 3: active power = 20 kW, voltage = 380 volt (L-L), frequency = 50 Hz; Low Voltage Lines 1,2, and 3: resistance R = 0,1273 Ohm/km, inductance L = 93,37 mH/km, capasitance C = 1,274 μF/km; Length of Low Voltage Lines: Line 1, Line 2, Line 3 = 1 km; DC link capasitor: capacitance= 2000 μF, frequency = 4 kHz; PWM generator for DC/AC inverter: Sampling time= 5 x 10^{-6} Second; Fuzzy inference system = mamdani method; Fuzzy model composition = max-min; Input membership function: delta voltage=gbellmf, trimf, delta power: gbellmf, trimf; Output membership function: delta duty cycle = trimf.

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Transient Power Quality Performance of Multi Photovoltaics using MPPT P and O/MPPT Fuzzy

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Abstract

This paper presents comparative performance of transient power quality due to multi photovoltaic (PV) integration to grid at both fixed temperature and solar irradiation connected using Maximum Power Point Tracking Perturb and Observe (MPPT P and O)/MPPT Fuzzy. This research is performed as five transient of short-circuit faults on point common coupling (PCC) bus. An artificial intelligence with fuzzy logic controller (FLC) is used to set duty cycle with step variable to control DC/DC boost converter, generate quick convergence to determine MPPT for controlling of PV output voltage. Furthermore the result is compared with MPPT P and O. During transient phase, non-symmetrical faults are able to result an unbalance current/voltage greater than symmetrical faults. On symmetrical faults, MPPT Fuzzy is able to resultan average THD voltage/THD current smaller than MPPT P and O. Otherwise on non-symmetrical faults, MPPT P and O is able to resultan average THD voltage/THD current slightly smaller than MPPT Fuzzy. Both of MPPT P and O and MPPT Fuzzy on all short circuit faults during transient phase are able to result significantly smaller current average THD current than average THD voltage and limits of THD prescribed in IEEE 519. This research is simulated using Matlab/Simulink environment.

Keywords: *MPPT fuzzy, MPPT P and O, multi photovoltaics, power quality, short circuit, transient*

1. Introduction

The PV beside being able to generate power, it also results harmonics due to inverter as a medium to convert DC into AC voltage andis capable to decrease power quality. The short circuit fault can cause rise of current and voltage drop in certain phases depend on fault types, so it is able to generate unbalance voltage and current on low voltage distribution network (grid). The research on power quality of PV connected grid to power system using LCL filter has been done KonKengWenget. al. A number of power quality problems i.e. over voltage, less voltage, power fluctuations, inrush currents, low power factor, and current harmonics or THD will appear on microgrid power system. This research is conducted only on constant solar irradiance and temperature condition (1000 W/m^2 and 25^{0}C) as environmental input parameters for PV systems [1]. The study on effect of solar radiation on grid connected to PV generator to power quality has been investigated by Minas Patsalides, et.al. It considers two different scenarios of average and low radiation [2]. Investigation of grid connected a single phase PV inverter using a current proportional resonant, proportional resonant integral, and genetic algorithm using an active filter to reduce current harmonics of inverter output has been studied by Renuet. al. The laxity of research is only done on a single phase PV and certain irradiance and temperature [3]. The dynamic analysis of power quality due to high penetration effect of distribution network connected to PV under variable irradiance has been studied by MassoudFarhoodnea, et. al. The result showed that high level penetration of grid connected PV will cause a number of power quality problems. However, the research was only analyzed on voltage harmonics and did not consider the ambient temperature condition [4]. Power quality characteristics in a number of three phase PV inverters at top roof PV has been performed by K.P. Kontogianis, et. al [5]. A comparative study of MPPT between FLC and conventional PI controller has been presented for interfacing PV array with utility grid through a three-phase line-commutated

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inverter by Omid Zhoulai Bakhoda, et.al. FLC was dominating PI in many important aspects like i.e., provided active power for grid, output current shape of inverter, grid current and current THD [6]. A grid interfaced solar PV (SPV) power generating system in a 3P4W system has been proposed by Arun Kumar Verma, et.al. This system was used for compensation of neutral current, harmonic currents, reactive power and to provide load balancing [7]. However, both of power quality analysis in both papers was only performed by using single PV. Power quality due to integration of multi units of PV generator connected to three phase grid under variable solar irradiation level has been implemented by Amirullah, et.al. At level of solar irradiation was fixed, the greater number of PV connected to three-phase grid, then average THD of grid voltage/current also increased. At level of solar irradiation increased, average THD of grid voltage/current also increased. The PV in this research was still using MPPT with P and O algorithm and not using intelligent control [8].

Adaptive Neuro-fuzzy Inference System (ANFIS)-based improvement of MPPT P and O for PV under different shading conditions has been investigated by Khaled Bataineh, et.al. The simulation show proposed algorithm efficiently reach MPP under uniform irradiation, sudden changes of irradiation, and partial shading [9]. The method for balancing line current and voltage, due to the presence of distributed generations (DGs) i.e. a number of single phase PV generation units in homes has been presented by Amirullah, et.al. This research shows that the combination of Battery Energy Storage (BES) and three single phase bi-directional inverter able to reduce unbalanced line current/voltage. Otherwise, the combination of both circuit able to inreases current/voltage harmonics [10]. Power quality enhancement on low voltage of three phase grid caused by different level of PV integration using MPPT Fuzzy under variabel solar irradiance level on constant temperature and load has been investigated by Amirullah, et.al. It was able to enhance profile of grid voltage and current THD due to different level of integration of PV to three phase grid corresponding with IEEE Standard 519. MPPT Fuzzy was also able to improve input power factor better than MPPT P and O [11]. RachidBelaidi, et.al has proposed a combined system of 3P4W shunt active filter and PV with MPPT P and O, to solve power quality such as harmonic currents, poor power factor, and unbalanced load [12]. Salah Eddine Mankour, et al has investigated on modeling of a PV stand alone power system using two widely-adopted MPPT algorithms, P & O and incremental conductance [13]. Bambang Purwahyudi, et. al has researched design of electrical characteristics of solar PV cell model by using self constructing neural network (SCNN) [14]. Julián A.C.C., et. al has used a mathematical model implemented in Matlab/Simulink to evaluate the performance of building integrated photovoltaic systems (BIPVS) [15]. Ahmad Saudi Samosir, et. al has investigated on modeling and simulation of MPPT used in solar power systems with fuzzy logic [16]. But the researchs on enhancement of power quality and MPPT characteristics for PV were only analyzed in normal condition.

This paper presents comparative performance of power quality due to the multi PV integration at both fixed temperature and solar irradiation levels connected to 380 V and 50 Hz distribution network using MPPT P and O/MPPT Fuzzy controller. The research is performed during transient disturbances of short-circuit fault on PCC bus based on five of short circuit faults. An artificial intelligence method with FLC is used to set duty cycle (D) with step variable to control DC/DC boost converter, generate quick convergence calculation to determine MPPT value for controlling of PV generator output voltage. Futhermore the result is compared with MPPT P and O method. The parameters are voltage/current unbalanced, voltage/current THD on each phase, and voltage/current average THD on PCC bus of three phase grid.

This paper is organized as follow. section 2 presents proposed method i.e. proposed model of single PV using MPPT Fuzzy, model multi PV connected three phase grid under short circuit fault, simulation parameters, equivalent circuit, mathematical, and characteristic curve of PV model, MPPT P and O method, MPPT Fuzzy method, voltage and current harmonics, voltage and current unbalance. Section 3 describes comparative performance of multi PV connected grid under short circuit fault during transient phase to current/voltage unbalance and current/voltage THD of three phase grid using MPPT P and O/MPPT Fuzzy method. In this section, example cases studied are presented and the results are verified with those of Matlab/Simulink. Finally, the paper in concluded in section 4.

2. Research Method
2.1. Proposed Model
Figure 1 shows model of a single PV system connected to a three phase grid. The DC/DC converter circuit consists of a boost converter circuit that serves to raise the DC output voltage from the PV. The DC output voltage of the boost converter circuit is then changed by a three phase DC/AC inverter into an AC voltage to three phase grid. The single PV model is then used as a reference to construct multiple PV models connected to grid through a three phase phase distribution transformer showed in Figure 2. This research uses three model group of PVs with an active power of 100 kW each. Besides connected three phase grid, multi PVs are also connected to three group of three phase loads with 20 kW of active power each. The aim of research is to compare performance of power quality due to the multi PV integration at both fixed temperature and solar irradiation levels connected to distribution network using MPPT P and O/MPPT Fuzzy. The research analysis includes transient disturbances of short-circuit fault on PCC bus based on a number of short circuit faults. An artificial intelligence with FLC is used to set duty cycle (D) with step variable to control DC/DC boost converter, generate quick convergence calculation to determine MPPT value for controlling of PV output voltage, and then its result is compared with MPPT P and O method. The DC/DC converter produces a constant DC voltage as an input for DC/AC inverter using pulse with modulation (PWM).

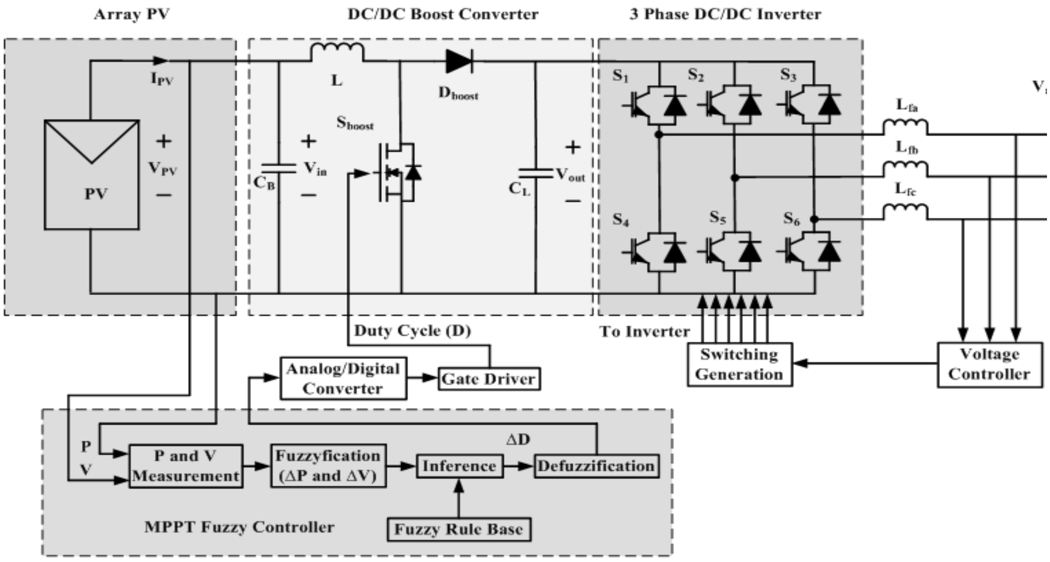


Figure 1. Proposed model of single PV using MPPT fuzzy

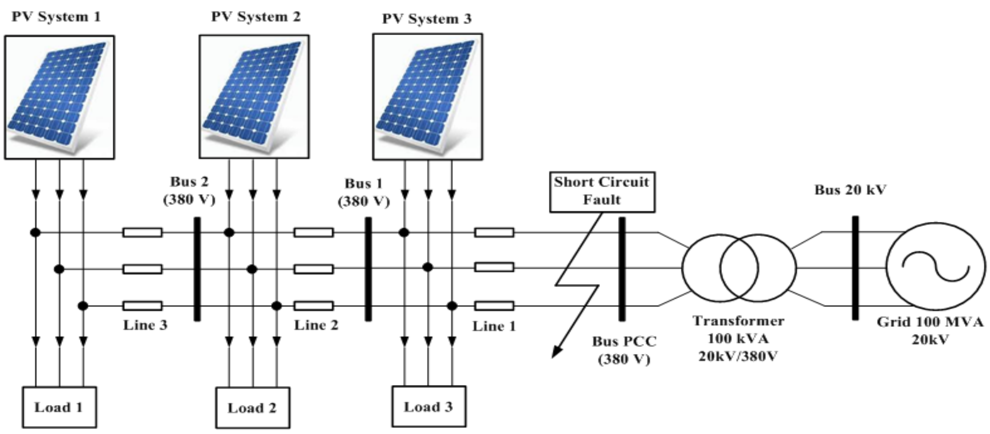


Figure 2. Proposed model of multi PV connected three phase grid under short circuit fault

There are two scenarios of multi PV connected three phase grids under fixed temperature and solar irradiation of 25^0 C and 1000 W/m^2, i.e. using MPPT P and O and MPPT Fuzzy methods respectively. The transient state in each of MPPT controllers are indicated by five short-circuit faults, resulting in a total of ten fault scenarios i.e. three phases to ground (3Ph-N), three phases (3Ph), two phases to ground (2Ph-N), two phases (2Ph), and single phase to ground (1Ph-N). The 3ph-N and 3ph are classified as symmetrical faults. Futhermore 2ph-N, 2Ph, and 1Ph-N are classified as non-symmetrical faults. The next process is to determine voltage/current unbalanced, voltage/current harmonics (THD) on each phase, and voltage/current average harmonics on PCC bus of three-phase low voltage grid. The final step is to validate the results referring to the ANSI/IEEE 241-1990 standard about unbalanced voltage and current and IEEE Standard 519-1992 about average grid voltage and current harmonics. Simulation and analysis of this research use Matlab/Simulink. The simulation parameter values of proposed model are shown in Appendix Section.

2.2. Modelling of PV Array

Figure 3 shows the equivalent circuit of a solar panel. A solar panel is composed of several PV cells that have series, parallel, or series-parallel external connections [17]. The V-I characteristic of a solar panel is showed in (1):

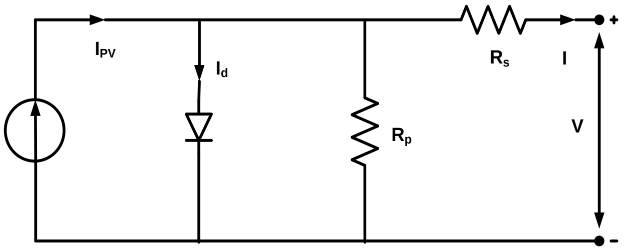


Figure 3. Equivalent circuit of solar panel

$$I = I_{PV} - I_o \left[\exp\left(\frac{V + R_S I}{aV_t} \right) - 1 \right] - \frac{V + R_S I}{R_P} \qquad (1)$$

where I_{PV} is the photovoltaic current, I_o is saturated reverse current, 'a' is the ideal diode constant, $V_t = N_S KTq^{-1}$ is the thermal voltage, N_S is the number of series cells, q is the electron charge, K is the Boltzmann constant, T is the temperature of p–n junction, R_S and R_P are series and parallel equivalent resistance of the solar panels. I_{PV} has a linear relation with light intensity and also varies with temperature variations. I_o is dependent on temperature variations.

2.3. MPPT P and O and MPPT Fuzzy

The initial research is to determine value of duty cycle (D) with a variable step to control DC/DC boost converter circuit with MPPT P and O. For PV converter, maximum power available is determined by PV cell characteristics, but this value often mismatches with the maximum power point (MPP) of the load. By implementing MPPT in PV systems, MPP can be maintained so that the number and size of PV panels can be reduced or energy yield can be optimized [18]. Because of moving of sun, PV panels angle, and variation of irradiance reaching the panels, energy generated from PV panels are absorbed does not constant over time. When this condition occurs, VI characteristics changes and MPP will move. To overcome these problems, MPPT has been developed. The system includes no moving parts. MPPT search for the maximum power independent based on environmental conditions (following changes in solar radiation and temperature) and maintain the PV terminal voltage remains constant at maximum value. The most used method of MPPT is P and O that algorithm is shown in Figure 4 [13] and its Matlab/Simulink model is presented in Figure 5.

The same procedure for determining MPPT is using FLC. Fuzzy set theory is a new method of controlling the MPPT in obtaining the peak power point. The MPPT is implemented to obtain MPP operation voltage point faster with less overshoot and also it can minimize voltage fluctuation after MPP has been recognized. It also is capable to enhance power quality problem unbalance current/voltage and current/voltage harmonics. Typical fuzzy based MPPT controller reffered to MPPT Fuzzy includes three basic components i.e. fuzzification, inference engine, and defuzzification block as shown in Figure 6 and its Matlab/Simulink presented in Figure 7.

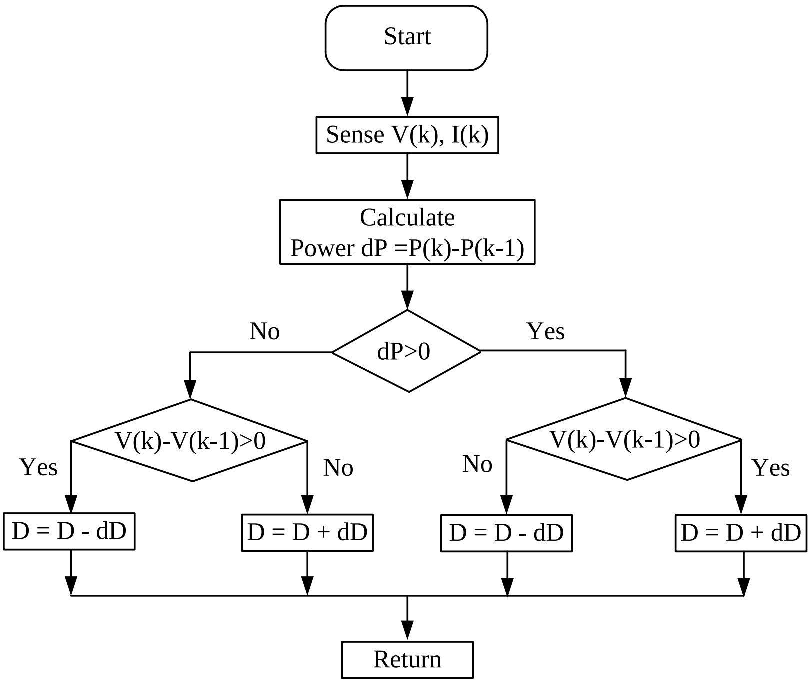


Figure 4. MPPT using P and O algorithm

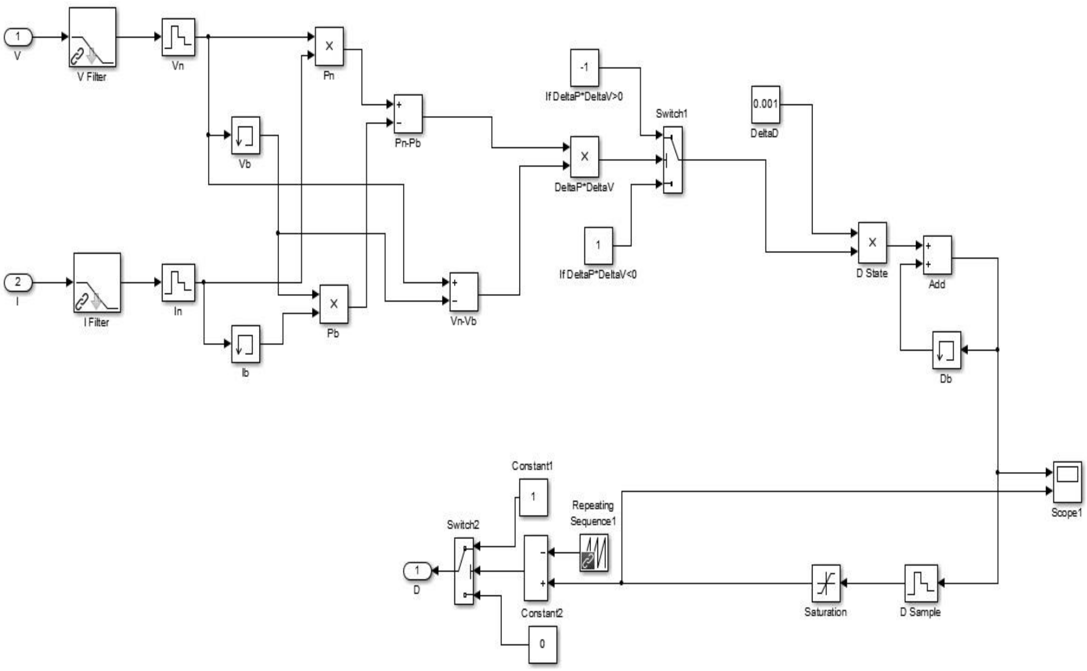
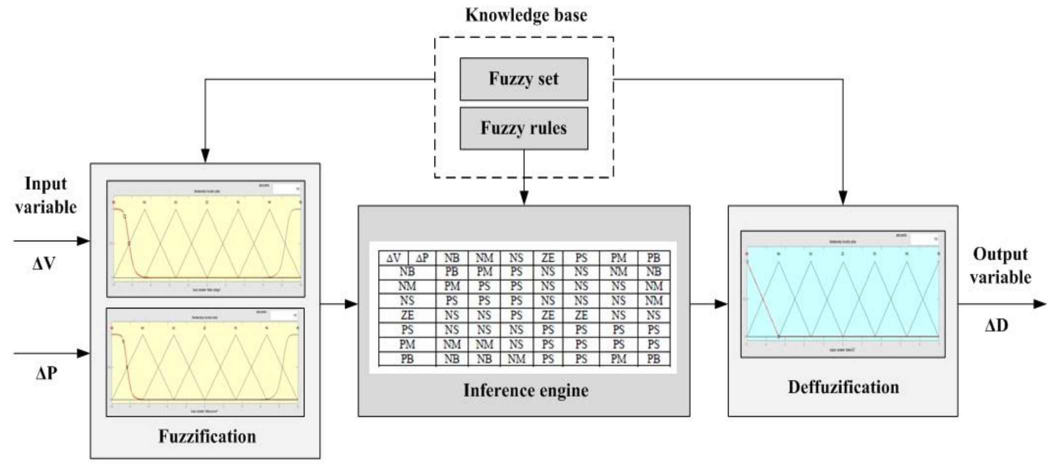


Figure 5. Matlab/Simulink for MPPT P and O



ΔV \ ΔP	NB	NM	NS	ZE	PS	PM	PB
NB	PB	PM	PS	NS	NS	NM	NB
NM	PM	PS	PS	NS	NS	NS	NM
NS	PS	PS	PS	NS	NS	NS	NM
ZE	NS	NS	PS	ZE	ZE	NS	NS
PS	NS	NS	NS	PS	PS	PS	PS
PM	NM	NM	NS	PS	PS	PS	PS
PB	NB	NB	NM	PS	PS	PM	PB

Figure 6. Structure of FLC

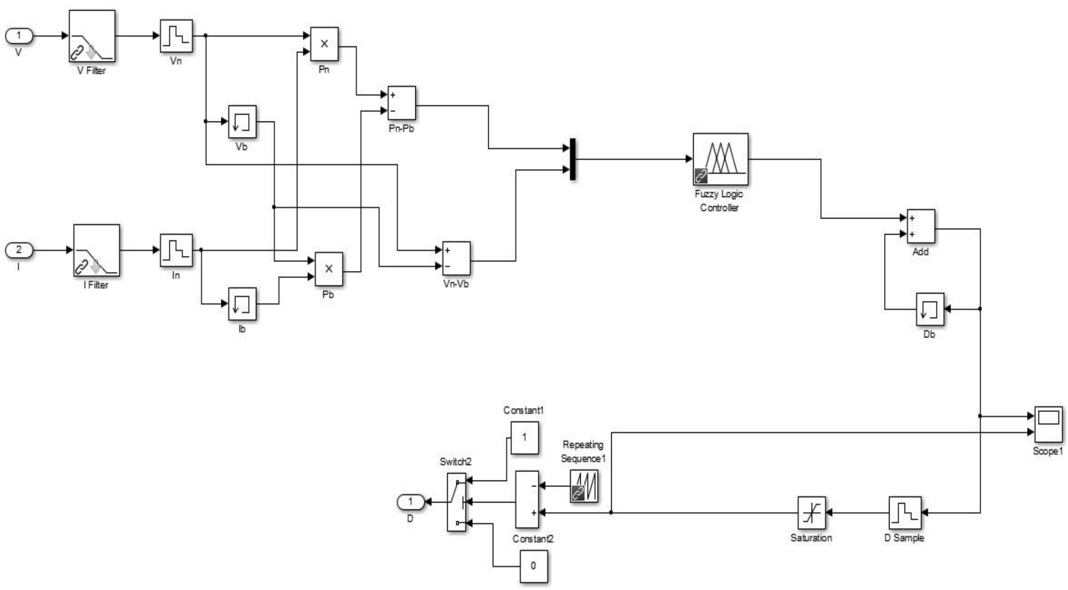


Figure 7. Matlab/Simulink for MPPT Fuzzy

Fuzzy MPPT method is done by determining input variables, namely fuzzy control output power (ΔP) and output voltage (ΔV) PV generator, seven linguistic variables fuzzy sets, fuzzy operating system block (fuzzification, fuzzy rules, and defuzzification), Function ΔP and Δ V during fuzzification, a table fuzzy rule base, crisp values to determine duty cycle (D) in defuzzification phase with variable step to control DC/DC boost converter. Figure 8 shows Matlab/Simulink model for MPPT Fuzzy.During fuzzification phase shown in Figure 7, a number of input variables is calculated and converted into a linguistic variable based on the subset called membership function (MF). To translate value of voltage change and power change in, input fuzzy "change of voltage" and "change of power" is designed to use seven fuzzy variable called PB (Positive Big), PM (Positive Medium), NS (Negative Small), PS (Positive Small) ZE (Zero), NM (Negative Medium), and Negative Big (NB). Voltage change (ΔV) and power changes (ΔP) is a proposed system input variables and output variable FLC is duty cycle change (ΔD). The membership functions i.e. voltage changes, power changes, and duty cycle change, each are shown in Figure 8 into Figure 10.

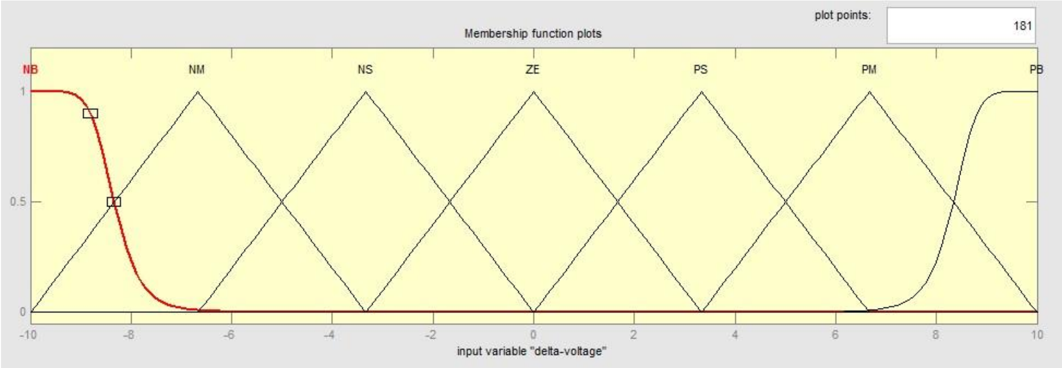


Figure 8. Input voltage change (delta voltage)

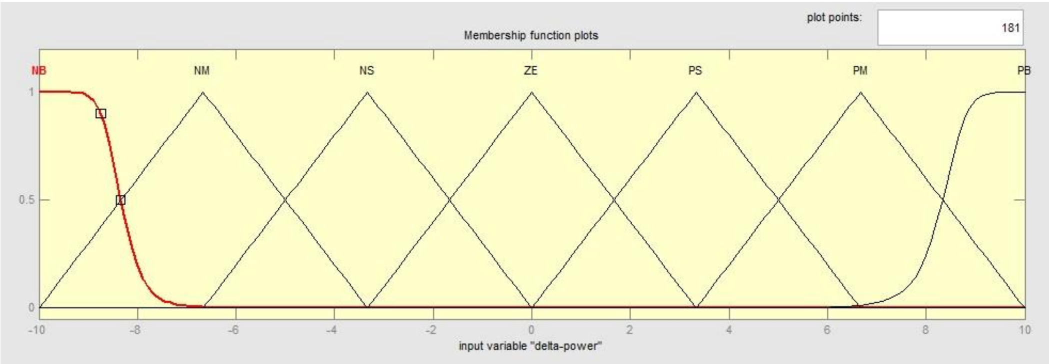


Figure 9. Input power change (delta power)

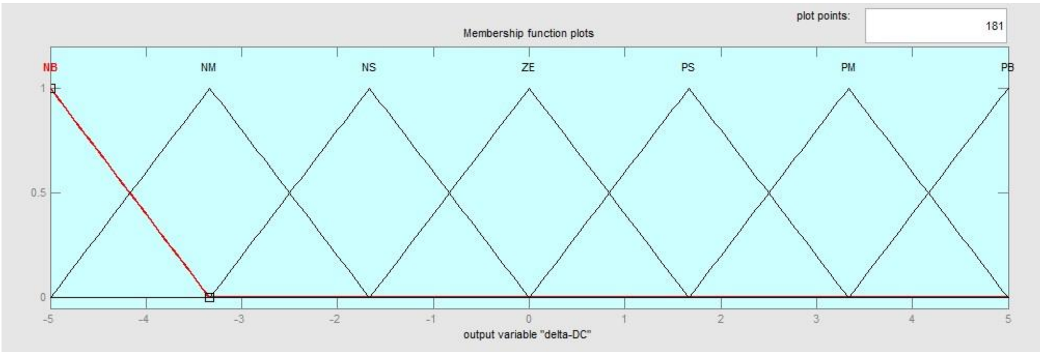


Figure 10. Output duty cycle change (delta D)

The fuzzy inference using a method that relates to a composition Mamdani Max-Min. Fuzzy inference system consists of three parts, namely rule base, database, and reasoning mechanism. After determining ΔV and ΔP, these value are then converted into linguistic variables and use them as input functions for FLC. The output value is ΔD is generated using block inference and fuzzy rules as shown in Table 1. Finally defuzzification block operates to change value of ΔD is raised from linguistic variables into numeric variables back. Numeric variables that become inputs signal for the IGBT switch of DC/DC boost converter to be able to determine MPPT for each generation PV accurately at the same time also improve power quality as a result of integration of multi PV to low voltage three phase grid under short circuit.

Table 1. Fuzzy Rules

ΔV ΔP	NB	NM	NS	ZE	PS	PM	PB
NB	PB	PM	PS	NS	NS	NM	NB
NM	PM	PS	PS	NS	NS	NS	NM
NS	PS	PS	PS	NS	NS	NS	NM
ZE	NS	NS	PS	ZE	ZE	NS	NS
PS	NS	NS	NS	PS	PS	PS	PS
PM	NM	NM	NS	PS	PS	PS	PS
PB	NB	NB	NM	PS	PS	PM	PB

2.4. Voltage and Current Harmonics/Unbalance

Generally, current and voltage waveforms are pure sinusoidal. One problem that occurs is non sinusoida or distorted current and voltage waves generated by harmonics in power system [11]. Harmonic is distorted periodic steady state wave caused by the interaction between the shapes of a sine wave at the fundamental frequency system with another wave component which is an integer multiples frequency of fundamental frequency. The most common harmonic index, which relates to voltage waveform is THD (2), which is defined as the root mean square (rms) of harmonics expressed as a percentage of fundamental component as showed in [19]. Second harmonic index is current THD means the ratio of rms harmonic current value to rms fundamental current which expressed in (3) [11].

$$THD_V = \frac{\sqrt{\sum_{n=2}^{N} V_n^2}}{V_1} \times 100\,\% \qquad (2)$$

$$THD_I = \frac{\sqrt{\sum_{n=2}^{N} I_n^2}}{I_1} \times 100\,\% \qquad (3)$$

$$V(\%) = \frac{\left| V_{a\,\text{var}age} - V_{a,b,c\,\min\,or\,\max} \right|}{V_{a\,\text{var}age}} \times 100\% \qquad (4)$$

Where $V_n$and I_n (the rms voltage and current at harmonic n), V_1 and I_1 (the fundamental rms voltageand current), N (the maximum harmonic order to be considered). The allowable maximum THD value for each country is different depending on the standard used. THD standards most often used in electric power system is IEEE 519-1992. There are two criteria used in analysis of harmonics distortion i.e. voltage distortion and current distortion limit [20]. The value of unbalance voltage use (8) is based ANSI/IEEE 241-1990 is showed in (4) [21].By using (4), value of unbalance voltage expressed in percent (%) and is defined as follows; $V_{avarage}$ is the average value of maximum voltage on phase a, b, c, in volt. $V_{a,b,c\ min}$ is minimum voltage on phase a, b, c in volt, $V_{a,b,c\ max}$ is maximum voltage on phase a, b, c in volt . By the same way, then unbalance current in % can be calculated by replacing voltage into current magnitude.

3. Results and Analysis

This research is started by determining the maximum and minimum of grid current in each phase, unbalanced current using (4), current THD on each phase (3), and average THD of three phase current grids on PCC bus using MPPT P and O/MPPT Fuzzy. By using the same procedure then obtained unbalanced voltage using (4), voltage THD on each phase using (2), and average voltage THD. Table 2 shows unbalanced current, THD grid current, and average THD of grid current of multi PV connected on a three phase low voltage grid using MPPT P and O/MPPT Fuzzy. Because, there are five short-circuit faults then there are three fault durations i.e. before, during (transient), and after fault phase with time durations are 0-0.02 sec, 0.02-0.04 sec, and 0.04-0.06 sec respectivelty. The simulation result of unbalanced current/voltage and average THD current/voltage is also presented as verification under five short circuit faults. The results analysis is conducted only on short circuit fault during transient phase. Figure 11 shows current waveform of multi PV connected to three phase grid on a PCC bus using MPPT P and O/MPPT Fuzzy under normal condition, 3Ph-N, 2Ph-N, and 1Ph-N fault.

Table 3 shows unbalanced voltage, THD grid voltage, and average THD of grid voltage of multi PV connected on a three phase low voltage grid using MPPT P and O/ MPPT Fuzzy.

Table 2. Unbalance Current and Average Current Harmonics under Transient Phase

No.	Fault Types	Phase Current (V) A	B	C	Unba Current (%)	THD_I (%) A	B	C	Avg THD_I (%)
				MPPT P and O Method					
1	Normal	10.61	10.74	10.69	0.562	2.65	3.22	3.40	3,090
2	3Ph-N	1331	1359	1296	2.283	4.41	2.05	2.38	2.947
3	3Ph	1331	1359	1296	2.283	4.41	2.05	2.38	2.947
4	2Ph-N	1336	1350	7.671	50.353	4.70	1.76	3.91	3.457
5	2Ph	1179	1179	10.32	49.347	3.67	3.67	3.33	3.557
6	1Ph-N	1132	9.451	9.482	195.065	4.96	3.27	4.06	4.097
				MPPT Fuzzy Method					
1	Normal	10.72	10.76	10.80	0.372	3.32	3.76	4.28	3.787
2	3Ph-N	1331	1359	1296	2.283	4.41	2.05	2.38	2.947
3	3Ph	1331	1359	1296	2.283	4.41	2.05	2.38	2.947
4	2Ph-N	1336	1350	7.475	50.364	4.70	1.76	6.0	4.154
5	2Ph	1179	1179	10.09	49.361	3.69	3.66	5.10	4.150
6	1Ph-N	1332	9.203	9.319	195.886	4.97	4.88	5.28	5.044

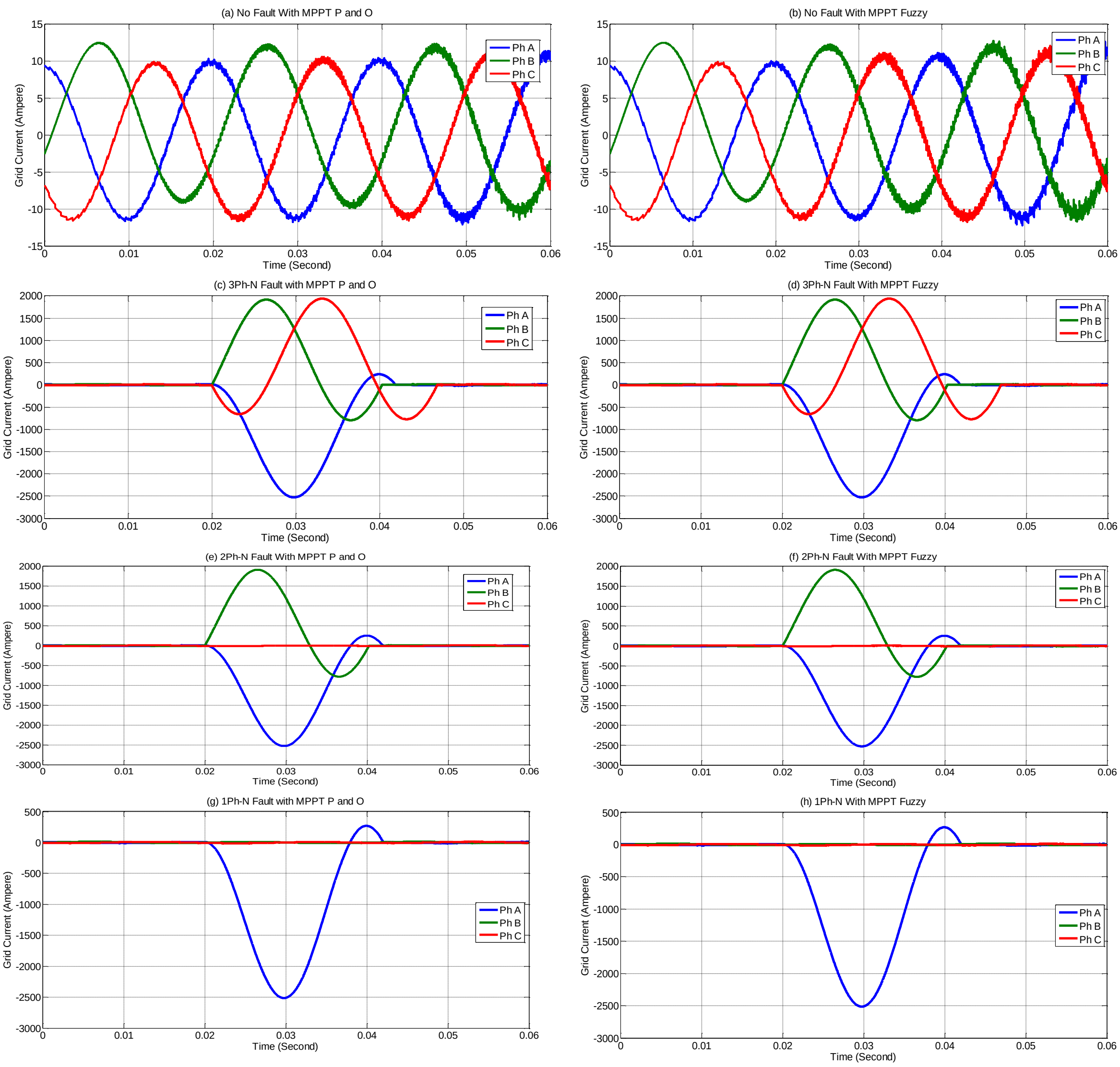
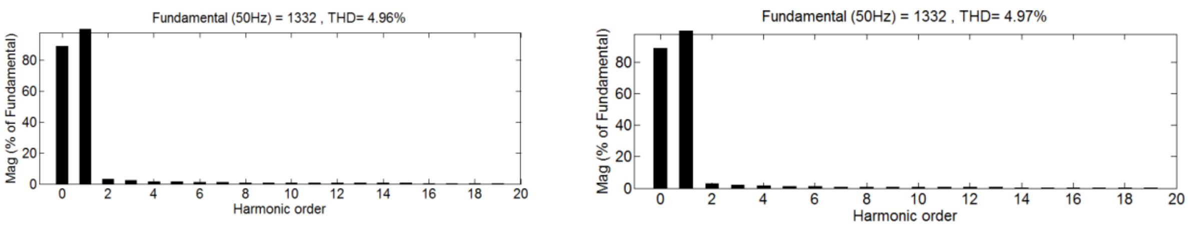


Figure 11. Current waveform of multi PV connected to a three phase grid on PCC bus

Table 3. Unbalance Voltage and Average Voltage Harmonics under Transient Phase

No.	Fault Types	Phase Voltage (V) A	B	C	Unba Voltage (%)	THD_V (%) A	B	C	Avg THD_V (%)
				MPPT P and O Method					
1	Normal	308.8	308.7	307.8	0	6.74	7.06	7.14	6.980
2	3 Ph-N	1.332	1.350	1.307	1.523	6.50	179.32	189.46	125.094
3	3 Ph	1.347	1.325	1.318	1.279	275.94	336.34	341.31	317.864
4	2 Ph-N	2.242	2.268	308.4	195.677	5.36	106.86	7.83	39.017
5	2 Ph	155.0	152.7	307.8	50.025	7.96	8.09	7.72	7.924
6	1Ph-N	2.658	308.1	308.1	49.356	5.48	7.56	7.88	6.974
				MPPT Fuzzy Method					
1	Normal	307.7	307.7	307.7	0	8.23	9.74	9.79	9.254
2	3 Ph-N	1.332	1.351	1.306	1.605	5.38	172.84	181.97	120.064
3	3 Ph	1.339	1.343	1.307	1.003	223.47	283.53	294.43	267.144
4	2 Ph-N	2.242	2.269	308.4	195.676	4.90	102.82	11.16	39.627
5	2 Ph	155.0	152.7	307.8	50.025	10.12	10.28	9.98	10.127
6	1Ph-N	2.657	308.1	308.0	49.381	5.22	9.77	10.63	8,570

Figure 12 shows grid current harmonics spectra of phase A during transient phase due to the multi PV connected to three phase grid on PCC bus using MPPT P and O and MPPT Fuzzy method under 1Ph-N fault.

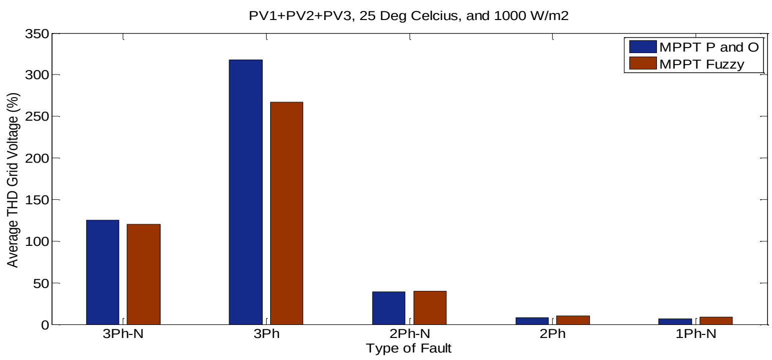


(a) MPPT P and O (b) MPPT Fuzzy

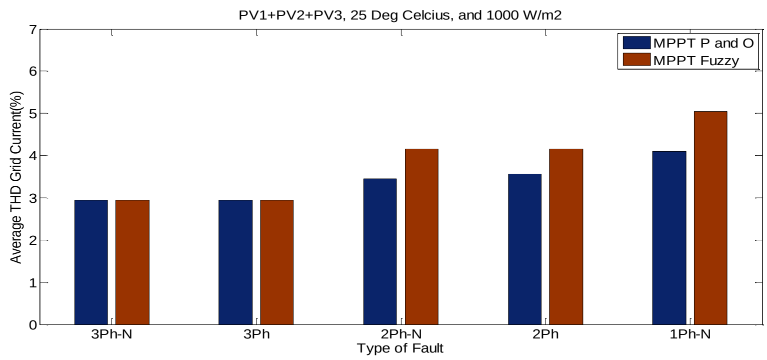
Figure 12. Current harmonics spectra of phase A under 1Ph-N fault

Table 2 presents that under normal condition, phase current of multi PV (PV1+PV2 + PV3) using MPPT P and O in transient phase are 10.61 A, 10.74 A, 10.69 A and able to result an unbalanced current of 0.562%. In short circuit faults, the highest unbalanced current of transient phase is generated by 1Ph-N fault of 195.886%. The 3Ph-N and 3Ph fault on transient phase are able equally produce an unbalanced current of 2,283%. The implementation of MPPT Fuzzy method under normal condition is able to generate an unbalanced current of 0.372%. If using MPPT Fuzzy under fault on transient phase, the highest unbalanced current is generated by 1Ph-N faults of 195.886%. At the same condition the smallest unbalanced current is equally generated by 3Ph-N and 3Ph fault of 2.282%. In non-symmetrical fault, the use of MPPT P and O is able to result an unbalanced current of transient phase slightly lower than MPPT Fuzzy. While in symmetrical faults, MPPT P and O/MPPT Fuzzy method for controlling of output power of multi PV gives same unbalanced current of transient phase of 2,283%.In normal condition, by using both MPPT P and O and MPPT Fuzzy method, the average THD current on transient phase are 3.090% and 3.787%, respectively. When using MPPT P and O, the highest average THD current is generated by 1Ph-N fault of 4,097%. In the same method, the smallest average THD voltage is equally generated by 3Ph-N and 3Ph of 2,947%. If using Fuzzy MPPT, the highest average THD current is generated by 1Ph-N fault of 5.044%. In the same method, the smallest average THD current is equally generated by 3Ph-N and 3Ph of 2,947%. In the symmetrical faults, both MPPT P and O and MPPT Fuzzy method is able equally resultan average THD current during transient phase of 2,947%. In non-symmetrical fault, MPPT P and O is able to result an average THD current slightly smaller than MPPT Fuzzy method.

Table 3 presents that under normal condition, multi PV using MPPT P and O under transient phase is able to result an unbalanced voltage of 0%. In the short circuit faults, the highest unbalanced voltage during transient phase is generated by a 2Ph-N fault of 195.677% volt. The 3Ph fault during transient phase is able to result the smallest unbalanced voltage of 1.279%. MPPT Fuzzy under normal condition is also able to result an unbalanced voltage of 0%. When using the MPPT Fuzzy under short-circuit fault during transient phase, the highest unbalanced voltage is generated by a 2Ph-N fault of 195.676% and the lowest unbalanced voltage is generated by 3Ph fault of 1.003%. In non-symmetrical faults, the implemantation of MPPT P and O and MPPT Fuzzy method to control output power of multi PV produces nominal unbalanced voltage during transient phase results a close the same value. While in symmetrical fault, MPPT P and O and MPPT Fuzzy are able to result different unbalance voltage on transient phase. During 3Ph-N fault on transient phase, MPPT P and O method is able to result an unbalanced transient phase voltage of 1.523% slightly lower than MPPT Fuzzy of 1.605%. However during 3Ph fault on transient phase, MPPT Fuzzy is able to produce an unbalanced voltage of 1.003% slightly lower than MPPT P and O of 1.279%.In normal condition, the use of both MPPT P and O and MPPT Fuzzy method are able to result THD average voltages i.e. 6.980% and 9.254%, respectively. If using MPPT P and O, the largest average THD voltage is generated by a 3Ph fault of 317.864%. By using the same method, the lowest average THD voltage is produced by 1Ph-N fault of 6.974%. If using Fuzzy MPPT, the largest average THD voltage is also generated by a 3Ph fault of 267.144%. By using the same method, the lowest average THD voltage is generated by 1Ph-N fault of 8.570%. During symmetrical fault on transient phase, MPPT Fuzzyis able to result an average THD voltage smaller than MPPT P and O. Otherwise during non-symmetrical fault on transient phase, MPPT P and O is able to result an average THD voltage slightly lower than MPPT Fuzzy. Performance of average voltage is shown as Figure 13 (a) and current harmonic during transient phase is shown as Figure 13 (b).



(a) Average THD voltage



(b) Average THD current

Figure 13. Performance of (a) average voltage and (b) current harmonic during transient phase

Figure 13 (a) shows that on symmetrical faults during transient phase (3Ph-N and 3Ph), MPPT Fuzzy is able to resultan average THD voltage smaller than MPPT P and O method. Otherwise on non-symmetrical faults during transient phase (2Ph-N, 2Ph, and 1Ph-N), MPPT P and O is able to result an average THD voltage slightly smaller than MPPT Fuzzy. Figure 13(b) shows that on symmetrical faults during transient phase, MPPT Fuzzy and MPPT P and O method are able to result the same average THD current. Furthermore on non-symmetrical faults during transient phase, MPPT P and O is able to result an average THD current slightly smaller than MPPT Fuzzy. The MPPT P and O and the MPPT Fuzzy on all short circuit fault during transient phase (3Ph-N, 3Ph, 2Ph-N, 2Ph, and 1Ph-N) are able to result smaller current average THD current significantly depend on average THD voltage.

4. Conclusion

Comparative performance of multi PVs connected grid under short circuit fault during transient phase to power quality using MPPT P and O/MPPT Fuzzy has been presented. During transient phase, non-symmetrical faults (2Ph-N, 2Ph, and 1Ph-N) is able to generate unbalance current/voltage greater depend on symmetrical faults (3Ph-N and 3Ph). On symmetrical faults, MPPT Fuzzy is able to resultan average THD voltage/THD current smaller than MPPT P and O. Otherwise on non-symmetrical faults, MPPT P and O is able to result an average THD voltage/THD current slightly smaller than MPPT Fuzzy.The MPPT P and O/MPPT Fuzzy method on all short circuit faults during transient phase are able to results smaller current average THD than average THD voltage significantly. Futhermore the nominal of average THD current using both methods has also met THD limit prescribed in IEEE 519.

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Appendix

PV generator 1, 2, and 3: active power=100 kW, temperature=25^0 C, irradiance=1000 W/m^2; Three phase grid: short circuit power=100 MVA, voltage=380 volt (L-L), frequency=50 Hz; Power transformer: rated power=100 kVA, frequency=50 Hz, voltage 380 Volt/20 kV (L-L), two winding type; Load 1, 2, and 3: active power=20 kW, voltage=380 volt (L-L), frequency=50 Hz; Low Voltage Lines 1, 2, and 3: resistance R=0,1273 Ohm/km, inductance L=93,37 mH/km, capasitance C=1,274 μF/km; Length of Low Voltage Lines: Line 1, Line 2, Line 3=1 km; DC link capasitor: capacitance= 2000 μF, frequency = 4 kHz; PWM generator for DC/AC inverter: Sampling time= 5x10^{-6} Second; Fuzzy inference system=mamdani method; Fuzzy model composition=max-min; Input membership function: delta voltage=gbellmf, trimf, delta power: gbellmf, trimf; Output membership function: delta duty cycle=trimf.