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/ 12 /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 Comparative Performance of Mitigation Voltage Sag/Swell and Harmonics Using DVR-BES-PV System with MPPT-Fuzzy Mamdani/MPPT-Fuzzy Sugeno yang telah dipublikasikan di International Journal of Intelligent Engineering and Systems (IJIES), Vol.12, No.2, 2019 pp. 222-235, ISSN: 2185-3118, Publisher: The Intilligent Network and Systems Society, **Terindeks Scopus Q2.**
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

Ubhara Surabaya

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

Send Paper Journal Inass_Amirullah_Ubhara_Sub_Indonesia

1 pesan

Amirullah Ubhara Surabaya <amirullah@ubhara.ac.id> 29 November 2018 pukul 10.41
Kepada: ijies@inass.org
Cc: ijies@inass.org
Bcc: Amirullah Ubhara Surabaya <amirullah@ubhara.ac.id>

Dear INASS Commitee

Here I send you the paper and cover letter entitled Comparative Performance of Mitigation Voltage Sag/Swell and Harmonics Using DVR-BES-PV System With MPPT-Fuzzy Mamdani/MPPT-Fuzzy Sugeno (Agus Kiswantono, Eko Prasetyo, Amirullah) to IJIES journal (INASS Publisher).

I select Regular Publication + Format Correction: (USD 150) as type of the paper publication processing.

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

Best Regards,

Amirullah
Lecturer in Electrical Engineering
University of Bhayangkara Surabaya Indonesia

---

2 lampiran

IJIES_Journal Inass_Amirullah_Sub_Indonesia_29 Nop 2018.docx
1608K

Cover Letter_Inass_Amirullah_Sub_Indonesia_29 Nop 2018.docx
28K

Ubhara Surabaya

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

ijies2039: Send Paper Journal Inass_Amirullah_Ubhara_Sub_Indonesia

3 pesan

Kei Eguchi <eguti@fit.ac.jp> 29 November 2018 pukul 11.07
Kepada: Amirullah Ubhara Surabaya <amirullah@ubhara.ac.id>

Dear author(s),

Thank you for your interest and support to IJIES.
I am hereby to confirm the delivery of your paper, Paper ID is " ijies2039".
It has been sent for reviewing.
The notification will be feedback within 1 month.
Appreciate your patiently wait.

If you have any question, please contact us with your paper ID.

Best regards,
IJIES Editors

From: Amirullah Ubhara Surabaya <amirullah@ubhara.ac.id>
Sent: Thursday, November 29, 2018 12:42 PM
To: ijies@inass.org
Subject: Send Paper Journal Inass_Amirullah_Ubhara_Sub_Indonesia

Dear INASS Commitee

Here I send you the paper and cover letter entitled Comparative Performance of Mitigation Voltage Sag/Swell and Harmonics Using DVR-BES-PV System With MPPT-Fuzzy Mamdani/MPPT-Fuzzy Sugeno (Agus Kiswantono, Eko Prasetyo, Amirullah) to IJIES journal (INASS Publisher).

I select Regular Publication + Format Correction: (USD 150) as type of the paper publication processing.

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

Best Regards,

Amirullah
Lecturer in Electrical Engineering
University of Bhayangkara Surabaya Indonesia

Amirullah Ubhara Surabaya <amirullah@ubhara.ac.id> 29 November 2018 pukul 18.09
Kepada: Kei Eguchi <eguti@fit.ac.jp>
Cc: Amirullah Ubhara Surabaya <amirullah@ubhara.ac.id>
Bcc: Agus Kiswantono <kiswantono@gmail.com>, Eko Prasetyo <eko@ubhara.ac.id>

Dear Dr. Kei Eguchi

Thanks a lot for sending me paper ID (ijies2039).

Amirullah
Electrical Engineering
Faculty of Engineering
University of Bhayangkara Surabaya Indonesia

[Kutipan teks disembunyikan]

Amirullah Ubhara Surabaya <amirullah@ubhara.ac.id> 11 Desember 2018 pukul 11.53
Kepada: lppm@ubhara.ac.id
Cc: R Dimas Nasywa Aliyya Zahwa <dimas@ubhara.ac.id>
Bcc: Heru Irianto <heru@ubhara.ac.id>, Agus Kiswantono <kiswantono@gmail.com>

Yth. Ka LPPM

Terlampir bukti submit jurnal INASS (Scopus Q3) PDP 2018 an. Agus Kiswantono.

Hormat,

Tim Peneliti

[Kutipan teks disembunyikan]

Ubhara Surabaya

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

ijies2039: Send Paper Journal Inass_Amirullah_Ubhara_Sub_Indonesia

3 pesan

Kei Eguchi <eguti@fit.ac.jp> 29 November 2018 pukul 11.07
Kepada: Amirullah Ubhara Surabaya <amirullah@ubhara.ac.id>

Dear author(s),

Thank you for your interest and support to IJIES.
I am hereby to confirm the delivery of your paper, Paper ID is " ijies2039".
It has been sent for reviewing.
The notification will be feedback within 1 month.
Appreciate your patiently wait.

If you have any question, please contact us with your paper ID.

Best regards,
IJIES Editors

From: Amirullah Ubhara Surabaya <amirullah@ubhara.ac.id>
Sent: Thursday, November 29, 2018 12:42 PM
To: ijies@inass.org
Subject: Send Paper Journal Inass_Amirullah_Ubhara_Sub_Indonesia

Dear INASS Commitee

Here I send you the paper and cover letter entitled Comparative Performance of Mitigation Voltage Sag/Swell and Harmonics Using DVR-BES-PV System With MPPT-Fuzzy Mamdani/MPPT-Fuzzy Sugeno (Agus Kiswantono, Eko Prasetyo, Amirullah) to IJIES journal (INASS Publisher).

I select Regular Publication + Format Correction: (USD 150) as type of the paper publication processing.

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

Best Regards,

Amirullah
Lecturer in Electrical Engineering
University of Bhayangkara Surabaya Indonesia

Amirullah Ubhara Surabaya <amirullah@ubhara.ac.id> 29 November 2018 pukul 18.09
Kepada: Kei Eguchi <eguti@fit.ac.jp>
Cc: Amirullah Ubhara Surabaya <amirullah@ubhara.ac.id>
Bcc: Agus Kiswantono <kiswantono@gmail.com>, Eko Prasetyo <eko@ubhara.ac.id>

Dear Dr. Kei Eguchi

Thanks a lot for sending me paper ID (ijies2039).

Amirullah
Electrical Engineering
Faculty of Engineering
University of Bhayangkara Surabaya Indonesia

[Kutipan teks disembunyikan]

Amirullah Ubhara Surabaya <amirullah@ubhara.ac.id> 11 Desember 2018 pukul 11.53
Kepada: lppm@ubhara.ac.id
Cc: R Dimas Nasywa Aliyya Zahwa <dimas@ubhara.ac.id>
Bcc: Heru Irianto <heru@ubhara.ac.id>, Agus Kiswantono <kiswantono@gmail.com>

Yth. Ka LPPM

Terlampir bukti submit jurnal INASS (Scopus Q3) PDP 2018 an. Agus Kiswantono.

Hormat,

Tim Peneliti

[Kutipan teks disembunyikan]

Ubhara Surabaya

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

ijies2039: review result

10 pesan

Kei Eguchi <eguti@fit.ac.jp> 20 Desember 2018 pukul 11.16
Kepada: Amirullah Ubhara Surabaya <amirullah@ubhara.ac.id>

Dear author(s),

Congratulations!
The 1st review for your paper was accepted.
However, we are sorry to inform you that your paper cannot be recommended for publication in IJIES, in its current form.
Please revise your paper according to the attached reviewers' comments.

Please note that if your paper is still not satisfactorily revised or cannot be returned to us within TWO months from the date of this letter, your paper will not be recommended to the journal above.

Thanks for your understanding and cooperation.

Kind Regards,
IJIES Editors.

2039.docx
42K

Amirullah Ubhara Surabaya <amirullah@ubhara.ac.id> 20 Desember 2018 pukul 15.02
Kepada: Kei Eguchi <eguti@fit.ac.jp>
Cc: Amirullah Ubhara Surabaya <amirullah@ubhara.ac.id>, Agus Kiswantono <kiswantono@gmail.com>, Eko Prasetyo <eko@ubhara.ac.id>

Dear Dr. Kei Equchi
IJIES Editor

Thanks a lot for your email.

I would revise my paper according to the attached reviewers' comments at least in one week.

Amirullah
Lecturer Electrical Eng.
Faculty of Engineering
University of Bhayangkara Surabaya
Indonesia

[Kutipan teks disembunyikan]

Amirullah Ubhara Surabaya <amirullah@ubhara.ac.id> 29 Desember 2018 pukul 08.32
Kepada: Kei Eguchi <eguti@fit.ac.jp>
Cc: Kei Eguchi <eguti@fit.ac.jp>
Bcc: Amirullah Ubhara Surabaya <amirullah@ubhara.ac.id>, Amirullah Amirullah <amirullah.ubhara.surabaya@gmail.com>

Dear Dr. Kei Aguchi
IJIES Editors

Here I send you revised paper **ID ijies2039** entitled Comparative Performance of Mitigation Voltage Sag/Swell and Harmonics Using DVR-BES-PV System With MPPT-Fuzzy Mamdani/MPPT-Fuzzy Sugeno (Agus Kiswantono, Eko Prasetyo, Amirullah-Amirullah).

This is my revised paper and I will be happy if you give me response about it.

Amirullah
Lecturer Electrical Eng.
Faculty of Engineering
University of Bhayangkara Surabaya
Indonesia

[Kutipan teks disembunyikan]

IJIES_Journal Inass_Amirullah_Sub_Indonesia Revised_29 Des 2018.docx
1675K

Kei Eguchi <eguti@fit.ac.jp> 1 Januari 2019 pukul 08.54
Kepada: Amirullah Ubhara Surabaya <amirullah@ubhara.ac.id>

Dear Author(s),

Thank you for submitting your revised version.
However, the response letter is not attached to your e-mail.

Please read the review form:
>* Please send your revised manuscript with the response letter for the 2nd review.

To clarify the revised points, authors have a duty to submit the reply form.
Otherwise, the reviewers will be confused.
This is a general form of paper reviews in international journals.
There is no format for the response letter.

Best regards,
IJIES Editors.

[Kutipan teks disembunyikan]
[Kutipan teks disembunyikan]

(Sample) Response letter.pdf
517K

Amirullah Ubhara Surabaya <amirullah@ubhara.ac.id> 1 Januari 2019 pukul 20.48
Kepada: Kei Eguchi <eguti@fit.ac.jp>
Cc: Amirullah Ubhara Surabaya <amirullah@ubhara.ac.id>
Bcc: Amirullah Amirullah <amirullah.ubhara.surabaya@gmail.com>

Dear Kei Aguchi,

I am apologize I though before that revised manuscript with the response letter includes in one doc file and marked with red font only.

It is okay thanks a lot for your request.

I promise send the response letter of my paper at least in next two days.

Best Regards,

Amirullah
Lecturer of Electrical Engineering

Faculty of Engineering
University of Bhayangkara Surabaya Indonesia

[Kutipan teks disembunyikan]

Amirullah Ubhara Surabaya <amirullah@ubhara.ac.id> 2 Januari 2019 pukul 20.22
Kepada: Kei Eguchi <eguti@fit.ac.jp>
Cc: Kei Eguchi <eguti@fit.ac.jp>
Bcc: Amirullah Ubhara Surabaya <amirullah@ubhara.ac.id>, Amirullah Amirullah <amirullah.ubhara.surabaya@gmail.com>

Dear Dr. Kei Eguchi
IJIES Editor in Chief

Here I attach you the revised paper and response letter (date on 2 January 2019) for the manuscipt entitled:
Comparative Performance of Mitigation Voltage Sag/Swell and Harmonics Using DVR-BES-PV System With MPPT-Fuzzy Mamdani/MPPT-Fuzzy Sugeno
(Agus Kiswantono, Eko Prasetyo, Amirullah Amirullah) ID paper ijies2039.

This is my email and I will be happy if you response it again.

Thanks a lot for your helping.

Best Regards,

Amirullah
Lecturer Electrical Eng.
Faculty of Engineering
University of Bhayangkara Surabaya
Indonesia
PhD Candidate in Electrical Eng.
Power Quality in Renewable Energy
Institut Teknologi Sepuluh Nopember (ITS)
Surabaya

[Kutipan teks disembunyikan]

2 lampiran

IJIES_2039_Journal Inass_Amirullah_Sub_Indonesia Revised_2 Jan 2019.docx
1676K

IJIES_2039_Response Letter_2 Jan 2019.docx
36K

Kei Eguchi <eguti@fit.ac.jp> 3 Januari 2019 pukul 09.09
Kepada: Amirullah Ubhara Surabaya <amirullah@ubhara.ac.id>

Dear author(s),

Thank you for your interest and support to IJIES.
We received your revised version.
It has been sent for reviewing.
The notification will be feedback within 1 month.
Appreciate your patiently wait.

If you have any question, please contact us with your paper ID.

Best regards,
IJIES Editors
[Kutipan teks disembunyikan]
Pada tanggal Sel, 1 Jan 2019 pukul 08.54 Kei Eguchi <mailto:eguti@fit.ac.jp> menulis:

Dear Author(s),

Thank you for submitting your revised version.
However, the response letter is not attached to your e-mail.

Please read the review form:
>* Please send your revised manuscript with the response letter for the 2nd review.

To clarify the revised points, authors have a duty to submit the reply form.
Otherwise, the reviewers will be confused.
This is a general form of paper reviews in international journals.
There is no format for the response letter.

Best regards,
IJIES Editors.

[Kutipan teks disembunyikan]
[Kutipan teks disembunyikan]

Amirullah Ubhara Surabaya <amirullah@ubhara.ac.id> 3 Januari 2019 pukul 09.37
Kepada: Kei Eguchi <eguti@fit.ac.jp>
Cc: Kei Eguchi <eguti@fit.ac.jp>
Bcc: Amirullah Amirullah <amirullah.ubhara.surabaya@gmail.com>, Amirullah Ubhara Surabaya <amirullah@ubhara.ac.id>

Dear Dr. Kei Eguchi
IJIES Editor

Thanks a lot for your reply.

Hopefully next I could hear good news about final status of my paper (IJIES ID 2039).

Best Regards,

Amirullah
Lecturer Electrical Eng.
Faculty of Engineering
University of Bhayangkara Surabaya
Indonesia
PhD Candidate in Electrical Eng.
Power Quality in Renewable Energy
Institut Teknologi Sepuluh Nopember (ITS)
Surabaya
[Kutipan teks disembunyikan]

Amirullah Ubhara Surabaya <amirullah@ubhara.ac.id> 3 Januari 2019 pukul 15.36
Kepada: Kei Eguchi <eguti@fit.ac.jp>
Cc: Kei Eguchi <eguti@fit.ac.jp>
Bcc: Amirullah Ubhara Surabaya <amirullah@ubhara.ac.id>, Amirullah Amirullah <amirullah.ubhara.surabaya@gmail.com>

Dear Dr. Kei Aguchi,

I am sorry forget to inform you before.

The revised IJIES paper (ID 2039) that I sent you on 29 December 2018 is withdrawn.

The final version of revised IJIES paper (ID 2039) and response letter are base on attachment files date 2 January 2019.

Hopefully, the both files which you give to the 2nd reviewers for reviewing again is date on 2 January 2019.

This is my email and thanks a lot for your cooperation.
[Kutipan teks disembunyikan]
[Kutipan teks disembunyikan]

Kei Eguchi <eguti@fit.ac.jp> 5 Januari 2019 pukul 14.19
Kepada: Amirullah Ubhara Surabaya <amirullah@ubhara.ac.id>

Dear author(s),

Thank you for your interest and support to IJIES.
We understood your request.
The latest version was sent to reviewers.
[Kutipan teks disembunyikan]
Pada tanggal Kam, 3 Jan 2019 pukul 09.09 Kei Eguchi <mailto:eguti@fit.ac.jp> menulis:
Dear author(s),

Thank you for your interest and support to IJIES.
We received your revised version.
It has been sent for reviewing.
The notification will be feedback within 1 month.
Appreciate your patiently wait.

If you have any question, please contact us with your paper ID.

Best regards,
IJIES Editors

[Kutipan teks disembunyikan]
Pada tanggal Sel, 1 Jan 2019 pukul 08.54 Kei Eguchi <mailto:mailto:eguti@fit.ac.jp> menulis:
Dear Author(s),

Thank you for submitting your revised version.
However, the response letter is not attached to your e-mail.

Please read the review form:
>* Please send your revised manuscript with the response letter for the 2nd review.

To clarify the revised points, authors have a duty to submit the reply form.
Otherwise, the reviewers will be confused.
This is a general form of paper reviews in international journals.
There is no format for the response letter.

Best regards,
IJIES Editors.

[Kutipan teks disembunyikan]
[Kutipan teks disembunyikan]

Ubhara Surabaya

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

---

ijies2039: review result

4 pesan

Kei Eguchi <eguti@fit.ac.jp> 16 Januari 2019 pukul 08.58
Kepada: Amirullah Ubhara Surabaya <amirullah@ubhara.ac.id>

Dear Author(s),

Paper ID: ijies2039

It is our great pleasure to inform you that the contribution referenced above, for which you are listed as the corresponding author, has been accepted for the 2nd review of the IJIES journal.
Congratulations!

*Important:
Please send your "signed" copyright and the payment proof of your publishing fee within one month.
Otherwise, your paper will be withdrawn.
The payment method will be sent from paypal. (Please check your mailbox carefully.)

* Publication fee USD300: (13 pages)
= USD150 + USD150 (3 extra pages)

After we received these documents, the camera-ready version of your paper will be sent to you within a few weeks.
After your confirmation, the acceptance letter and receipt will be sent to you.

Best regards,
IJIES Editors.

Amirullah Ubhara Surabaya <amirullah@ubhara.ac.id> 16 Januari 2019 pukul 09.29
Kepada: Kei Eguchi <eguti@fit.ac.jp>
Cc: Kei Eguchi <eguti@fit.ac.jp>
Bcc: Amirullah Ubhara Surabaya <amirullah@ubhara.ac.id>

Dear Dr. Kei Aguchi,

Thanks a lot for your information.

I would process payment of Paper ID: ijies2039 at least in one week.

Best Regards,

Amirullah
Faculty of Engineering
Electrical Engineering
Universitas Bhayangkara Surabaya
Ahmad Yani 114 St, Surabaya
East-Java Province Indonesia
[Kutipan teks disembunyikan]

Amirullah Ubhara Surabaya <amirullah@ubhara.ac.id> 17 Januari 2019 pukul 01.36
Kepada: Kei Eguchi <eguti@fit.ac.jp>
Cc: Kei Eguchi <eguti@fit.ac.jp>

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

Dear Dr. Kei Eguchi,

Because I have no credit card, I would borrow and use the credit card from my friend to pay invoice of Paper ID: ijies2039.

Is it okay if I have to do that process?

This is my request and I will be happy if you fullfill it.

Amirullah
Faculty of Engineering
Electrical Engineering
Universitas Bhayangkara Surabaya
Ahmad Yani 114 St, Surabaya
East-Java Province Indonesia

[Kutipan teks disembunyikan]

Kei Eguchi <eguti@fit.ac.jp> 17 Januari 2019 pukul 06.37
Kepada: Amirullah Ubhara Surabaya <amirullah@ubhara.ac.id>

Dear author(s),

Thank you for your interest and support to IJIES.

Of course, you can.
After you finished your payment, please send the signed copyright form & your payment proof.

If you have any question, please contact us with your paper ID.

Best regards,
IJIES Editors

From: Amirullah Ubhara Surabaya <amirullah@ubhara.ac.id>
Sent: Thursday, January 17, 2019 3:37 AM
To: 江口 啓 <eguti@fit.ac.jp>
Subject: Re: ijies2039: review result

Dear Dr. Kei Eguchi,

Because I have no credit card, I would borrow and use the credit card from my friend to pay invoice of Paper ID: ijies2039.

Is it okay if I have to do that process?

This is my request and I will be happy if you fullfill it.

Amirullah
Faculty of Engineering
Electrical Engineering
Universitas Bhayangkara Surabaya
Ahmad Yani 114 St, Surabaya
East-Java Province Indonesia

Pada tanggal Rab, 16 Jan 2019 pukul 09.29 Amirullah Ubhara Surabaya <mailto:amirullah@ubhara.ac.id> menulis:
Dear Dr. Kei Aguchi,

Thanks a lot for your information.

I would process payment of Paper ID: ijies2039 at least in one week.

Best Regards,

Amirullah
Faculty of Engineering
Electrical Engineering
Universitas Bhayangkara Surabaya
Ahmad Yani 114 St, Surabaya
East-Java Province Indonesia

[Kutipan teks disembunyikan]

Ubhara Surabaya

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

Amirullah Ubhara Surabaya - You've just sent a payment to Intelligent Networks and Systems Society for invoice 0355

2 pesan

service@intl.paypal.com <service@intl.paypal.com>
Kepada: Amirullah Amirullah <amirullah@ubhara.ac.id>

22 Januari 2019 pukul 14.02

Amirullah Ubhara Surabaya - You've just made a payment to Intelligent Networks and Systems Society.

21 January 2019 23:01:35 PST

Transaction ID:
4VK14322HH0256901

PayPal

You've just made a 300,00 $ USD payment.

You made a payment to Intelligent Networks and Systems Society. It may take a few moments for this transaction to appear in your Activity page.

View Your Invoice

Invoice # 0355

Payment to:
Intelligent Networks and Systems Society
eguti@fit.ac.jp

Shipping address:

Universitas Bhayangkara Surabaya
Jl. Ahmad Yani 114
Surabaya EAST JAVA 60231
Indonesia

Description	Quantity	Price	Amount
Publication fee: Intelligent Networks and Systems Society (INASS) Publication fee	1	300,00 $ USD	300,00 $ USD

for the
International
Journal of
Intelligent
Engineering and
Systems (IJIES)

	Subtotal	300,00 $ USD
	Discount	0,00 $ USD
Total	300,00 $ USD	
Amount paid	300,00 $ USD	
Amount due	0,00 $ USD	
Payment method		
VISA x-3777	300,00 $ USD	

This transaction will appear on your card statement as PAYPAL *INTELLIGENT.

Amirullah Ubhara Surabaya <amirullah@ubhara.ac.id> 22 Januari 2019 pukul 16.08
Kepada: Kei Eguchi <eguti@fit.ac.jp>
Cc: ijies@inass.org
Bcc: Amirullah Ubhara Surabaya <amirullah@ubhara.ac.id>, Agus Kiswantono <kiswantono@gmail.com>, Eko Prasetyo <eko@ubhara.ac.id>

Dear Dr. Kei Eguchi,

Here I send you proof of payment and copyright transfer for the paper ID ijies2039 entiltled Comparative Performance of Mitigation Voltage Sag/Swell and Harmonics Using DVR-BES-PV System With MPPT-Fuzzy Mamdani/MPPT-Fuzzy Sugeno (Agus Kiswantono, Eko Prasetyo, Amirullah Amirullah).

My invoice number is #0355.

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

Best Regards,

Amirullah
Elect. Engineering
Faculty of Engineering

University of Bhayangkara Surabaya
[Kutipan teks disembunyikan]

---

3 lampiran

Invoice - 0355_Amirullah_IJIES_22 Jan 2019.pdf
40K

IJIES_Copyright_Form_Amirullah_22 Jan 2016_Paper ID IJIES2309.docx
22K

Copyright Form Amirullah 22 Jan 2019_ID Paper IJIES2039.pdf
94K

Ubhara Surabaya

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

---

ijies2039: acceptance letter

1 pesan

Kei Eguchi <eguti@fit.ac.jp> 22 Januari 2019 pukul 16.30
Kepada: Amirullah Ubhara Surabaya <amirullah@ubhara.ac.id>

Dear Author(s),

Paper ID: ijies2039

It is our great pleasure to inform you that the contribution referenced above, for which you are listed as the corresponding author, has been accepted for the IJIES journal.
Congratulations!

The camera-ready version of your paper will be sent to you within a few weeks.

----- Announcement -----
** Excellent Citation Award:

The Citation Award of IJIES is granted to an individual or group who has made significant and important contributions to the International Journal of Intelligent Engineering and Systems (IJIES).

Nomination criteria:
More than 15 citation counts are necessary within a year after paper publication.
(e.g. If your paper was published in 2018, more than 15 citation counts are necessary until 31/12/2019.)

How to apply "Excellent Citation Award":
To proof your citation counts, please submit "Author search result" of "Scopus Preview" to IJIES office. (Check https://www.scopus.com/)
* The citation is counted by using "Scopus" database.

For Excellnt Citation Award recipients:
Honorary certificate & Free Publication Charge will be provided to an individual or group.

Best regards,
IJIES Editors.

From: Amirullah Ubhara Surabaya <amirullah@ubhara.ac.id>
Sent: Tuesday, January 22, 2019 6:09 PM
To: 江口 啓 <eguti@fit.ac.jp>
Cc: ijies@inass.org
Subject: Fwd: Amirullah Ubhara Surabaya - You've just sent a payment to Intelligent Networks and Systems Society for invoice 0355

Dear Dr. Kei Eguchi,

Here I send you proof of payment and copyright transfer for the paper ID ijies2039 entiltled Comparative Performance of Mitigation Voltage Sag/Swell and Harmonics Using DVR-BES-PV System With MPPT-Fuzzy Mamdani/MPPT-Fuzzy Sugeno (Agus Kiswantono, Eko Prasetyo, Amirullah Amirullah).

My invoice number is #0355.

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

Best Regards,

Amirullah
Elect. Engineering
Faculty of Engineering
University of Bhayangkara Surabaya

---------- Forwarded message ---------
From: mailto:service@intl.paypal.com <mailto:service@intl.paypal.com>
Date: Sel, 22 Jan 2019 pukul 14.02
Subject: Amirullah Ubhara Surabaya - You've just sent a payment to Intelligent Networks and Systems Society for invoice 0355
To: Amirullah Amirullah <mailto:amirullah@ubhara.ac.id>

Amirullah Ubhara Surabaya - You've just made a payment to Intelligent Networks and Systems Society. ..

Amirullah Ubhara Surabaya - You've just made a payment to Intelligent Networks and Systems Society.

21 January 2019 23:01:35 PST
Transaction ID: https://www.paypal.com/id/cgi-bin/?cmd=_pay-inv&id=4VK14322HH0256901&ppid=PPC000954&cnac=ID&rsta=en_ID(en_C2)&cust=SQXKMEHM9S2N6&unptid=a2125ac0-1e13-11e9-834a-101f7436f90c&t=&cal=3cbb9af8b870&calc=3cbb9af8b870&calf=3cbb9af8b870&unp_tpcid=invoice-buyer-payment-notification&page=main:email&pgrp=main:email&e=op&mchn=em&s=ci&mail=sys

Amirullah Ubhara Surabaya - You've just made a payment to Intelligent Networks and Systems Society.

You've just made a 300,00 $ USD payment.

You made a payment to Intelligent Networks and Systems Society. It may take a few moments for this transaction to appear in your Activity page.

https://www.paypal.com/cgi-bin/?ppid=PPC000954&cnac=ID&rsta=en_ID(en_C2)&cust=SQXKMEHM9S2N6&unptid=a2125ac0-1e13-11e9-834a-101f7436f90c&t=&cal=3cbb9af8b870&calc=3cbb9af8b870&calf=

3cbb9af8b870&unp_tpcid=invoice-buyer-payment-notification&page=main:email&pgrp=main:email&e=op&mchn=em&s=ci&mail=sys
Invoice # 0355
Payment to:
Intelligent Networks and Systems Society
mailto:eguti@fit.ac.jp

Shipping address:
Universitas Bhayangkara Surabaya
Jl. Ahmad Yani 114
Surabaya EAST JAVA 60231
Indonesia

Description
Quantity
Price
Amount
Publication fee: Intelligent Networks and Systems Society (INASS)
Publication fee for the International Journal of Intelligent Engineering and Systems (IJIES)
1
300,00 $ USD
300,00 $ USD

Subtotal
300,00 $ USD

Discount
0,00 $ USD

Total
300,00 $ USD

Amount paid
300,00 $ USD

Amount due
0,00 $ USD

Payment method

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300,00 $ USD

This transaction will appear on your card statement as PAYPAL *INTELLIGENT.

Please don't reply to this email. To get in touch with us, click https://www.paypal.com/selfhelp/home?ppid=PPC000954&cnac=ID&rsta=en_ID(en_C2)&cust=SQXKMEHM9S2N6&unptid=a2125ac0-1e13-11e9-834a-101f7436f90c&t=&cal=3cbb9af8b870&calc=3cbb9af8b870&calf=3cbb9af8b870&unp_tpcid=invoice-buyer-payment-notification&page=main:email&pgrp=main:email&e=op&mchn=em&s=ci&mail=sys.

---

2 lampiran

(ijies2039) Acceptance Letter.pdf
138K

(ijies2039) Receipt.pdf
139K

Ubhara Surabaya

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

---

ijies2039: acceptance letter

1 pesan

Kei Eguchi <eguti@fit.ac.jp> 22 Januari 2019 pukul 16.30
Kepada: Amirullah Ubhara Surabaya <amirullah@ubhara.ac.id>

Dear Author(s),

Paper ID: ijies2039

It is our great pleasure to inform you that the contribution referenced above, for which you are listed as the corresponding author, has been accepted for the IJIES journal.
Congratulations!

The camera-ready version of your paper will be sent to you within a few weeks.

----- Announcement -----
** Excellent Citation Award:

The Citation Award of IJIES is granted to an individual or group who has made significant and important contributions to the International Journal of Intelligent Engineering and Systems (IJIES).

Nomination criteria:
More than 15 citation counts are necessary within a year after paper publication.
(e.g. If your paper was published in 2018, more than 15 citation counts are necessary until 31/12/2019.)

How to apply “Excellent Citation Award”:
To proof your citation counts, please submit “Author search result” of “Scopus Preview” to IJIES office. (Check https://www.scopus.com/)
* The citation is counted by using “Scopus” database.

For Excellnt Citation Award recipients:
Honorary certificate & Free Publication Charge will be provided to an individual or group.

Best regards,
IJIES Editors.

From: Amirullah Ubhara Surabaya <amirullah@ubhara.ac.id>
Sent: Tuesday, January 22, 2019 6:09 PM
To: 江口 啓 <eguti@fit.ac.jp>
Cc: ijies@inass.org
Subject: Fwd: Amirullah Ubhara Surabaya - You've just sent a payment to Intelligent Networks and Systems Society for invoice 0355

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3cbb9af8b870&unp_tpcid=invoice-buyer-payment-notification&page=main:email&pgrp=main:email&e=op&mchn=em&s=ci&mail=sys
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Ubhara Surabaya

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

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10 pesan

Kei Eguchi <eguti@fit.ac.jp> 22 Januari 2019 pukul 16.31
Kepada: Amirullah Ubhara Surabaya <amirullah@ubhara.ac.id>

Dear author(s),

Thank you for your interest and support to IJIES.
I'd like to send the camera-ready version of your final manuscript.
Please check and confirm the attached file, and send the check result within 5 days.
Otherwise, your paper will not be published on schedule.

If you have any question, please contact us with your paper ID.

Best regards,
IJIES Editors

From: Amirullah Ubhara Surabaya <amirullah@ubhara.ac.id>
Sent: Tuesday, January 22, 2019 6:09 PM
To: 江口 啓 <eguti@fit.ac.jp>
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notification&page=main:email&pgrp=main:email&e=op&mchn=em&s=ci&mail=sys.

2019043022.pdf
1523K

Amirullah Ubhara Surabaya <amirullah@ubhara.ac.id> 22 Januari 2019 pukul 21.57
Kepada: Kei Eguchi <eguti@fit.ac.jp>
Cc: Kei Eguchi <eguti@fit.ac.jp>
Bcc: Amirullah Ubhara Surabaya <amirullah@ubhara.ac.id>, Agus Kiswantono <kiswantono@gmail.com>, Eko Prasetyo <eko@ubhara.ac.id>

Dear Prof. Dr. Kei Eguchi,

Here I attach you final check (revision) of camera ready version of paper ID ijies2039.

It has 7 small revisions marked on balloon and yellow highlight.

The paper entiltled "Comparative Performance of Mitigation Voltage Sag/Swell and Harmonics Using DVR-BES-PV System With MPPT-Fuzzy Mamdani/MPPT-Fuzzy Sugeno" (Agus Kiswantono, Eko Prasetyo, Amirullah Amirullah).

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

Best Regards,

Amirullah
[Kutipan teks disembunyikan]

2019043022_Final Author Check (Revision) ID ijies2039_22 Jan 2019.pdf
1479K

Kei Eguchi <eguti@fit.ac.jp> 23 Januari 2019 pukul 12.25
Kepada: Amirullah Ubhara Surabaya <amirullah@ubhara.ac.id>

Dear author(s),

Thank you for your confirmation.
You finished all processes.
Please see the attached file.

On 28/2/2018 (tentative), your paper will appear in the INASS HP.
Appreciate your patiently wait.

P.S.
We cannot understand your request.
>7. Please giive (show) the line below AI and Artificial Intelligent in Table 1. Abbreviation.
[Kutipan teks disembunyikan]
[Kutipan teks disembunyikan]
mailto:mailto:eguti@fit.ac.jp
[Kutipan teks disembunyikan]

2019043022.pdf
1522K

Amirullah Ubhara Surabaya <amirullah@ubhara.ac.id> 23 Januari 2019 pukul 15.05
Kepada: Kei Eguchi <eguti@fit.ac.jp>
Cc: Amirullah Ubhara Surabaya <amirullah@ubhara.ac.id>
Bcc: Agus Kiswantono <kiswantono@gmail.com>, Eko Prasetyo <eko@ubhara.ac.id>

Dear Prof. Dr. Kei Aguchi

I am sorry because making you difficult to understand about revised point of 7.

I means the line in bottom row in Table 1 cannot be seen before.

But now the line is visible fully.

Next for last revision I hope you remove underline below "AI" (balloon 1), "A" (balloon 2), and "I" (balloon 3).

I also attach you last PDF revised file.

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

Best Regards,

Amirullah

[Kutipan teks disembunyikan]

2019043022_Final Author Check (Revision) ID ijies2039_23 Jan 2019.pdf
1465K

Kei Eguchi <eguti@fit.ac.jp> 23 Januari 2019 pukul 15.39
Kepada: Amirullah Ubhara Surabaya <amirullah@ubhara.ac.id>

Thank you.
[Kutipan teks disembunyikan]
[Kutipan teks disembunyikan]
[Kutipan teks disembunyikan]
mailto:mailto:mailto:mailto:eguti@fit.ac.jp
[Kutipan teks disembunyikan]

2019043022.pdf
1522K

Amirullah Ubhara Surabaya <amirullah@ubhara.ac.id> 23 Januari 2019 pukul 15.52
Kepada: Kei Eguchi <eguti@fit.ac.jp>
Cc: Amirullah Ubhara Surabaya <amirullah@ubhara.ac.id>
Bcc: Agus Kiswantono <kiswantono@gmail.com>, Eko Prasetyo <eko@ubhara.ac.id>

Dear Prof. Dr. Kei Aguchi,

Thanks a lot of for your fast response.

Amirullah
Faculty of Engineering
University of Bhayangkara Surabaya
East-Java Indonesia
[Kutipan teks disembunyikan]

Amirullah Ubhara Surabaya <amirullah@ubhara.ac.id> 29 Januari 2019 pukul 08.39

Kepada: Kei Eguchi <eguti@fit.ac.jp>
Cc: Amirullah Ubhara Surabaya <amirullah@ubhara.ac.id>
Bcc: Agus Kiswantono <kiswantono@gmail.com>, Eko Prasetyo <eko@ubhara.ac.id>

Dear Prof. Dr. Kei Eguchi
Ijies Editor in Chief

I am sorry Prof I would ask you when my paper ID ijies2039 avialable on http://www.inass.org/ContentsPapers.html.

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

Amirullah
Faculty of Engineering
University of Bhayangkara Surabaya
[Kutipan teks disembunyikan]

Kei Eguchi <eguti@fit.ac.jp> 29 Januari 2019 pukul 10.09
Kepada: Amirullah Ubhara Surabaya <amirullah@ubhara.ac.id>

Please read the following e-mail.

-----Original Message-----
From: 江口 啓
Sent: Wednesday, January 23, 2019 2:25 PM
To: 'Amirullah Ubhara Surabaya' <amirullah@ubhara.ac.id>
Subject: RE: ijies2039: camera-ready version

Dear author(s),

Thank you for your confirmation.
You finished all processes.
Please see the attached file.

On 28/2/2018 (tentative), your paper will appear in the INASS HP.
Appreciate your patiently wait.

P.S.
We cannot understand your request.
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If you have any question, please contact us with your paper ID.

Best regards,
IJIES Editors

From: Amirullah Ubhara Surabaya <amirullah@ubhara.ac.id>
Sent: Tuesday, January 29, 2019 10:40 AM
To: 江口 啓 <eguti@fit.ac.jp>
Cc: Amirullah Ubhara Surabaya <amirullah@ubhara.ac.id>
Subject: Re: ijies2039: camera-ready version

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Amirullah
Faculty of Engineering
University of Bhayangkara Surabaya

Pada tanggal Rab, 23 Jan 2019 pukul 15.52 Amirullah Ubhara Surabaya <mailto:amirullah@ubhara.ac.id> menulis:

Dear Prof. Dr. Kei Aguchi,

Thanks a lot of for your fast response.

Amirullah
Faculty of Engineering
University of Bhayangkara Surabaya
East-Java Indonesia

Pada tanggal Rab, 23 Jan 2019 pukul 15.39 Kei Eguchi <mailto:eguti@fit.ac.jp> menulis:
Thank you.

[Kutipan teks disembunyikan]
[Kutipan teks disembunyikan]
[Kutipan teks disembunyikan]
mailto:mailto:mailto:mailto:mailto:mailto:mailto:eguti@fit.ac.jp
[Kutipan teks disembunyikan]

Amirullah Ubhara Surabaya <amirullah@ubhara.ac.id> 29 Januari 2019 pukul 11.35
Kepada: Kei Eguchi <eguti@fit.ac.jp>
Cc: Amirullah Ubhara Surabaya <amirullah@ubhara.ac.id>
Bcc: Agus Kiswantono <kiswantono@gmail.com>, Eko Prasetyo <eko@ubhara.ac.id>

Dear Prof. Dr. Kei Aguchi,

Oh I am apologize to you, because I though before date of publication was yesterday (28/1/2019).

Amirullah

University of Bhayangkara Surabaya
[Kutipan teks disembunyikan]

Kei Eguchi <eguti@fit.ac.jp> 29 Januari 2019 pukul 15.06
Kepada: Amirullah Ubhara Surabaya <amirullah@ubhara.ac.id>

Dear authors,

Our journal is bi-monthly journal.
On 28/2/2018 (tentative), your paper will appear in the INASS HP.
Thank you for your understanding.

From: Amirullah Ubhara Surabaya <amirullah@ubhara.ac.id>
Sent: Tuesday, January 29, 2019 1:36 PM
To: 江口 啓 <eguti@fit.ac.jp>
Cc: Amirullah Ubhara Surabaya <amirullah@ubhara.ac.id>
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Amirullah

University of Bhayangkara Surabaya

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Thank you.

[Kutipan teks disembunyikan]
[Kutipan teks disembunyikan]
[Kutipan teks disembunyikan]
mailto:mailto:mailto:mailto:mailto:mailto:mailto:mailto:mailto:mailto:mailto:eguti@fit.ac.jp
[Kutipan teks disembunyikan]

Lampiran 2

Bukti Pendukung

Lampiran 2.1

Naskah Makalah Submitted

Received: January 1, 2017
1

International Journal of
Intelligent Engineering & Systems

http://www.inass.org/

Comparative Performance of Mitigation Voltage Sag/Swell and Harmonics Using DVR-BES-PV System With MPPT-Fuzzy Mamdani/MPPT-Fuzzy Sugeno

Agus Kiswantono[1], Eko Prasetyo[2], Amirullah[1*]

[1]*Electrical Engineering Study Program Faculty of Engineering, University of Bhayangkara Surabaya*
Surabaya, Indonesia
[2]*Informatics Engineering Study Program Faculty of Engineering, University of Bhayangkara Surabaya*
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Abstract: The paper presents comparative performance between Maximum Power Point Tracking-Fuzzy Mamdani (MPPT-FM) and MPPT-Fuzzy Sugeno (FS) methods as controller on Photovoltaic (PV) output power using Dynamic Voltage Restorer-Battery Energy Storage-PV (DVR-BES-PV) system connected to three phase three wire (3P3W) distribution network. The combination of DVR-BES-PV system using two methods is used in order to mitigate voltage sag/swell and harmonics on load bus. The PV is used as an alternative DC voltage source to charge BES when its capacity decreases and provides active power needed to compensate for sag/swell. In nine sag/swell disturbances scenario, MPPT-FM is able to give better performance in percentage of sag/swell on load voltage than MPPT-FS. Both methods are also able to result percentage of sag/swell on load voltage under IEEE 1159. In sag voltage, MPPT-FM is able to result an average Total Harmonics Distortion (THD) of load voltage higher than MPPT-FS. Otherwise in swell voltage, MPPT-FM is able to result an average THD of load voltage smaller than MPPT-FS. The average THD of load voltage using MPPT-FM/MPPT-FS in nine swell voltage disturbances scenario on source bus, is smaller than sag voltage and it has met the limits prescribed IEEE 519. This research is simulated using Matlab/Simulink environment.

Keywords: MPPT-FM, MPPT-FS, Sag/Swell, Harmonics, THD, DVR, BES, PV

1. Introduction

The diminishing of fossil energy sources and increasing concerns about environmental impacts have caused renewable energy (RE) sources i.e. PV and wind to develop into alternative energy of power generation. The electrical power produced by PV is direct current (DC), so it requires an inverter before it is operated and connected to distribution system (grid). The disadvantage of PV is beside able to supply power to grid, it also generates harmonics due to presence of voltage source inverter (VSI) type filter as a medium to convert DC to AC voltage so that it can reduce power quality. On the other hand, with increasing sensitive load penetration, causing power quality problems in modern distribution systems has increased significantly. The most serious and frequent disturbances in grid voltage are sag, swell, and short circuit. The sag is a decrease in rms voltage between 10-90% which lasts from one half cycle to one minute. The swell is an increase in the source rms voltage in a short time interval whose values range from 1.1 pu to 1.8 p.u from nominal source voltage. The device that is capable of effectively and comprehensively overcoming sag/swell disturbance is DVR. Research on sag compensation using DVR with unit vector template generation (UVTG)

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method has been done [1]. DVR is able to compensate for balanced and unbalanced sag voltage and inject the desired voltage component to quickly repair a number of interference anomalies at the source voltage to keep load voltage balanced and constant at nominal value.

The comparative analysis of three compensation techniques i.e. phase-by-method compensation, pre-dip compensation method (called large voltage difference compensation), and intelligent phase compensation method has been investigated [2]. A model for DVR control independently has been proposed [3]. The three of three phase harmonics filters (double tuned) were used to migrate harmonics generated by a voltage source converter (VSC). The low DVR rating was able to compensate for sag, swell, and reduce THD voltage on load bus according to IEEE-519. DVR performance on sag voltage and load voltage harmonics using Sinusoidal Pulse control Width Modulation (SPWM) and Space Vector Pulse Width Modulation (SVPWM) have been done [4]. The Synchronous Reference Frame (SRF) method has been used to detect sag and generate modulation signals. The load voltage THD using the SVPWM method was smaller than SPWM.

The grid integration system connected PV system with self supported DVR has been proposed [5]. The system was called a "six-port converter," whole consists of nine semiconductor switches, reduced from 12 previous semiconductors. The configuration was able to operate in different modes based on grid conditions and PV power. The research were conducted on normal grid mode, interference mode, sag mode, and non-active PV mode. PV based DVR model to overcome sag/swell voltage and outages in single phase low voltage housing distribution systems have been proposed [6]. The simulation shows that DVR-based PV with fuzzy logic control (FLC) is able to provide better dynamic performance in overcoming voltage variations. DVR was operated in standby, active, bypass, power saver mode. DVR performance to mitigate sag voltage and reduce the THD of load voltage has been investigated [7]. The sag compensation on balanced and unbalanced disturbances conditions with variations in source voltage level sag uses PI and FLC method respectively on series active filter of DVR control. The simulation showed that FLC was able to maintain load voltage constant at nominal value and reduce load voltage THD better than PI.

Efficient FLC based on the power management scheme on the DVR in mitigating a number of voltage disturbances has been proposed [8]. The simulation showed that proposed model was efficiently able to maintain DVR output power below the predetermined value and reduce disturbance according to the priority given. The design and analysis of dynamic FLC on DVR is presented and expanded to perform fast error detection. The combination of DVR control methods using FLC and modulation of PWM carriers in an inverter circuit to detect voltage disturbances quickly has been investigated [9]. The proposed model is able to achieve superior performance for balanced and unbalanced sag/swell voltage mitigation. The start and end times of sag/swell voltage can be quickly detected and without oscillation. Fast switching capabilities can also be used in static transfer switches to improve power system reliability. Analysis of sag/swell voltage compensation using DVR and PV systems supported by energy storage elements (battery) has been carried out [10]. The PV system uses MPPT control with an incremental conductance (IC) algorithm as a RE source, which functions to inject reactive power during disturbance. Otherwise the energy storage (battery) element was used to improve system reliability. Integration of solar PV, battery, and DVR during dynamic disturbance conditions in distribution system has been done [11]. The solar PV system using boost converter was implemented using MPPT with IC algorithm. The PV system was supplied in two ways i.e. to meet load demands and maintain the DC link voltage of DVR in voltage sources converter VSC. The sensitive load and grid voltage were balanced by injecting voltage in series with distribution line.

The DVR consists of injection transformers, filter circuits, three-phase series active filters, DC source voltage, and energy storage. The energy storage commonly used is DC-link capacitor. The disadvantage of this device has limited energy storage capacity. In order to overcome these problems, this paper proposes BES supplied by PV to mitigate sag/swell and harmonics on low voltage distribution network. This combination is called DVR-BES-PV system and installed on three phase three wire (3P3W) distribution network to maintain voltage on sensitive load. The advantage of BES has a larger storage capacity than capacitor. Moreover, PV is used as an alternative DC voltage source to charge BES when its capacity decreases and provides active power needed to compensate for sag/swell. The UVTG method is used to control series active filter in DVR when it injects compensation voltage during voltage sag/swell disturbance. The PV also helps with the self charging process of the system during uninterrupted condition (stand by mode).

This paper also proposes and compares two methods i.e. FM and FS as MPPT control on PV. The PV is connected to 3P3W of 380 V and 50 Hz on low voltage distribution line through DVR-BES system. The nominal percentage of sag voltage disturbances scenarios is nine disturbances started from 10% to 90%. The swell voltage are the same number strarted from 110% to 190%. So that the total number of sag/swell voltage scenario using both methods are 18 disturbances scenario. The combination of the DVR-BES-PV system uses two methods connected to a 3P3W system is used in order to mantain the voltage at sensitive load remain constant. This research are performed on the percentage of sag/swell load voltage, average THD of source voltage, and average THD of load voltage in each MPPT methods and disturbances scenario. Furthermore the results were compared and validated with IEEE 1159 and IEEE 519. This paper is presented as follow. Section 2 describes proposed method and model of DVR-BES-PV system. Section 3 shows results and discusions about performance of percentage and average THD load voltage of sag/swell. Finally, this paper in concluded in Section 4.

2. Reseach Method

2.1. Proposed Method

Fig. 1 shows DVR proposed model using BES supplied by PV. The proposed DVR model is located between source or point common coupling (PCC) bus and load bus which it is connected to sensitive load. The PCC bus is then connected to a 3P3W of 380 Volt 50 Hz low voltage distribution line. The DVR consists of injection transformers, filter circuit, active filter series, DC voltage sources, and energy storage. The energy storage which is commonly used is DC link capacitor. The disadvantage of this device has limited energy storage capacity. The series active filter on DVR is controlled by UVTG method to mantain magnitude of voltage between PCC bus and load bus remain constant, balanced, and distortion free. The UVTG method is also used to generate trigger pulses in PWM circuit of six pulses by the active series filter, so as able to generate injection voltage to compensate for sag/swell voltage on load bus.

This paper proposes model of DVR-BES system supplied by 0.6 kW PV system. The PV generator produces an output voltage and is an input for the DC/DC boost converter. There are two FLC method proposed in MPPT of PV system i.e. MPPT FM and MPPT-FS respectively. The MPPT-FM/MPPT-FS helps single phase PV generate MPP in DVR-BES-PV system output. The DC output voltage of the PV is relatively low and then it is raised by a DC/DC boost converter at the appropriate voltage level in order to generate active power for BES charging process. The BES has a larger storage capacity than capacitor, otherwise PV are used as an alternative DC voltage source to charge BES when its capacity decreases. The PV also provides active power to compensate for sag/swell voltage. The PV also helps self charging process of BES during uninterrupted conditions (stand by mode). Fig. 2 shows PV system using MPPT-FM/MPPT-FS method connected to DC load.

The analysis of the proposed model is investigated by determination of nine sag/swell disturbances scenario on source bus in the 3P3W system using the DVR-BES-PV. Each sag/swell disturbances on source bus uses MPPT-FM and MPPT-FS respectively. The nominal percentage of sag voltage disturbance are 10%, 20%, 30%, 40%, 50%, 60%, 70% and 80%. Whereas, swell voltage disturbances are 110%, 120%, 130%, 140%, 150%, 160%, 170%, 180%, and 190%. So that the total number of sag/swell voltage scenarios using MPPT-FM and MPPT-FS each is 18 disturbances scenario. The combination of DVR-BES-PV system which uses MPPT-FM/MPPT-FS is installed on a 3P3W system to mantain voltage in sensitive load constant. The analysis of this paper is performed on percentage of sag/swell and average THD of load voltage in each MPPT method and disturbances scenario. Then, the results are compared and validated with IEEE 1159 for voltage disturbance standards and IEEE 519 for power quality standards [12-16]. Simulation and analysis of this paper using Matlab/Simulink. Parameters for the proposed model are shown in Appendix. Table 1 shows abbreviation in this paper.

Table 1. Abbreviation

Symbol	Description
MPPT	Maximum Power Point Tracking
FM	Fuzzy Mamdani
FS	Fuzzy Sugeno
FIS	Fuzzy Inference System
MFs	Membership Functions
FLC	Fuzzy Logic Controller
THD	Total Harmonics Distortion
DVR	Dynamic Voltage Restorer
BES	Battery Energy Storage
PV	Photovoltaic
RE	Renewable Energy
UVTG	Unit Vector Template Generation

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PWM	Pulse With Modulation
3P3W	Three Phase Three Wire

PCC	Point Common Coupling

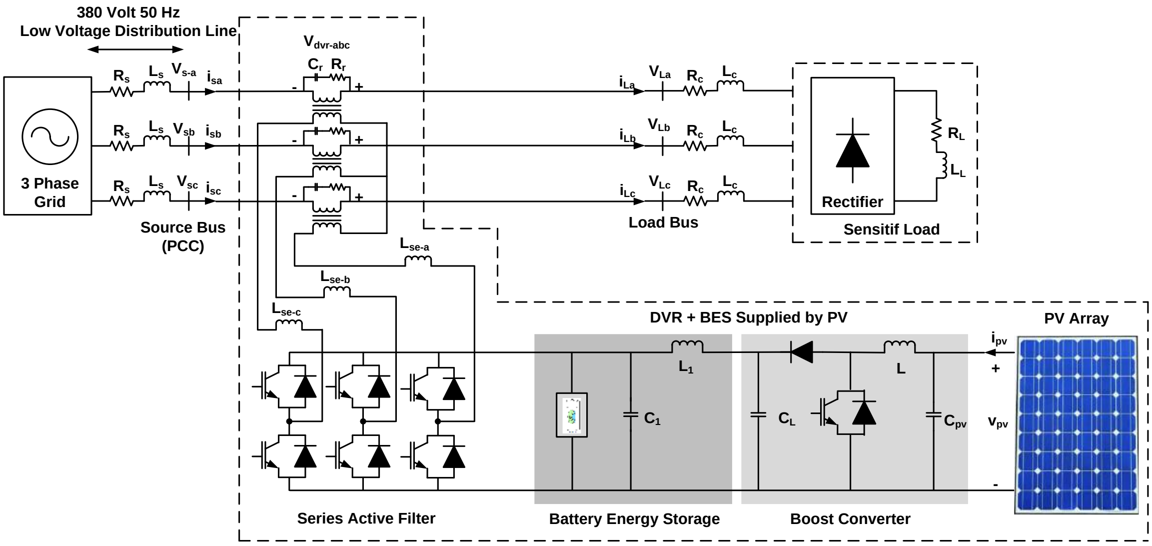

Figure 1. Proposed model of DVR using BES supplied by PV system

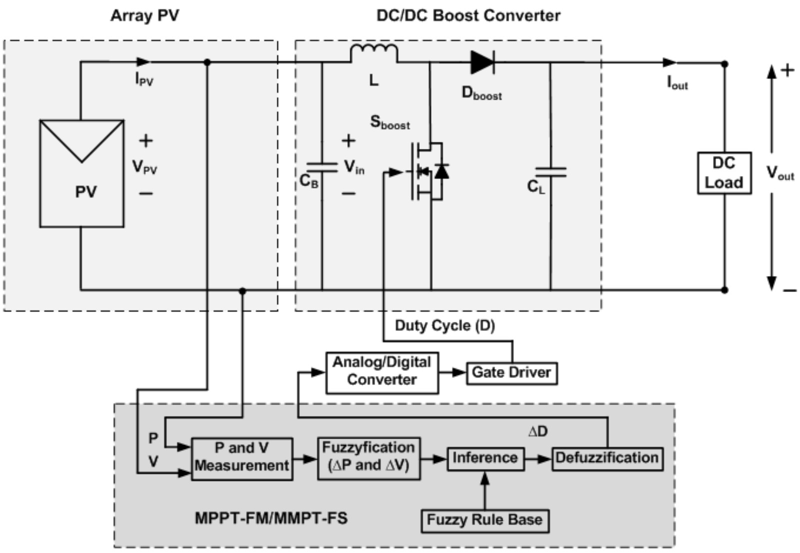

Figure 2. PV system using MPPT-FM/MPPT-FS method connected to DC load

2.2. Modelling of PV Array

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

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

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. The values of I_{pv} and I_o are calculated as following Eq. (2) and Eq. (3):

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

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

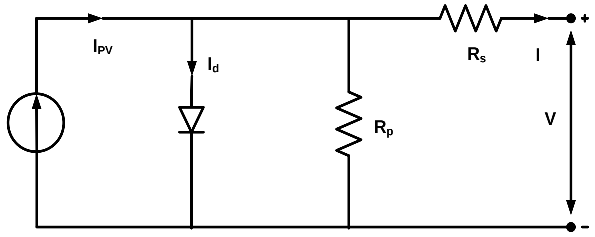

Figure 3. Equivalent circuit of solar panel

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 the variations of atmospheric conditions. By using Eq. (4) and Eq. (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. UVTG Control on Series Active Filter

The main function of series active filter is the sensitive load protection against a number of voltage distrubances at source bus. The control strategy algorithm of the source and load voltage in series active filter is shown in Fig 4. It extracts the UVTG from the distorted input supply. Furthermore, the templates are expected to be ideal sinusoidal signal with unity amplitude. The distorted supply voltages are measured and divided by peak amplitude of fundamental input voltage V_m given in Eq.(6) [18].

$$V_m = \sqrt{\frac{2}{3}\left(V_{sa}^2 + V_{sb}^2 + V_{sc}^2\right)} \tag{6}$$

A three phase locked loop (PLL) is used in order to generate sinusoidal unit vector templates with a phase lagging by the use of sinus function. The reference load voltage signal is determined by multiplying the unit vector templates with the peak amplitude of the fundamental input voltage V_m. The load reference voltage ($V_{La}{}^*$, $V_{Lb}{}^*$, $V_c{}^*$) is then compared to the sensed load voltage (V_{La}, V_{Lb}, V_{Lc}) by a PWM controller used to generate the desired trigger signal on series active filter.

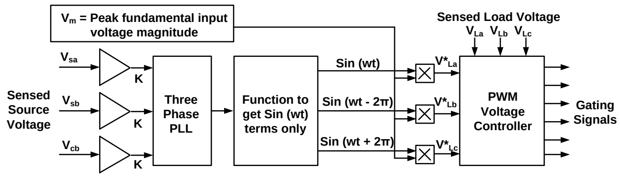

Figure 4. UVTG control of series active filter

2.4. Voltage Sag/Swell

The voltage sag is defined as a decrease in the value of rms voltage between 10-90% which goes on from one half cycle to one minute. The voltage sag can affect to the phase or amplitude. The most voltages sag occurs caused by a single phase to ground short circuit. An unbalanced short circuit can trigger an unbalanced phase and shift it from its nominal value. The starting of motor with high power also can generate voltage sag. The amplitude of the voltage sag depends on several factors i.e. type, location, and impedance disturbance. The voltage sag in each busbar is different depends on location of disturbance. The duration of sag is determined by duration of protection clearing time i.e. the extent to which voltage sag is able to be removed.

The voltage swell is an increase in source rms voltage in short time intervals whose value ranges from 1.1 pu to 1.8 p.u from nominal source voltage. Although the duration time of voltage sag/swell is short, the interference can affect sensitive loads such as the computers, the programmable logic controllers (PLCs) and the variable speed drives (VSDs) on motor and simultaneously reducing efficiency of these devices. The DVR is a special power electronics device used to reduce voltage sag/swell. The DVR is able to protect sensitive loads that may be drastically affected by voltage fluctuations in the distribution system [19]. The recommended standard of practice on monitoring voltage sag/swell as the part of electric power quality parameters is IEEE 1159-1995 [20]. This standard presents definition and table of voltage sag/voltage base on catagories (instantaoeous, momentary, temporary) typical duration, and typical magnitude. The percentage of voltage sag is formulated in Eq. (7) [21] and with the same prosedur, the authors propose Eq. (8) for percentage of voltage swell.

$$Sag(\%) = \frac{Vpre\ sag - Vsag}{Vpre\ sag} \tag{7}$$

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$$Swell(\%) = \frac{|Vpre\,swell - Vswell|}{Vpre\,swell} \quad (8)$$

2.5. MPPT-FM and MPPT-FS

The initial research is to determine value of duty cycle (D) with a variable step to control DC/DC boost converter circuit using MPPT algorithm on PV power output. MPPT has been developed. MPPT searchs for the maximum power independent based on environmental conditions, follows changes in solar radiation and temperature, as well as maintains PV output voltage remains constant at maximum value. In this paper FLC method is proposed as MPPT control in PV panel. The fuzzy inference system (FIS) used in this research are FM and FS respectively.

The difference between FM and FM is how to determine the output crips generated from fuzzy inputs. The FM uses a technique of fuzzy output defuzzification, while FS uses weighted average to compute output crips. The ability to express and interpret on FM output is lost in FS, because the consequents of rules are not fuzzy. However FS has a better processing time because weighted average replaces defuzzification process which takes a relatively long time. Because the basic nature of rules that can be interpreted and intuitively, FM can be widely used especially for decision support applications. The FM has an output membership functions (MFs), while FS has no output MFs [22].

MPPT-FLC with FM and FS FIS method respectively is applied by determining input variables, namely fuzzy control output of voltage (V) and power (P) of PV, seven linguistic variables fuzzy sets, fuzzy operating system block (fuzzyfication, fuzzy rule base, and defuzzyfication), function delta voltage (ΔV) and delta power (ΔP) during fuzzfication, a table fuzzy rule base, crisp values to determine delta duty-cycle (ΔD) in defuzzification phase with variable step to control DC/DC boost converter circuit. Fig. 4 shows MPPT-FLC using Mamdani/Sugeno FIS.

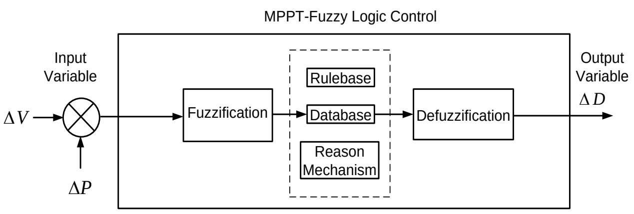

Figure 5. MPPT-Fuzzy Mamdani/MPPT Fuzzy Sugeno

In the fuzzification phase shown in Fig. 5, a number of input variables ΔV and ΔP are calculated and converted into a linguistic variable based on the subset ΔV and ΔP called MFs. The input of ΔV and ΔP are designed to use seven variable fuzzy sets i.e. PB (Positive Big), PM (Positive Medium), PS (Positive Small), Z (Zero), NS (Negative Small), NM (Negative Medium), and Negative Big (NB). The delta voltage (ΔV) and delta power (ΔP) are proposed as input variables. While output variable is duty cycle change value (ΔD). The input MFs of MPPT-FM and MPPT-FS are same in Max-Min but output MFs of them is different. MPPT-FM has MFs in Max-Min but MPPT-FS has MFs in constant [0,1]. The MFs of MPPT-FM input and output are presented with triangle and trapezoid. The value of ΔV range from -10 to 10, ΔP from -10 to 10, and ΔD from -5 to 5. The output MFs of MPPT-FS is ΔD [0,11] from -5 to 5. The delta voltage and delta power for MPPT-FM/MPPT-FS are showed in Fig. 6 and Fig. 7. While delta duty cycle for MPPT-FM and MPPT-FS are showed in Fig. 8 and Fig. 9. Fig. 10 and Fig. 11 show surface view of MFs of MPPT-FM and MPPT-FS respectively.

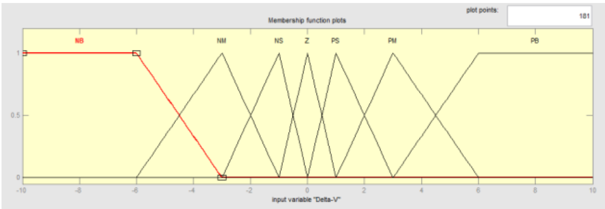

Figure 6. Input MFs of MPPT-FM/MPPT-FS (ΔV)

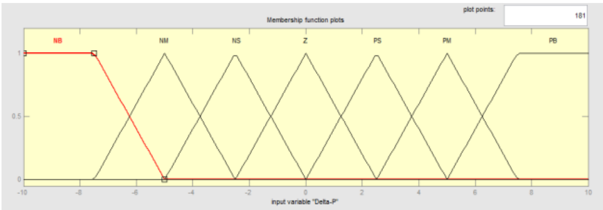

Figure 7. Input MFs of MPPT-FM/MPPT-FS (ΔP)

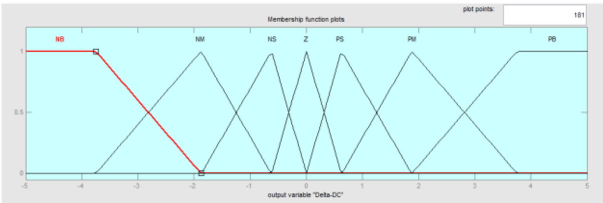

Figure 8. Output MFs of MPPT-FM (ΔD)

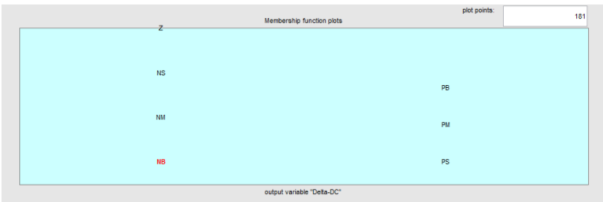

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Figure 9. Output MFs of MPPT-FS (ΔD)

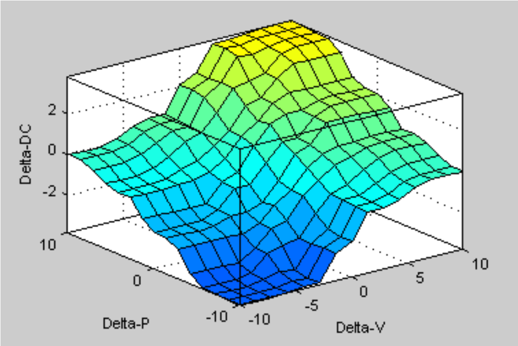


Figure 10. MFs survace view of MPPT-FM

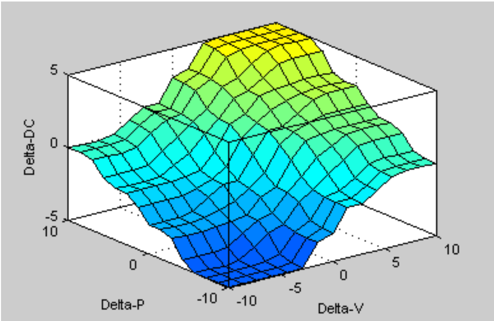


Figure 11. MFs survace view of MPPT-FS

The limit of input and output MFs, determined by prior knowledge of parameter variations. The FIS consists of three parts, namely rule base, database, and reasoning mechanism as shown in Fig. 5. After determine ΔV and ΔP, then both are converted into linguistic variables and use them as input functions for MPPT-FM/MPPT-FS. The output value is ΔD is generated using block inference and fuzzy rules as shown in Table 2. Finally defuzzyfication 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 PV connected to DVR-BES and 3P3W system.

Table 2. Fuzzy Rule Base

ΔV / ΔP	NB	NM	NS	Z	PS	PM	PB
PB	Z	PS	PS	PM	PM	PB	PB
PM	NS	Z	PS	PS	PM	PM	PB
PS	NS	NS	Z	PS	PS	PM	PM
Z	NM	NS	NS	Z	PS	PS	PM
NS	NM	NM	NS	NS	Z	PS	PS
NM	NB	NM	NM	NS	NS	Z	PS
NB	NB	NB	NM	NM	NS	NS	Z

3. Result and Discussion

The proposed model is analyzed through the determination of nine sag/swell voltage disturbance scenarios on source bus of 3P3W using DVR-BES-PV system. Each disturbances scenario on source bus uses MPPT-FM and MPPT-FS Methods. The nominal percentage of sag/swell voltage disturbances are nine so the total are 18 scenarios. The combination of DVR-BES-PV system circuit with MPPT-FM/MPPT-FS method is used to maintain voltage at sensitive load bus. By using Matlab/Simulink, the model then is run based on desired scenario to obtain source voltage (V_S) and load voltage (V_L) curves, percentage of sag voltage (%), and percentage of swell voltage (%) using Eq. (7) and Eq. (8) with average pre-sag/swell voltage equal as 310,234 V.

Furthermore, source voltage THD and load voltage THD in each phase, as well as their average values are also determined based on the curve obtained previously. The total duration simulation time occurs for 0.2 seconds with duration of sag/swell voltage disturbance between 0.06-0.14 second. The THD voltage in each phase is determined for one cycle starting at t = 0.1 seconds. The next step, percentage of sag/swell load voltage (%), average THD of source voltage (%), and average THD of load voltage (%) on each MPPT control methods and scenarios are presented in Table 3. By using the same procedure for swell voltage disturbances, the parameters and simulation results are also shown in Table 4. Fig. 12 and Fig. 13 present performance of sag and swell voltage using DVR-BES-PV with MPPT-FM/MPPT-FS.

Tabel 3. Percentage of voltage sag and voltage harmonics

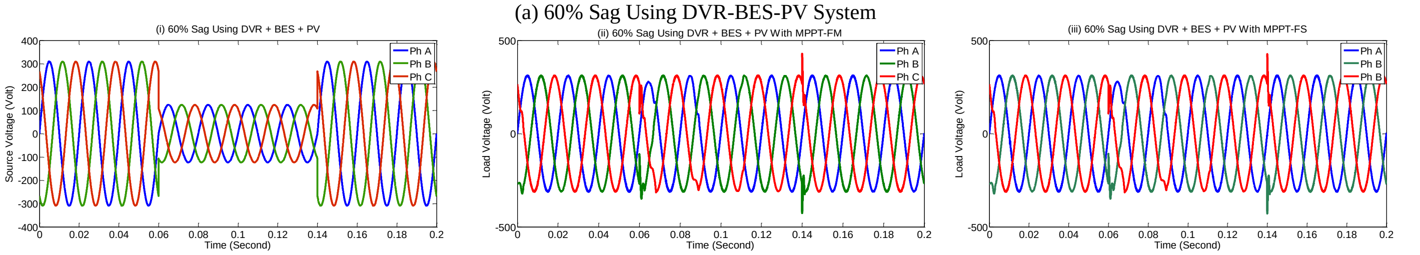
Sag Scenarios	**Source Voltage V_S (Volt)**			**Load Voltage V_L (Volt)**			**Sag (%)**	**Source Voltage THD (%)**				**Load Voltage THD (%)**			
	Ph A	**Ph B**	**Ph C**	**Ph A**	**Ph B**	**Ph C**		**Ph A**	**Ph B**	**Ph C**	**Avg**	**Ph A**	**Ph B**	**Ph C**	**Avg**
MPPT Fuzzy Mamdani															
10% Sag	278.3	278.3	278.3	310.2	310.2	310.2	**0.011**	0.21	0.21	0.21	0.21	0.37	0.37	0.37	**0.370**
20% Sag	247.3	247.3	247.3	310.2	310.2	310.2	**0.011**	0.23	0.23	0.23	0.23	0.37	0.37	0.37	**0.370**
30% Sag	216.2	216.2	216.2	310.2	310.3	310.2	**0.011**	0.27	0.27	0.27	0.27	0.38	0.36	0.36	**0.367**
40% Sag	185.2	185.2	185.2	310.2	310.2	310.2	**0.011**	0.31	0.31	0.31	0.31	0.37	0.36	0.35	**0.360**
50% Sag	154.2	154.2	154.2	310.2	309.9	309.9	**0.075**	0.37	0.37	0.38	0.37	0.38	0.42	0.41	**0.404**
60% Sag	123.2	123.2	123.2	310.1	307.4	307.4	**0.623**	0.47	0.46	0.47	0.47	0.38	2.09	2.07	**1.514**
70% Sag	92.13	92.16	92.17	309.9	301.7	302.2	**1.816**	0.61	0.60	0.62	0.61	0.43	5.35	5.27	**3.684**
80% Sag	61.11	61.14	61.18	308.2	295.6	293.4	**3.600**	0.88	0.89	0.94	0.91	2.46	8.51	8.00	**6.324**
90% Sag	30.10	30.13	30.19	305.6	288.4	283.1	**5.759**	1.72	1.80	1.90	1.81	6.35	13.14	11.46	**10.32**

MPPT Fuzzy Sugeno														
10% Sag	278.3	278.3	278.3	310.2	310.2	310.2	**0.011**	0.21	0.21	0.21	0.21	0.37	0.37	0.37	**0.370**
20% Sag	247.3	247.3	247.3	310.2	310.2	310.2	**0.011**	0.23	0.23	0.23	0.23	0.37	0.37	0.37	**0.370**
30% Sag	216.2	216.2	216.2	310.2	310.2	310.2	**0.011**	0.27	0.27	0.27	0.27	0.38	0.38	0.36	**0.374**
40% Sag	185.2	185.2	185.2	310.2	310.2	310.2	**0.011**	0.31	0.31	0.31	0.31	0.38	0.36	0.34	**0.360**
50% Sag	154.2	154.2	154.2	310.1	310.0	309.9	**0.076**	0.37	0.37	0.38	0.37	0.38	0.37	0.39	**0.380**
60% Sag	123.2	123.2	123.2	310.0	307.7	307.6	**0.581**	0.47	0.46	0.47	0.47	0.40	1.75	1.73	**1.294**
70% Sag	92.13	92.16	92.17	309.9	301.6	302.2	**1.826**	0.61	0.60	0.63	0.61	0.44	5.41	5.34	**3.730**
80% Sag	61.11	61.14	61.18	308.1	295.6	293.5	**3.600**	0.88	0.89	0.94	0.91	2.23	8.52	2.23	**4.327**
90% Sag	30.10	30.13	30.19	304.9	288.6	283.5	**5.770**	1.71	1.80	1.88	1.80	6.38	12.87	11.17	**10.14**

Tabel 4. Percentage of voltage swell and voltage harmonics

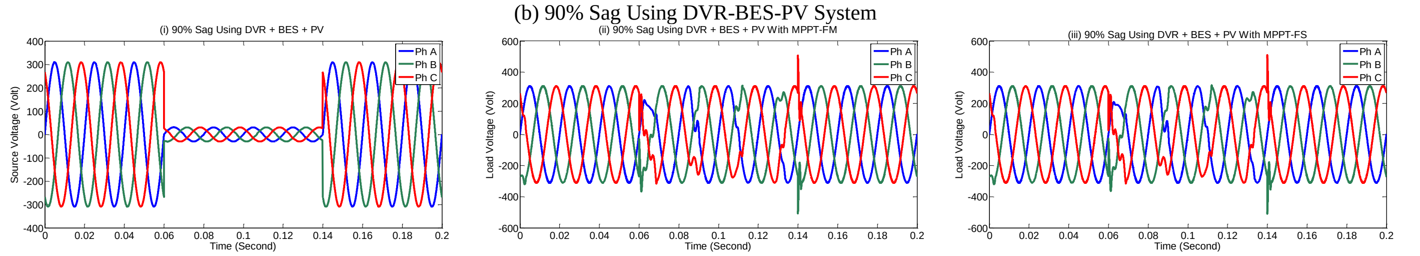
Swell Scenarios	**Source Voltage V_S (Volt)**			**Load Voltage V_L (Volt)**			**Sag (%)**	**Source Voltage THD (%)**				**Load Voltage THD (%)**			
	Ph A	***Ph B***	***Ph C***	***Ph A***	***Ph B***	***Ph C***		***Ph A***	***Ph B***	***Ph C***	***Avg***	***Ph A***	***Ph B***	***Ph C***	***Avg***
MPPT Fuzzy Mamdani															
110% Swell	340.3	340.3	340.3	310.3	310.3	310.3	**0.021**	0.17	0.17	0.17	0.17	0.37	0.37	0.37	**0.370**
120% Swell	371.4	371.4	371.4	310.3	310.3	310.4	**0.032**	0.16	0.16	0.16	0.16	0.37	0.37	0.37	**0.370**
130% Swell	402.4	402.4	402.4	310.4	310.4	310.4	**0.054**	0.14	0.14	0.14	0.14	0.37	0.37	0.37	**0.370**
140% Swell	433.4	433.4	433.4	310.4	310.4	310.4	**0.054**	0.13	0.13	0.13	0.13	0.37	0.37	0.35	**0.364**
150% Swell	464.5	464.5	464.5	310.4	310.3	310.4	**0.042**	0.12	0.12	0.12	0.12	0.38	0.37	0.35	**0.367**
160% Swell	495.5	495.5	495.5	310.4	310.4	310.5	**0.064**	0.12	0.12	0.12	0.12	0.35	0.37	0.35	**0.357**
170% Swell	526.5	526.5	526.5	310.4	310.4	310.6	**0.075**	0.11	0.11	0.11	0.11	0.36	0.37	0.38	**0.370**
180% Swell	557.5	557.5	557.5	310.5	310.7	311.1	**0.172**	0.10	0.10	0.10	0.10	0.39	0.41	0.48	**0.427**
190% Swell	588.6	588.6	588.6	311.4	312.8	314.8	**0.892**	0.10	0.10	0.10	0.10	1.16	1.72	1.90	**1.594**
MPPT Fuzzy Sugeno															
110% Swell	340.3	340.3	340.3	310.3	310.3	310.3	**0.021**	0.17	0.17	0.17	0.17	0.37	0.37	0.36	**0.367**
120% Swell	371.4	371.4	371.4	310.3	310.4	310.4	**0.043**	0.16	0.16	0.16	0.16	0.37	0.36	0.37	**0.367**
130% Swell	402.4	402.4	402.4	310.3	310.4	310.2	**0.021**	0.14	0.14	0.14	0.14	0.37	0.37	0.35	**0.364**
140% Swell	433.4	433.4	433.4	310.3	310.3	310.3	**0.021**	0.13	0.13	0.13	0.13	0.37	0.37	0.34	**0.360**
150% Swell	464.5	464.5	464.5	310.4	310.3	310.4	**0.043**	0.12	0.12	0.12	0.12	0.37	0.37	0.35	**0.363**
160% Swell	495.5	495.5	495.5	310.4	310.4	310.5	**0.065**	0.12	0.12	0.12	0.12	0.37	0.37	0.36	**0.367**
170% Swell	526.5	526.5	526.5	310.4	310.4	310.6	**0.075**	0.11	0.11	0.11	0.11	0.37	0.37	0.39	**0.377**
180% Swell	557.5	557.5	557.5	310.5	310.8	311.3	**0.204**	0.10	0.10	0.10	0.10	0.39	0.58	0.69	**0.554**
190% Swell	588.6	588.6	588.5	311.3	313.4	315.9	**1.064**	0.10	0.10	0.10	0.10	1.49	2.11	2.66	**2.087**

(a) 60% Sag Using DVR-BES-PV System



(i) Source Voltage (ii) Load Voltage With MPPT Fuzzy Mamdani (iii) Load Voltage With MPPT Fuzzy Sugeno

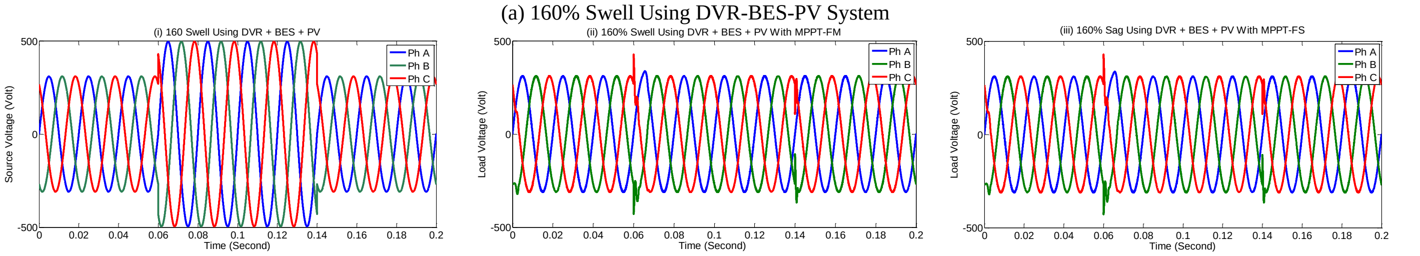
(b) 90% Sag Using DVR-BES-PV System



(i) Source Voltage (ii) Load Voltage With MPPT Fuzzy Mamdani (iii) Load Voltage With MPPT Fuzzy Sugeno

Fig. 12. Performance of sag using DVR-BES-PV with MPPT-FM/MPPT-FS: (a) 60% and (b) 90%

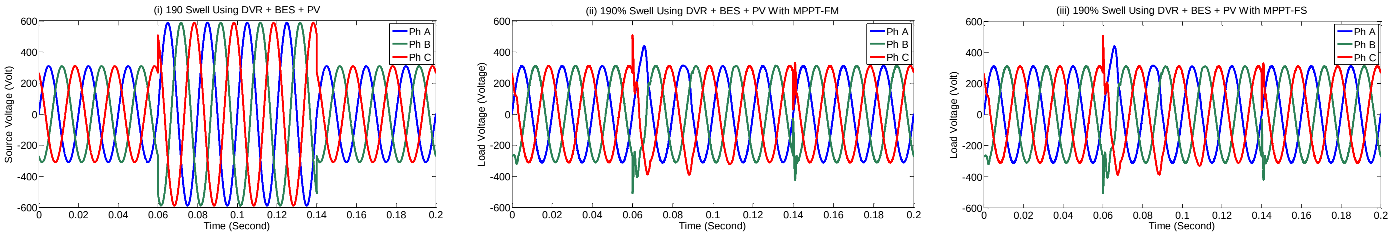
(a) 160% Swell Using DVR-BES-PV System



(i) Source Voltage (ii) Load Voltage With MPPT Fuzzy Mamdani (iii) Load Voltage With MPPT Fuzzy Sugeno

(b) 190% Swell Using DVR-BES-PV System

Received: January 1, 2017



(i) Source Voltage (ii) Load Voltage With MPPT Fuzzy Mamdani (iii) Load Voltage With MPPT Fuzzy Sugeno

Fig. 13. Performance of swell using DVR-BES-PV with MPPT-FM/MPPT-FS: (a) 160% and (b) 190%

Fig. 14 and Fig. 15 show percentage of load voltage sag and load voltage swell in nine disturbances scenario using DVR-BES-PV system with MPPT-FM/MPPT-FS.

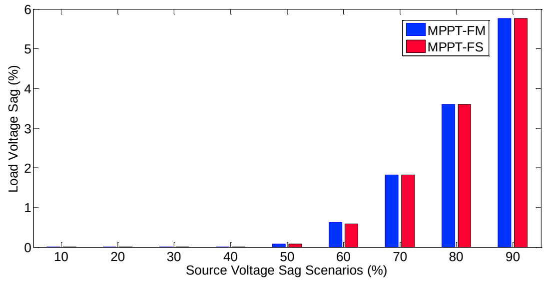


Figure 14. Percentage of load voltage sag

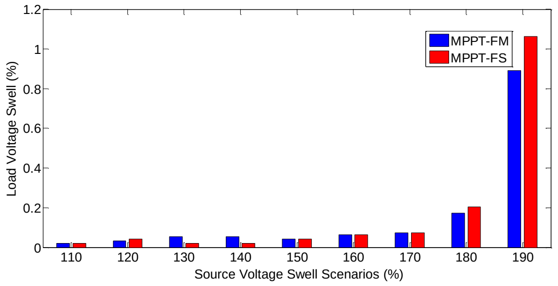


Figure 15. Percentage of load voltage swell

Table 3 and Fig. 14 show that for sag voltage disturbances scenario on source bus, the 3P3W system using DVR-BES-PV with MPPT-FM/MPPT-FS, the higher percentage drop of sag voltage on source bus, then percentage of sag voltage on load bus is also higher. The MPPT-FM is able to result a smaller percentage of sag voltage than MPPT-FS. In 90% sag voltage on source bus, MPPT-FM is able to result percentage of load sag voltage of 5.759%, lower than MPPT-FS of 5.770%. Reviewed from harmonics mitigation, MPPT-FM is able to result a voltage THD higher than MPPT-FS. In 90% sag voltage on source bus, MPPT-FM is able to results an average THD of load voltage of 10.32%, higher than MPPT-FS of 10.14%.

Table 4 and Fig. 15 show that for swell voltage disturbances scenario on the source bus in 3P3W system using DVR-BES-PV with MPPT-FM/MPPT-FS method, the higher percentage increase in swell voltage on source bus, then percentage of swell voltage on load bus is also higher. The MPPT-FM method is able to result a smaller percentage of swell voltage than MPPT-FS. In 190% swell voltage on source bus, MPPT-FM method is able to result a percentage of swell load voltage of 0.892%, lower than MPPT-FS of 1.064%. Reviewed from harmonics mitigation, MPPT-FM method is able to result an average of THD voltage smaller than the MPPT-FS. For 190% swell voltage on source bus, MPPT-FM method is able to result an average THD of load voltage of 1.594%, smaller than the MPPT-FS of 2.087%. The average THD of load voltage using MPPT-FM/MPPT-FS in nine swell voltage disturbances scenario on source bus is smaller than sag voltage and its already has met the limits prescribed in IEEE 519. Fig. 16 and Fig. 17 show spectra of harmonic load voltage on phase A for 90% sag using MPPT-FM and MPPT-FS.

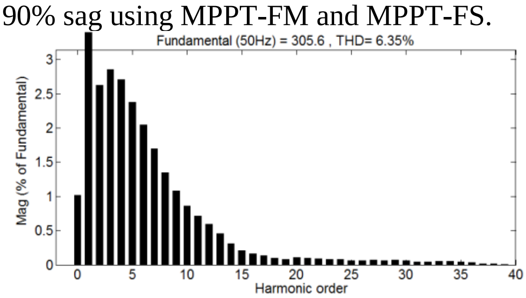


Figure 16. Spectra of harmonic load voltage on phase A for 90% sag using DVR-BES-PV with MPPT-FM

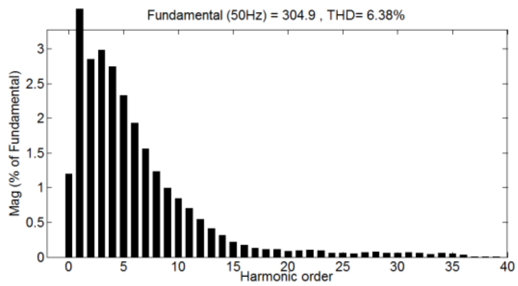


Figure 17. Spectra of harmonic load voltage on phase A for 90% sag using DVR-BES-PV with MPPT-FS

Fig. 18 shows performance of average THD of load voltage in nine voltage sag disturbances scenario using DVR-BES-PV system with MPPT-FM/MPPT-FS. Fig. 19 also shows the same performance for voltage swell.

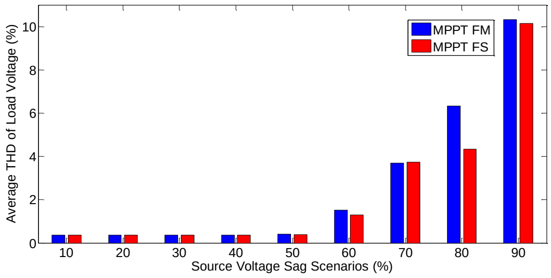


Figure 18. Performance of average THD load voltage for voltage sag

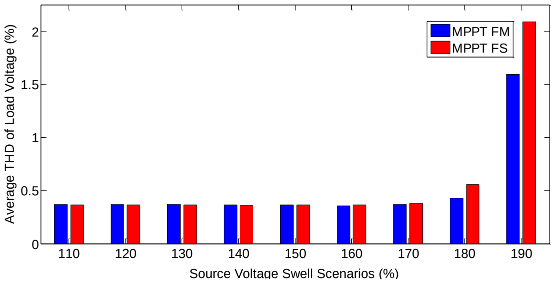


Figure 19. Performance of average THD load voltage for voltage swell

Fig. 18 shows that in the 3P3W system using DVR-BES-PV with MPPT-FM/MPPT-FS method, the higher percentage drop of sag voltage on source bus, then average THD of load voltage is also higher. The MPPT-FM method is able to result an average THD of load voltage THD higher than MPPT-FS method. Fig. 19 shows that in the 3P3W system using DVR-BES-PV with MPPT-FM/MPPT-FS method, the higher percentage increase of swell voltage on source bus, then an average THD of load voltage is also higher. The MPPT-FM method is able to result an average THD of load voltage smaller than MPPT-FS method. The average THD of load voltage using MPPT-FM/MPPT-FS in nine swell voltage disturbances on the source bus, is smaller than sag voltage and it has met the limits prescribed in IEEE 519.

4. Conclusion

Comparative performance analysis between MPPT-FM and MPPT-FS as controller on PV output power using DVR-BES-PV system connected to 3P3W distribution network have been discussed. The combination of DVR-BES-PV system using two methods is used in order to mitigate voltage sag/swell and harmonics on load bus . The UVTG is used to control series active filter in DVR when it injects compensation voltage during voltage sag/swell disturbance. The PV is used as an alternative DC voltage source to charge BES when its capacity decreases and provides active power needed to compensate for sag/swell.

In nine sag/swell disturbances scenario, the higher percentage drop of sag/increase of swell voltage on source bus, then percentage of sag/swell voltage on load bus is also higher. In the same disturbances and scenarios, the higher percentage drop of sag/increase of swell voltage on source bus, then average THD of load voltage is also higher. The MPPT-FM is able to produce a smaller percentage of sag/swell voltage than MPPT-FS. In nine disturbances scenario, both of MPPT-FM and MPPT-FS are able to result percentage of sag/swell on load voltage under IEEE 1159. In sag voltage, MPPT-FM is able to result an average THD of load voltage THD higher than MPPT-FS. Otherwise in swell voltage, MPPT-FM is able to result an average THD of load voltage smaller than MPPT-FS. The average THD of load voltage using MPPT-FM/MPPT-FS in nine swell voltage disturbances scenario on source bus, is smaller than sag voltage and it has met the limits prescribed in IEEE 519.

Acknowledgments

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Appendix

Three phase grid: RMS voltage = 380 volt (L-L), frequency = 50 Hz, line source impedance R_s = 0.1 Ohm, line source inductance L_s = 15 mH; Series active filter: series inductance L_{se} = 0.015 mH, Series transformer: kVA rating = 10 kVA, frequency 50 Hz, N_1/N_2 = 1:1; Sensite Load: load resistance R_L = 60 Ohm, load inductance L_L = 0.15 mH, line load resistance R_c = 0.4 Ohm, line load inductance L_c = 15 mH; Battery energy storage: Type = nickel metal hibrid, DC voltage = 650 V, capacity = 200 Ah, initial SOC, 100%, inductance L_1 = 6 mH, capacitance C_1 = 200 μF; PV array active power = 0.6 kW, temperature = 25^0 C, irradiance = 1000 W/m^2; MPPT-FM model: FIS = mamdani, composition = max-min; input membership function: delta voltage (ΔV) = trapmf, trimf, delta power (ΔP) = trapmf, trimf; output membership function: delta duty cycle (ΔD) = trapmf, trimf, defuzzyfication = centroid; MPPT-FS model: FIS = sugeno, composition = max-min; input membership function: delta voltage (ΔV) = trapmf, trimf, delta power (ΔP) = trapmf, trimf;

output membership function: delta duty cycle (ΔD) = constant [0,1], defuzzyfication = wtaver.

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Co-author(s)	**Agus Kiswantono[1], Eko Prasetyo[2],**
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    [1] R. Ruskone, S. Airault, and O. Jamet, "Vehicle Detection on Aerial Images", *International Journal of Intelligent Engineering and Systems*, Vol.1, No.1, pp.123-456, 2009.
    (In the case of Journal Papers)
    [2] R. Ruskone, L. Guigues, S. Airault, and O. Jamet, "Vehicle Detection on Aerial Images", In: *Proc. of International Conf. On Pattern Recognition*, Vienna, Austria, pp.900-904, 1996.
    (In the case of Conference Proceedings)

*Note: e.g. In the case of the author name:"John Doe", express as "J. Doe". ("John" is the first name and "Doe" is the family name.)

* * Please send your revised manuscript with the response letter for the 2nd review. (Please highlight modifications and additions inside the paper by red font.)

** The extra page charge USD50 per extra page will be charged if the paper length exceeds 10 pages.

Evaluation of Paper		
Contents	**Innovation**	~~□Highly Innovate~~ ~~□Sufficiently Innovate~~ □Slightly Innovate ~~□Not Novel~~
	Integrality	~~□Poor~~ ~~□Fair~~ □Good ~~□Outstanding~~
	Presentation	~~□Totally Accessible~~ □Mostly Accessible ~~□Partially Accessible~~ ~~□Inaccessible~~
	Technical depth	~~□Superficial~~ ~~□Suitable for the non-specialist~~ □Appropriate for the generally knowledgeable individual working in the field ~~□Suitable only for an expert~~
Presentation & English	~~□Satisfactory~~ □Needs improvement ~~□Poor~~	
Overall organization	~~□Satisfactory~~ □Could be improved ~~□Poor~~	

Lampiran 2.4

Response Letter

(ijies2039) Reply Form:

Title: Comparative Performance of Mitigation Voltage Sag/Swell and Harmonics Using DVR-BES-PV System With MPPT-Fuzzy Mamdani/MPPT-Fuzzy Sugeno (Agus Kiswantono, Eko Prasetyo, Amirullah Amirullah*) *Corresponding Author

<u>Reviewer comment to the authors:</u>

[1] English presentation should be further polished. There are many editing problems (spacing problems) in English.

<u>Answer:</u>

Thank you for your comment.

1. I have tried to edit false phrases in abstract adjusted to the paper title for example:
   a. sag/swell voltage change to voltage sag/swell (abtract line 5-red font).
   b. sag voltage change to voltage sag (abtract line 8,9,12,14,18-all red fonts).
   c. swell voltage change to voltage swell (abtract line 10,13,15,17-all red fonts).
2. For your comment….There are many editing problems….I would be happy if you show more specifically the false editing of words or sentences so I can fix them.

<u>Reviewer comment to the authors:</u>

[2] Give the full name of authors. See the 3rd author.

<u>Answer:</u>

Thank you for your comment. My name is AMIRULLAH (only) and have no family name. However in many cases, if the editor in chief of international journals or documents (passport and international flight ticket) asked me to mention the family name, I usually have repeated my name twice as AMIRULLAH AMIRULLAH (3rd author-red font).

<u>Reviewer comment to the authors:</u>

[3] In abstract, the result of this work must be described briefly. The result of this work is not clear.

Answer:

Thank you for your comment.

1. Abstract in my paper consists of three parts:
   a. Objective (This paper presents…..line 1-4)
   b. Method (The combination of two methods….line 4-6)
   c. Results and Conclusions (In nine sag/swell disturbance scenario…..line 7-18)
2. In abstract, I add the results in number results (% voltage sag/swell and % harmonics/THD) to explain briefly the general results.
   a. Case general results (In nine sag/swell disturbances scenario,…..line 6-7) *explained in number results* (In 90% voltage sag, MPPT-FM is able to result percentage of voltage sag onload voltage…..line 7-10-red fonts).
   b. Standard general result (both methods are also able to result percentage of sag/swell….IEEE 1159…..line 10-11)
   c. Case general results (In voltage sag, MPPT-FM is able to result an average Total Harmonics Distortion (THD) of load voltage higher than MPPT-FS. Otherwise in voltage swell, MPPT-FM is able to result an average THD of load voltage smaller than MPPT-FS…..line 12-14) *explained in number results* (In 90% voltage sag, MPPT-FM is able to result average THD of load voltage of 10.32% higher than MPPT-FS of 10.14%. …..line 14-16-red fonts).
   d. Standard general result (The average THD of load voltage using MPPT-FM/MPPT-FS in nine voltage swell disturbances scenario on source bus, is smaller than voltage sag and it has met limit of IEEE 519 (.….Line 16-18).

Reviewer comment to the authors:

[4] In the Introduction part, strong points of this proposed method should be further stated.The new features of the proposed method and the main advantages of the results over others should be clearly described.As you know, many MPPT techniques and its comparative study have already been undertaken in past studies. What’s the novelty of this work?

Answer:

Thank you for your comment.

1. The strong points of this proposed method is implementation of DVR-BES-PV model connected 3P3W distribution network to overcome voltage sag/swell problem in source voltage with less percentage of voltage sag/swell and harmonics (THD) in load voltage

(Please see the end of paragraph 4 in introduction/Section 1…red fonts).

2. Novelty of this works is implementation of fuzzy logic controller (FLC) method as a part of artificial intelligent (AI) to determine MPPT in PV panel. This method could be an alternative to replace conventional MPPT methods that has been developed before i.e. Perturb and Observer (P and O) or Incremental Conductance (IC) method. The advantages of fuzzy set theory in FLC is a new method of controlling MPPT in obtaining peak of power point. The MPPT is implemented to obtain MPP operation voltage point faster with less overshoot and it also can minimize voltage fluctuation after MPP has been recognized. The fuzzy inference system (FIS) used in this research are FM and FS respectively. (Please see the end of paragraph 5 in Introduction/Section 1….red fonts).
3. The fuzzy inference system (FIS) used in this paper are FM and FS respectively. Both methods are proposed and compared as MPPT control on PV panel which connected to 3P3W of 380 V and 50 Hz on low voltage distribution line through DVR-BES system. (Please see in paragraph 6 in Introduction/Section 1….red fonts). The advantages and disadvantages of both methods is explained briefly in Paragraph 2 Section 2.6 (MPPT-FM and MPPT-FS). Then depend of advantages and disadvantages, I compare both of them which it have better performance base on percentage of voltage sag/swell and harmonics (THD) in load bus.

Reviewer comment to the authors:

[5] The quotation of previous articles, such as [12-16], is rough. These citations are meaningless. You must quote articles properly.

Answer:

Thank you for your comment.

1. I deleted Ref. 15 in the original paper (before revised) because it could not accessible online now.
2. I am rearranging the reference sequences of numbers 12, 13, 14, and 16 in the original paper (before revised) to reference numbers 17, 19, 20, and 21 in the revised paper.
    a. Ref. 17 describes about IEEE 1159 standard which presents definition and table of voltage sag/swell base on catagories (instantaoeous, momentary, temporary) typical duration, and typical magnitude. The typical residential utility power after sag/swell disturbance is in the range of +/-5% from the nominal value (See the end of Section 2.4/Voltage Sag/Swell).

b. - Ref. 19 describes about harmonics concept (C. Sankaran).

- Ref. 20 describes concept about Total Harmonics Distortion (THD) and its equation as parameter to measure harmonics values generates by sag/swell and harmonics disturbances from source side (J. Arrilaga, B.C. Smith, N.R. Watson, and A.R. Wood).
- Ref 21. describes about IEEE 519 of THD voltage standard in electric power systems (T.M. Bloming, P.E. and D.J. Carnovale, P.E).

Reviewer comment to the authors:

[6] In sentences/equations, mathematical expressions must be Italic font.Unify the font style. e.g. seep.3.

Answer:

Thank you for your comment.

I have revised them and please see in Section 2.3 (paragraph 3), Section 2.5 (paragraph 2), Section 2.6 (paragraph 3 and 4).

Reviewer comment to the authors:

[7] Don't use equation environment such as Microsoft Math environment in sentences. Equation Editor (such as Microsoft Equation 3.0) was included in previous versions of Word but has removed from all versions that have installed the January 2018 Public Update (PU). Please rewrite all equations.

Answer:

Thank you for your comment.

I have revised and updated all equations in this paper depend on last version Microsoft Office Math Equation (Please see Eq. 1, 2, 3, 4, 5, 6, 7, 8, and Eq. 9).

Reviewer comment to the authors:

[8] Which articles did you compare in Sect.3? Indicate the reference number in sentences. Besides, you must cite the compared articles in References.

Answer:

Thank you for your comment.

1. I have used Ref. 18 to analyze percentage of voltage sag/swell results in this paper…..By using Matlab/Simulink, the model then is run based on desired scenario to obtain source

voltage (V_S) and load voltage (V_L) curves, percentage of voltage sag (%), and percentage of voltage swell (%) using Eq. (7) and Eq. (8) [18] with average pre-sag/swell voltage equal as 310,234 V. (Please see the end of Paragraph 1 Section 3).

2. I have used Ref. 20 to analyze and determine THD of load voltage results in this paper…. Furthermore, source voltage THD and load voltage THD in each phase are determined by using fast fourier transform (FFT) analysis base on the curve with Eq. 9 [20]. (Please see the initial of Paragraph 2 Section 3).

Reviewer comment to the authors:

[9] In figures, letters are too small. Unify the font size of letters (more than 10pt).Enlarge or Redraw figures. e.g. Fig.4, 6-9, etc. You can use single column format for these figures.

Answer:

Thank you for your comment.

I have enlarged all fonts and redrawn Fig. 4 and also Fig. 6-9 in order more visible by readers. However, I still have used them in double column format because Fig. 4 and Fig. 6-9 have been seen by readers. (Please see all revised figure in Fig. 4 and Fig. 6-9).

Reviewer comment to the authors:

[10] In Figs.6-9, do not insert the title into figures. It's redundant.

Answer:

Thank you for your comment.

I have revised and redrawn Fig. 6-9. Now each figure has an X and Y axis.

1. X axis is a label for horizontal axis (not title of figure).
   a. X axis of Fig. 6. Memberships fuction of input variable "Delta-V"
   b. X axis of Fig. 7. Memberships fuction of input variable "Delta-P"
   c. X axis of Fig. 8. Memberships fuction of output variable "Delta-DC"
   d. X axis of Fig. 9. Memberships fuction of output variable "Delta-DC"
2. Y axis is a label for vertical axis (degree of membership). This axis label is same for Fig. 6-9 (Please see revised figure of X and Y axis in Fig 6-9).

Reviewer comment to the authors:

[11] There is no Y-axis label in Fig.6-9.

Answer:

Thank you for your comment.

I have revised and redrawn Fig. 6-9. Now each figure has an X and Y axis. Y axis is a label for vertical axis (degree of membership). This axis label is same for Fig. 6-9 (Please see revised figure of X and Y axis in Fig 6-9).

Reviewer comment to the authors:

[12] In Tables 3 and 4, the width is too wide. Besides, the font size of tables must be 10pt. You should improve presentation.

Answer:

Thank you for your comment.

1. I have revised width and enlarged font size of Tables 3 and 4 from 8 pt (before revised) to 10 pt (after revised).
2. In Table 3.
    a. The word sag of 10% sag……90% sag is changed into 10%....90% in order to reduce the width of table and sag have been stated in **Sag Scn** (Please see Table 3 column 1).
    b. The word scenario is abbreviated into **Scn** in order to reduce the width of table (Please see Table 3 line 1).
    c. The words of Ph A, Ph B, Ph C (meaning Phase A, Phase B, Phase C) in Table 3 line 2 is replace into A, B, C only in order to reduce the width of table.
3. In Table 4.
    d. The word swell of 110% swell……90% swell is changed into 110%...190% in order to reduce the width of table and swell have been stated in **Swell Scn** (Please see Table 4 column 1).
    e. The word scenario is abbreviated into **Scn** in order to reduce the width of table (Please see Table 3 line 1 column 1).
    f. The words of Ph A, Ph B, Ph C (meaning Phase A, Phase B, Phase C) in Table 4 line 2 is replace into A, B, C only in order to reduce the width of table.

Reviewer comment to the authors:

[13] In Figs.12 and 13, the width is too wide. Besides, the font size of figures must be 10pt. You should improve presentation.

Answer:

Thank you for your comment.

1. I have revised the model and width of Fig. 12 from horizontal to vertical model, in order to reduce the width of table.
    a. In 90% sag for Fig. 12.a.i, Fig. 12.a.ii, and Fig. 12.a.iii from horizontal model (three colomn figures) are replaced into Fig. 12.a.i, Fig. 12.a.ii, and Fig. 12.a.iii in vertical model (double column).
    b. In 60% sag for Fig. 12.b.i, Fig. 12.b.ii, and Fig. 12.b.iii from horizontal model (three colomn figures) are replaced into Fig. 12b.i, Fig. 12.b.ii, and Fig. 12.b.iii in vertical model (double column).
2. I have revised the model and width of Fig. 13 from horizontal to vertical model, in order to reduce the width of table.
    a. In 190% swell for Fig. 13.a.i, Fig. 13.a.ii, and Fig. 13.a.iii from horizontal model (three colomn figures) are replaced into Fig. 13.a.i, Fig. 13.a.ii, and Fig. 13.a.iii in vertical model (double column).
    b. In 160% swell for Fig. 13.b.i, Fig. 13.b.ii, and Fig. 13.b.iii from horizontal model (three colomn figures) are replaced into Fig. 13b.i, Fig. 13.b.ii, and Fig. 13.b.iii in vertical model (double column).
3. I have revised the width and enlarged font size of Fig. 12 and Fig. 13 from 8 pt to 10 pt so that both figures can be seen by the readers.

Reviewer comment to the authors:

[14] The result demonstrated in Sect.3 seems a special case, because the comparison data is not based on mathematical theory. You should explain the data of Sect.3 theoretically.

Answer:

Thank you for your comment.

1. As theoretically, I have used Matlab/Simulink to run DVR-BES-PV system model with MPPT-FM and MPPT FS on desired scenario to obtain source voltage (V_S) and load voltage (V_L) curves, percentage of voltage sag (%), and percentage of voltage swell (%) using Eq. (7) and Eq. (8) [18] with average pre-sag/swell voltage equal as 310,234 V. (Please see the end of Paragraph 1 Section 3).
2. As theoretically, I have used fast fourier transform (FFT) analysis with Matlab/Simulink base on the wave curve and have used Eq. 9 [20] to analyze and determine THD of load voltage in sag/swell disturbances using MPPT-FM and MPPT-FS. (Please see the initial of Paragraph 2 Section 3).
3. Explaination of comparation data for voltage sag using MPPT-FM/MPPT-FS is showed in Fig 12 and Table 3. (Please see paragraph 4 section 3-red font).
4. Explaination of comparation data for voltage swell using MPPT-FM/MPPT-FS is showed in Fig 13 and Table 4. (Please see paragraph 5 section 3-red font).
5. Explaination of comparation data in percentage of sag and swell for 10%-90% voltage sag and 110%-190% voltage swell on source bus using MPPT-FM/MPPT-FS is showed in Fig 14 and Fig. 15. (Please see paragraph 6 and 7, section 3).
6. Explaination of comparation data in average THD on load voltage for 10%-90% voltage sag and 110%-190% voltage swell on source bus using MPPT-FM/MPPT-FS is showed in Fig 18 and Fig.19 (Please see paragraph 10 section 3).

Reviewer comment to the authors:

[15]   Future works as an integral part should be included in the Conclusions.

Answer:

Thank you for your comment.

The future work as an integral part of this paper has been included in the last paragraph Section 4 (Conclusion). Nevertheless, the average THD of load voltage in 90% sag scenario (deep voltage sag) using MPPT-FM/MPPT-FS has exceeded the limit prescribed in IEEE 519. The implementation of advanced Fuzzy Method i.e. Fuzzy Type 2, Fuzzy Sliding Mode, or both combination for controlling MPPT on PV connected to DVR-BES system is proposed as future work to overcome this problem.

Reviewer comment to the authors:

[16] Please improve the reference format. **This is very important for indexing service**. If you did not follow the following format, your paper will automatically rejected.

Answer:

Thank you for your comment.

1. I have followed ijies format for writing references in this paper from Ref. [1] into Ref. [22] in the cases*:
   a. Do not use "et al." in author names.
   b. Note: e.g. In the case of the author name:"John Doe", express as "J. Doe". ("John" is the first name and "Doe" is the family name.)
2. I have deleted Ref. [15] (T. Hoevenaar, P.Eng, K. LeDoux, P.E., M. Colosino, 2003….) in original paper (before revised) because it could not accessible online now.
3. I have inserted Ref. [12] (Amirullah, A. Kiswantono, O. Penangsang, Adi Soeprijanto, 2018…..) in revised paper as additional reference to explain novelty on this paper (Please see paragraph 5 in Introduction/Section 1….red fonts).
4. I also have sorted all the references Ref. [1-22] based on the order in which they appear in this paper.

*) Note: The total number of pages are expanded from 11 pages (in original paper) into 13 pages (in revised paper).

**) For 2nd Author

1. Thanks a lot for your constructive comments.
2. We are appreciate for your kind guidance and valuable advices.

Lampiran 2.5

Hasil Revisi Makalah

Submitted

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Comparative Performance of Mitigation Voltage Sag/Swell and Harmonics Using DVR-BES-PV System With MPPT-Fuzzy Mamdani/MPPT-Fuzzy Sugeno

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Abstract: This paper presents comparative performance between Maximum Power Point Tracking-Fuzzy Mamdani (MPPT-FM) and MPPT-Fuzzy Sugeno (FS) methods as controller on Photovoltaic (PV) output power using Dynamic Voltage Restorer-Battery Energy Storage-PV (DVR-BES-PV) system connected to three phase three wire (3P3W) distribution network. The combination of DVR-BES-PV system using two methods is used in order to mitigate voltage sag/swell and harmonics on load bus. The PV is used as an alternative DC voltage source to charge BES when its capacity decreases and provides active power needed to compensate for sag/swell. In nine sag/swell disturbances scenario, MPPT-FM is able to give better performance in percentage of sag/swell on load voltage than MPPT-FS. In 90% voltage sag, MPPT-FM is able to result percentage of voltage sag on load bus of 5.759% smaller than MPPT-FS of 5.770%. Then, in 190% voltage swell, MPPT-FM is able to result percentage of voltage swell on load bus of 0.892% smaller than MPPT-FS of 1.064%. Both methods are also able to result percentage of sag/swell on load voltage under IEEE 1159. In voltage sag, MPPT-FM is able to result an average Total Harmonics Distortion (THD) of load voltage higher than MPPT-FS. Otherwise in voltage swell, MPPT-FM is able to result an average THD of load voltage smaller than MPPT-FS. In 90% voltage sag, MPPT-FM is able to result average THD of load voltage of 10.32% higher than MPPT-FS of 10.14%. Otherwise, in 190% voltage swell, MPPT-FM is able to result average THD on load bus of 1.594% smaller than MPPT-FS of 2.087%. The average THD of load voltage using MPPT-FM/MPPT-FS in nine voltage swell disturbances scenario on source bus, is smaller than voltage sag and it has met limit of IEEE 519. This research is simulated using Matlab/Simulink environment.

Keywords: MPPT-FM, MPPT-FS, Sag/Swell, Harmonics, THD, DVR, BES, PV

1. Introduction

The diminishing of fossil energy sources and increasing concerns about environmental impacts have caused renewable energy (RE) sources i.e. PV and wind to develop into alternative energy of power generation. The electrical power produced by PV is direct current (DC), so it requires an inverter before it is operated and connected to distribution system (grid). The disadvantage of PV is beside able to supply power to grid, it also generates harmonics due to presence of voltage source inverter (VSI) type filter as a medium to convert DC to AC voltage so that it can reduce power quality. On the other hand, with increasing sensitive load penetration, causing power quality problems in modern distribution systems has increased significantly. The most serious and frequent disturbances in grid voltage are sag, swell, and short circuit. The sag is a decrease in rms voltage between

10-90% which lasts from one half cycle to one minute. The swell is an increase in the source rms voltage in a short time interval whose values range from 1.1 pu to 1.8 p.u from nominal source voltage. The device that is capable of effectively and comprehensively overcoming sag/swell disturbance is DVR. Research on sag compensation using DVR with unit vector template generation (UVTG) method has been done [1]. DVR is able to compensate for balanced and unbalanced sag voltage and inject the desired voltage component to quickly repair a number of interference anomalies at the source voltage to keep load voltage balanced and constant at nominal value.

The comparative analysis of three compensation techniques i.e. phase-by-method compensation, pre-dip compensation method (called large voltage difference compensation), and intelligent phase compensation method has been investigated [2]. A model for DVR control independently has been proposed [3]. The three of three phase harmonics filters (double tuned) were used to migrate harmonics generated by a voltage source converter (VSC). The low DVR rating was able to compensate for sag, swell, and reduce THD voltage on load bus according to IEEE-519. DVR performance on sag voltage and load voltage harmonics using Sinusoidal Pulse control Width Modulation (SPWM) and Space Vector Pulse Width Modulation (SVPWM) have been done [4]. The Synchronous Reference Frame (SRF) method has been used to detect sag and generate modulation signals. The load voltage THD using the SVPWM method was smaller than SPWM.

The grid integration system connected PV system with self supported DVR has been proposed [5]. The system was called a "six-port converter," whole consists of nine semiconductor switches, reduced from 12 previous semiconductors. The configuration was able to operate in different modes based on grid conditions and PV power. The research were conducted on normal grid mode, interference mode, sag mode, and non-active PV mode. PV based DVR model to overcome sag/swell voltage and outages in single phase low voltage housing distribution systems have been proposed [6]. The simulation shows that DVR-based PV with fuzzy logic controller (FLC) is able to provide better dynamic performance in overcoming voltage variations. DVR was operated in standby, active, bypass, power saver mode. DVR performance to mitigate sag voltage and reduce the THD of load voltage has been investigated [7]. The sag compensation on balanced and unbalanced disturbances conditions with variations in source voltage level sag uses PI and FLC method respectively on series active filter of DVR control. The simulation showed that FLC was able to maintain load voltage constant at nominal value and reduce load voltage THD better than PI.

Efficient FLC based on the power management scheme on the DVR in mitigating a number of voltage disturbances has been proposed [8]. The simulation showed that proposed model was efficiently able to maintain DVR output power below the predetermined value and reduce disturbance according to the priority given. The design and analysis of dynamic FLC on DVR is presented and expanded to perform fast error detection. The combination of DVR control methods using FLC and modulation of PWM carriers in an inverter circuit to detect voltage disturbances quickly has been investigated [9]. The proposed model is able to achieve superior performance for balanced and unbalanced sag/swell voltage mitigation. The start and end times of sag/swell voltage can be quickly detected and without oscillation. Fast switching capabilities can also be used in static transfer switches to improve power system reliability. Analysis of sag/swell voltage compensation using DVR and PV systems supported by energy storage elements (battery) has been carried out [10]. The PV system uses MPPT control with an incremental conductance (IC) algorithm as a RE source, which functions to inject reactive power during disturbance. Otherwise the energy storage (battery) element was used to improve system reliability. Integration of solar PV, battery, and DVR during dynamic disturbance conditions in distribution system has been done [11]. The solar PV system using boost converter was implemented using MPPT with IC algorithm. The PV system was supplied in two ways i.e. to meet load demands and maintain the DC link voltage of DVR in voltage sources converter VSC. The sensitive load and grid voltage were balanced by injecting voltage in series with distribution line. The DVR consists of injection transformers, filter circuits, three-phase series active filters, DC source voltage, and energy storage. The energy storage commonly used is DC-link capacitor. The disadvantage of this device has limited energy storage capacity. In order to overcome these problems, BES supplied by PV is used to mitigate sag/swell and harmonics on low voltage distribution network. This combination is called DVR-BES-PV system and installed on three phase three wire (3P3W) distribution network to maintain voltage on sensitive load. The advantage of BES has a larger storage capacity than capacitor. Moreover, PV is used as an alternative DC voltage source to charge BES when its capacity decreases and provides active power needed to compensate for sag/swell. The UVTG method is used to control series active filter in DVR when it injects compensation voltage during voltage sag/swell disturbance. The PV also helps with the self charging process of the system during uninterrupted condition (stand by mode).

Because of movement of sun, PV panel angle, and irradiance variation reaching the panel, sunlight absorbed and power generated by PV panel is not always constant. If this condition occurs then VI characteristic will change and MPP will move. To overcome this problem, MPPT method has been developed. MPPT is looking for independent maximum power based on environmental conditions following movement of sun, radiation and temperature to keep PV terminal voltage constant at its maximum value. The conventional MPPT methods that has been developed are Perturb and Observer (P and O) and Incremental Conductance (IC) method [12]. In this paper, FLC method as a part of artificial intelligent (AI) is used for determining MPPT in PV panel. The fuzzy set theory is a new method of controlling MPPT in obtaining peak of power point. The MPPT is implemented to obtain MPP operation voltage point faster with less overshoot and it also can minimize voltage fluctuation after MPP has been recognized. The fuzzy inference system (FIS) used in this research are FM and FS respectively.

This paper proposes and compares two methods i.e. FM and FS as MPPT control on PV. The PV is connected to 3P3W of 380 V and 50 Hz on low voltage distribution line through DVR-BES system. The nominal percentage of sag voltage disturbances scenarios is nine disturbances started from 10% to 90%. The swell voltage are the same number strarted from 110% to 190%. So that the total number of voltage sag/swell scenario using both methods are 18 disturbances scenario. The combination of the DVR-BES-PV system uses two methods connected to a 3P3W system is used in order to mantain the voltage at sensitive load remain constant. This research are performed on the percentage of sag/swell load voltage, average THD of source voltage, and average THD of load voltage in each MPPT methods and disturbances scenario. Furthermore the results were compared and validated with IEEE 1159 and IEEE 519. This paper is presented as follow. Section 2 describes proposed model of DVR-BES-PV, modelling of PV, UVTG control, sag/swell, harmonics, as well as MPPT-FM and MPPT-FS. Section 3 shows the results and the discusions about performance of percentage and average THD load voltage of sag/swell. Finally, this paper in concluded in Section 4.

2. Reseach Method

2.1. Proposed Method

Fig. 1 shows DVR proposed model using BES supplied by PV. The proposed DVR model is located between source or point common coupling (PCC) bus and load bus which it is connected to sensitive load. The PCC bus is then connected to a 3P3W of 380 Volt 50 Hz low voltage distribution line. The DVR consists of injection transformers, filter circuit, active filter series, DC voltage sources, and energy storage. The energy storage which is commonly used is DC link capacitor. The disadvantage of this device has limited energy storage capacity. The series active filter on DVR is controlled by UVTG method to mantain magnitude of voltage between PCC bus and load bus remain constant, balanced, and distortion free. The UVTG method is also used to generate trigger pulses in PWM circuit of six pulses by the active series filter, so as able to generate injection voltage to compensate for sag/swell voltage on load bus. Table 1 shows abbreviation in this paper.

Table 1. Abbreviation

Symbol	Description
MPPT	Maximum Power Point Tracking
FM	Fuzzy Mamdani
FS	Fuzzy Sugeno
FIS	Fuzzy Inference System
MFs	Membership Functions
FLC	Fuzzy Logic Controller
THD	Total Harmonics Distortion
DVR	Dynamic Voltage Restorer
BES	Battery Energy Storage
PV	Photovoltaic
RE	Renewable Energy
UVTG	Unit Vector Template Generation
PWM	Pulse With Modulation
3P3W	Three Phase Three Wire
PCC	Point Common Coupling
P and O	Perturb and Observe
IC	Incremental Conductance
AI	Artificial Intelligent

This paper proposes model of DVR-BES system supplied by 0.6 kW PV system. The PV generator produces an output voltage and is an input for the DC/DC boost converter. There are two FLC method proposed in MPPT of PV system i.e. MPPT FM and MPPT-FS respectively. The MPPT-FM/MPPT-FS helps single phase PV generate MPP in DVR-BES-PV system output. The DC output voltage of the PV is relatively low and then it is

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raised by a DC/DC boost converter at the appropriate voltage level in order to generate active power for BES charging process. The BES has a larger storage capacity than capacitor, otherwise PV are used as an alternative DC voltage source to charge BES when its capacity decreases. The PV also provides active power to compensate for sag/swell voltage. The PV also helps self charging process of BES during uninterrupted conditions (stand by mode). Fig. 2 shows PV system using MPPT-FM/MPPT-FS method connected to DC load.

The analysis of the proposed model is investigated by determination of nine sag/swell disturbances scenario on source bus in the 3P3W system using the DVR-BES-PV. Each sag/swell disturbances on source bus uses MPPT-FM and MPPT-FS respectively. The nominal percentage of sag voltage disturbance are 10%, 20%, 30%, 40%, 50%, 60%, 70%, 80%, and 90%. Whereas, swell voltage disturbances are 110%, 120%, 130%, 140%, 150%, 160%, 170%, 180%, and 190%. So that the total number of sag/swell voltage scenarios using MPPT-FM and MPPT-FS each is 18 disturbances scenario. The combination of DVR-BES-PV system which uses MPPT-FM/MPPT-FS is installed on a 3P3W system to mantain voltage in sensitive load constant. The analysis of this paper is performed on percentage of sag/swell and average THD of load voltage in each MPPT method and disturbances scenario. Then, the results are compared and validated with IEEE 1159 for voltage disturbance standards and IEEE 519 for voltage harmonic standards. Simulation and analysis of this paper using Matlab/Simulink. Parameters for the proposed model are shown in Appendix.

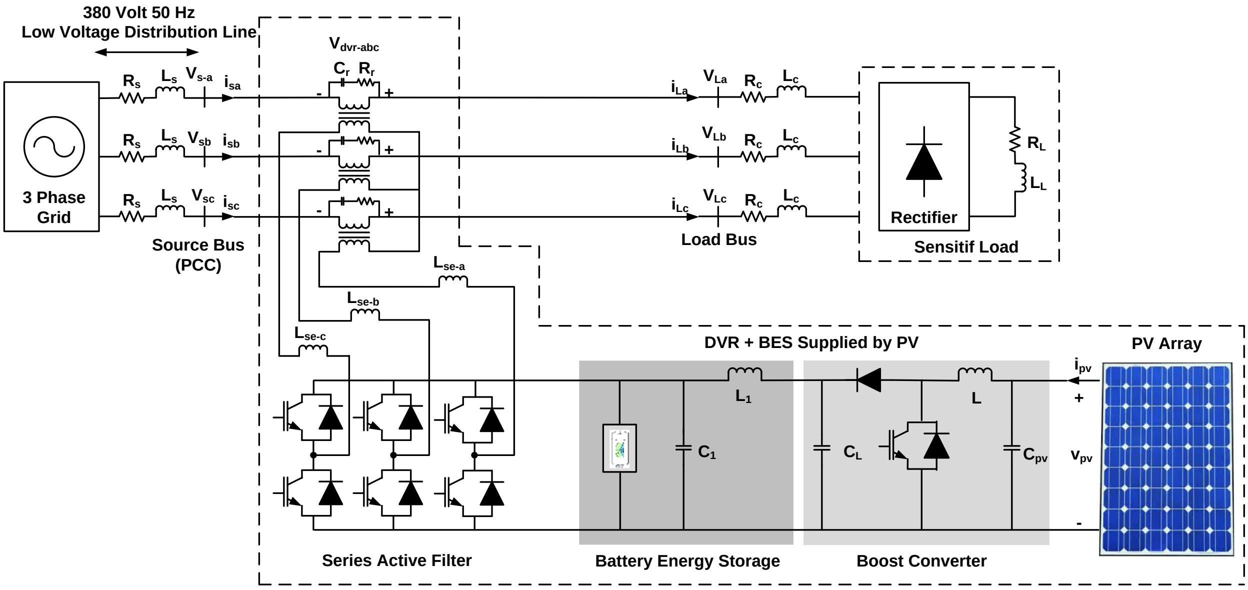

Figure 1. Proposed model of DVR using BES supplied by PV system

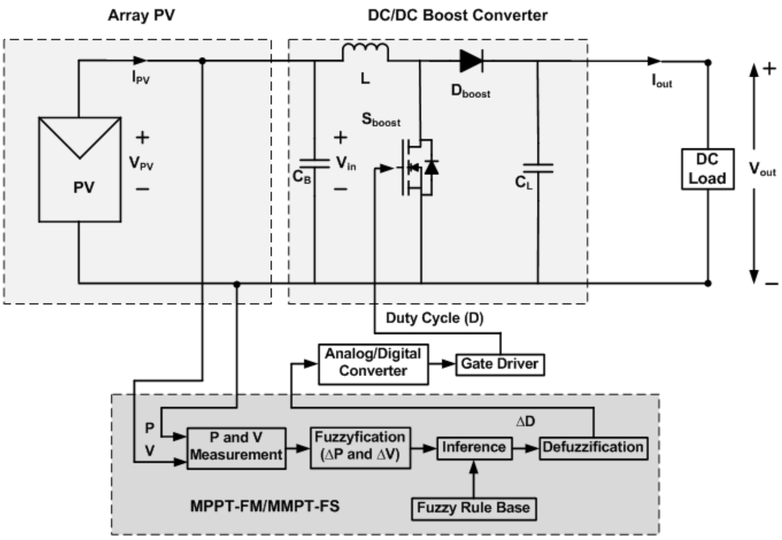

Figure 2. PV system using MPPT-FM/MPPT-FS method connected to DC load

2.2. Modelling of PV Array

Fig. 3 shows the equivalent circuit of a solar panel. A solar panel is composed by several PV cells that have series, parallel, or series-parallel external connections [13]. The V-I characteristic of a solar panel is showed in Eq. (1):

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

Where I_{PV} is the photovoltaic current, I_o is saturated reverse current, 'a' is the ideal diode constant, $V_t = N_S K T q^{-1}$ 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 Eq. (2) and Eq. (3):

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

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

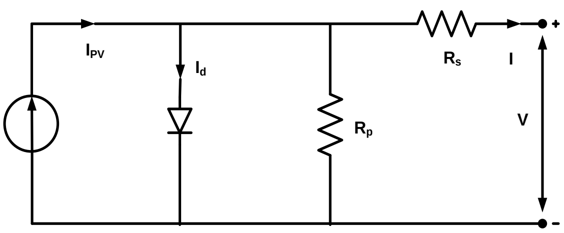

Figure 3. Equivalent circuit of solar panel

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 the variations of atmospheric conditions. By using Eq. (4) and Eq. (5) which are derived from PV model equations, short circuit current and open circuit voltage can be calculated in different atmospheric conditions.

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

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

2.3. UVTG Control on Series Active Filter

The main function of series active filter is the sensitive load protection against a number of voltage distrubances at source bus. The control strategy algorithm of the source and load voltage in series active filter is shown in Fig 4. It extracts the UVTG from the distorted input supply. Furthermore, the templates are expected to be ideal sinusoidal signal with unity amplitude. The distorted supply voltages are measured and divided by peak amplitude of fundamental input voltage V_m given in Eq.(6) [14].

$$V_m = \sqrt{\frac{2}{3}(V_{sa}^2 + V_{sb}^2 + V_{sc}^2)} \qquad (6)$$

A three phase locked loop (PLL) is used in order to generate sinusoidal unit vector templates with a phase lagging by the use of sinus function. The reference load voltage signal is determined by multiplying the unit vector templates with the peak amplitude of the fundamental input voltage V_m. The load reference voltage *(V_{La}^*, V_{Lb}^*, V_c^*)* is then compared to the sensed load voltage *(V_{La}, V_{Lb}, V_{Lc})* by a PWM controller used to generate the desired trigger signal on series active filter.

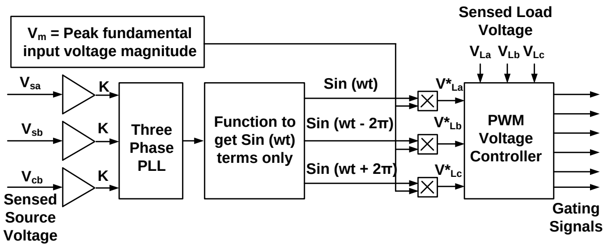

Figure 4. UVTG control of series active filter

2.4. Voltage Sag/Swell

The voltage sag is defined as a decrease in the value of rms voltage between 10-90% which goes on from one half cycle to one minute. The voltage sag can affect to the phase or amplitude. The most voltages sag occurs caused by a single phase to ground short circuit. An unbalanced short circuit can trigger an unbalanced phase and shift it from its nominal value. The starting of motor with high power also can generate voltage sag. The amplitude of the voltage sag depends on several factors i.e. type, location, and impedance disturbance. The voltage sag in each busbar is different depends on location of disturbance. The duration of sag is determined by duration of protection clearing time i.e. the extent to which voltage sag is able to be removed. The voltage swell is an increase in source rms voltage in short time intervals whose value ranges from 1.1 pu to 1.8 p.u from nominal source voltage. Although the duration time of voltage sag/swell is short, the interference can affect sensitive loads such as the computers, the programmable logic controllers (PLCs) and the variable speed drives (VSDs) on motor and simultaneously reducing efficiency of these devices. The DVR is a special power electronics device used to reduce voltage sag/swell. The DVR is able to protect sensitive loads that may be drastically affected by voltage fluctuations in the distribution system [15]. The recommended standard of practice on monitoring voltage sag/swell as the part of electric power quality parameters is IEEE 1159-1995 [16]. This standard presents definition and table of voltage sag/swell base on catagories (instantaoeous, momentary, temporary) typical duration, and typical magnitude. The typical residential utility power after sag/swell disturbance is in the range of +/-5% from the nominal value [17]. The percentage of voltage sag is formulated in Eq. (7) [18] and with the same prosedur, the authors propose Eq. (8) for percentage of voltage swell.

$$Sag(\%) = \frac{Vpre\ sag - Vsag}{Vpre\ sag} \tag{7}$$

$$Swell(\%) = \frac{|Vpre\ swell - Vswell|}{Vpre\ swell} \tag{8}$$

2.5. Voltage Harmonics

Harmonics of power systems are low frequency phenomena characterized by waveform distortion, which introduces harmonic frequency components. Voltage and current harmonics have an undesirable effect on the operation of power systems and power system components [19]. In general, current and voltage waves form pure sinusoidal. The prominent problem in the distribution system is voltage harmonics waves generated by source of a distorted power system and non-sinusoidal currents due to the presence of sensitive/ non-linear loads. Harmonics is a periodic steady state wave that occurs due to interaction between sine wave forms at fundamental frequency with other waves where the wave is a multiple of fundamental frequency. The most common harmonics index, which is related to voltage waveforms, is THD which is defined as root mean square (rms) value of harmonics expressed as a percentage of fundamental component, as stated in Eq. 9 [20].

$$THD_V = \frac{\sqrt{\sum_{n=2}^{N} V_n^2}}{V_1} \times 100\% \tag{9}$$

Where V_n is a single frequency r.m.s voltage at the harmonic *n*, *N* is maximum harmonic order to be considered, and V_1 is fundamental line to neutral rms voltage. THD standard most often used in electric power systems is IEEE 519. According to IEEE 519, voltage harmonic distortion in power systems 69 kV and below is limited to 5% THD with each individual harmonis limited by 3% [21].

2.6. MPPT-FM and MPPT-FS

The initial research is to determine value of duty cycle (D) with a variable step to control DC/DC boost converter circuit using MPPT algorithm on PV power output. MPPT has been developed. MPPT searches for the maximum power independent based on environmental conditions, follows changes in solar radiation and temperature, as well as maintains PV output voltage remains constant at maximum value. In this paper FLC method is proposed as MPPT control in PV panel. The fuzzy inference system (FIS) used in this research are FM and FS respectively.

The difference between FM and FS is how to determine the output crips generated from fuzzy inputs. The FM uses a technique of fuzzy output defuzzification, while FS uses weighted average to compute output crips. The ability to express and interpret on FM output is lost in FS, because the consequents of rules are not fuzzy. However FS has a better processing time because weighted average replaces defuzzification process which takes a relatively long time. Because the basic nature of rules that can be interpreted and intuitively, FM can be widely used especially for decision support applications. The FM has an output membership functions (MFs), while FS has no output MFs [22].

MPPT-FLC with FM and FS FIS method respectively is applied by determining input variables, namely fuzzy control output of voltage *(V)* and power *(P)* of PV, seven linguistic variables fuzzy sets, fuzzy operating system block (fuzzification, fuzzy rule base, and defuzzification), function delta voltage *(ΔV)* and delta power (ΔP) during fuzzification, a table fuzzy rule base, crisp values to determine delta duty-cycle *(ΔD)* in defuzzification phase with variable step to control DC/DC boost converter circuit. Fig. 5 shows MPPT-FLC using Mamdani/Sugeno FIS.

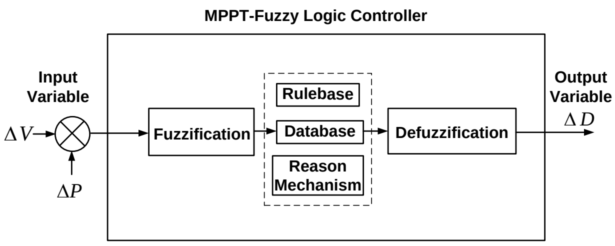

Figure 5. MPPT-Fuzzy Mamdani/MPPT Fuzzy Sugeno

In the fuzzification phase shown in Fig. 5, a number of input variables ΔV and ΔP are calculated and converted into a linguistic variable based on the subset *ΔV* and *ΔP* called MFs. The input of ΔV and *ΔP* are designed to use seven variable fuzzy sets i.e. *PB* (Positive Big), *PM* (Positive Medium), PS (Positive Small), Z (Zero), *NS* (Negative Small), *NM* (Negative Medium), and *NB* (Negative Big). The delta voltage *(ΔV)* and delta power *(ΔP)* are proposed as input variables. While output variable is duty cycle change value *(ΔD)*. The input MFs of MPPT-FM and MPPT-FS are same in Max-Min but output MFs of them is different. MPPT-FM has MFs in Max-Min but MPPT-FS has MFs in constant [0,1]. The MFs of MPPT-FM input and output are presented with triangular and trapezoidal. The value of *ΔV* range from -10 to 10, ΔP from -10 to 10, and *ΔD* from -5 to 5. The output MFs of MPPT-FS is *ΔD* [0,1] from -5 to 5. The delta voltage and delta power for MPPT-FM/MPPT-FS are showed in Fig. 6 and Fig. 7. While delta duty cycle for MPPT-FM and MPPT-FS are showed in Fig. 8 and Fig. 9. Fig. 10 and Fig. 11 show surface view of MFs of MPPT-FM and MPPT-FS respectively.

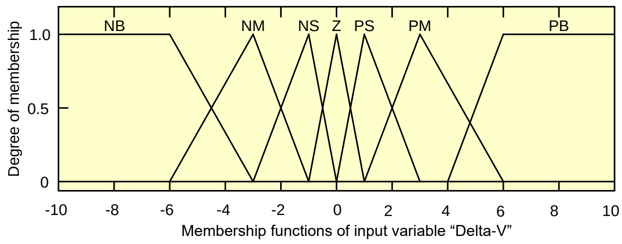

Figure 6. Input MFs of MPPT-FM/MPPT-FS (ΔV)

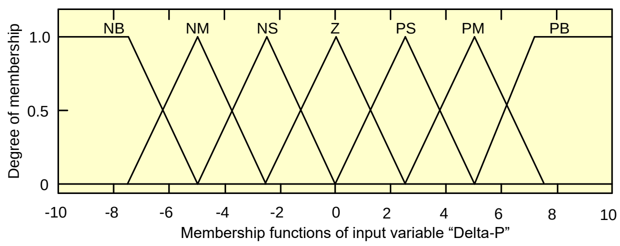

Figure 7. Input MFs of MPPT-FM/MPPT-FS (ΔP)

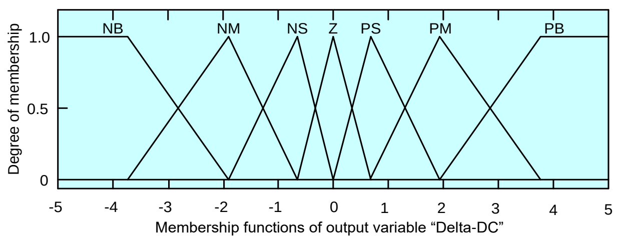

Figure 8. Output MFs of MPPT-FM (ΔD)

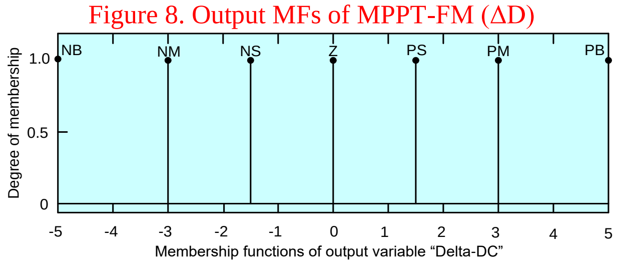

Figure 9. Output MFs of MPPT-FS (ΔD)

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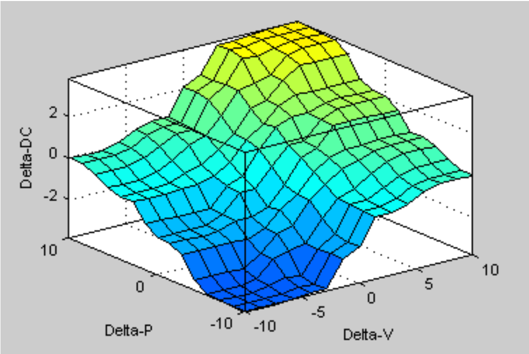


Figure 10. MFs surface view of MPPT-FM

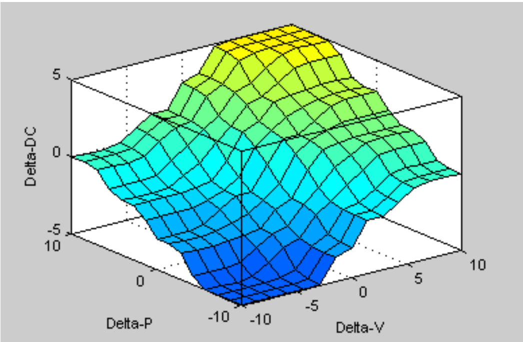


Figure 11. MFs surface view of MPPT-FS

The limit of input and output MFs, determined by prior knowledge of parameter variations. The FIS consists of three parts, namely rule base, database, and reasoning mechanism as shown in Fig. 5. After determine ΔV and ΔP, then both are converted into linguistic variables and use them as input functions for MPPT-FM/MPPT-FS. The output value is ΔD is generated using block inference and fuzzy rules as shown in Table 2.

Table 2. Fuzzy Rule Base

ΔV / ΔP	NB	NM	NS	Z	PS	PM	PB
PB	Z	PS	PS	PM	PM	PB	PB
PM	NS	Z	PS	PS	PM	PM	PB
PS	NS	NS	Z	PS	PS	PM	PM
Z	NM	NS	NS	Z	PS	PS	PM
NS	NM	NM	NS	NS	Z	PS	PS
NM	NB	NM	NM	NS	NS	Z	PS
NB	NB	NB	NM	NM	NS	NS	Z

Finally defuzzyfication block operates to change value of ΔD is raised from linguistic variables into numeric variables back. Then, the numeric variables become an inputs signal for the IGBT switch of DC/DC boost converter to determine MPPT value for PV connected to DVR-BES and 3P3W system.

3. Result and Discussion

The proposed model is analyzed through the determination of nine sag/swell voltage disturbance scenarios on source bus of 3P3W using DVR-BES-PV system. Each disturbances scenario on source bus uses MPPT-FM and MPPT-FS Methods. The nominal percentage of voltage sag/swell disturbances are nine so the total are 18 scenarios. The combination of DVR-BES-PV system circuit with MPPT-FM/MPPT-FS method is used to maintain voltage at sensitive load bus. By using Matlab/Simulink, the model then is run based on desired scenario to obtain source voltage *(V_S)* and load voltage *(V_L)* curves, percentage of voltage sag *(%)*, and percentage of voltage swell *(%)* using Eq. (7) and Eq. (8) [18] with average pre-sag/swell voltage equal as 310,234 V.

Furthermore, source voltage THD and load voltage THD in each phase are determined by using fast fourier transform (FFT) analysis base on the curve with Eq. 9 [20]. Then, the average THD of source voltage and load voltage are calculated from both of THD values in each phase previously. The total duration simulation occurs for 0.2 seconds with duration of sag/swell voltage disturbance between 0.06-0.14 second. The THD voltage in each phase is determined for one cycle starting at t = 0.1 seconds. The next step, percentage of sag/swell load voltage *(%)*, average THD of source voltage *(%)*, and average THD of load voltage (%) on each MPPT control methods and scenarios are presented in Table 3. By using the same procedure for swell voltage disturbances, the parameters and simulation results are also shown in Table 4. Fig. 12 and Fig. 13 present performance of sag and swell voltage using DVR-BES-PV with MPPT-FM/MPPT-FS.

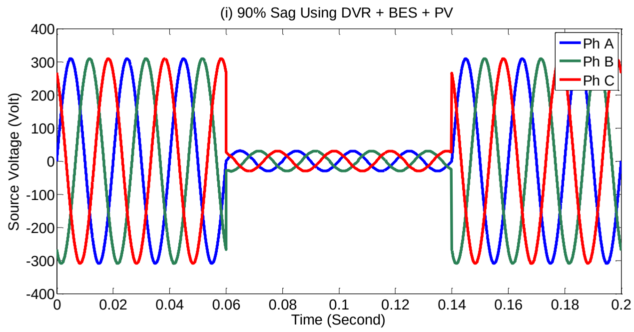
Tabel 3. Percentage of voltage sag and voltage harmonics

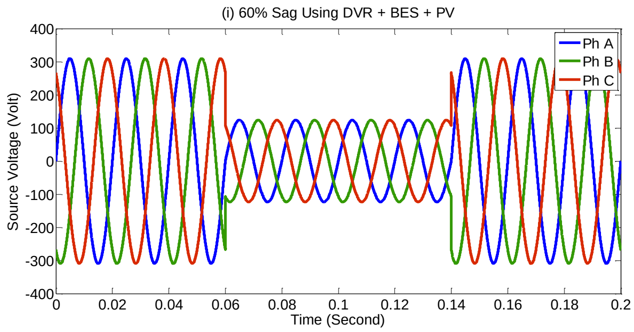
Sag Scn	**Source Voltage (Volt)**			**Load Voltage (Volt)**			**Sag (%)**	**Source Voltage THD (%)**				**Load Voltage THD (%)**			
	A	**B**	**C**	**A**	**B**	**C**		**A**	**B**	**C**	**Avg**	**A**	**B**	**C**	**Avg**
MPPT Fuzzy Mamdani															
10%	278.3	278.3	278.3	310.2	310.2	310.2	**0.011**	0.21	0.21	0.21	0.21	0.37	0.37	0.37	**0.370**
20%	247.3	247.3	247.3	310.2	310.2	310.2	**0.011**	0.23	0.23	0.23	0.23	0.37	0.37	0.37	**0.370**
30%	216.2	216.2	216.2	310.2	310.3	310.2	**0.011**	0.27	0.27	0.27	0.27	0.38	0.36	0.36	**0.367**
40%	185.2	185.2	185.2	310.2	310.2	310.2	**0.011**	0.31	0.31	0.31	0.31	0.37	0.36	0.35	**0.360**
50%	154.2	154.2	154.2	310.2	309.9	309.9	**0.075**	0.37	0.37	0.38	0.37	0.38	0.42	0.41	**0.404**

60%	123.2	123.2	123.2	310.1	307.4	307.4	**0.623**	0.47	0.46	0.47	0.47	0.38	2.09	2.07	**1.514**
70%	92.13	92.16	92.17	309.9	301.7	302.2	**1.816**	0.61	0.60	0.62	0.61	0.43	5.35	5.27	**3.684**
80%	61.11	61.14	61.18	308.2	295.6	293.4	**3.600**	0.88	0.89	0.94	0.91	2.46	8.51	8.00	**6.324**
90%	30.10	30.13	30.19	305.6	288.4	283.1	**5.759**	1.72	1.80	1.90	1.81	6.35	13.14	11.46	**10.32**
MPPT Fuzzy Sugeno															
10%	278.3	278.3	278.3	310.2	310.2	310.2	**0.011**	0.21	0.21	0.21	0.21	0.37	0.37	0.37	**0.370**
20%	247.3	247.3	247.3	310.2	310.2	310.2	**0.011**	0.23	0.23	0.23	0.23	0.37	0.37	0.37	**0.370**
30%	216.2	216.2	216.2	310.2	310.2	310.2	**0.011**	0.27	0.27	0.27	0.27	0.38	0.38	0.36	**0.374**
40%	185.2	185.2	185.2	310.2	310.2	310.2	**0.011**	0.31	0.31	0.31	0.31	0.38	0.36	0.34	**0.360**
50%	154.2	154.2	154.2	310.1	310.0	309.9	**0.076**	0.37	0.37	0.38	0.37	0.38	0.37	0.39	**0.380**
60%	123.2	123.2	123.2	310.0	307.7	307.6	**0.581**	0.47	0.46	0.47	0.47	0.40	1.75	1.73	**1.294**
70%	92.13	92.16	92.17	309.9	301.6	302.2	**1.826**	0.61	0.60	0.63	0.61	0.44	5.41	5.34	**3.730**
80%	61.11	61.14	61.18	308.1	295.6	293.5	**3.600**	0.88	0.89	0.94	0.91	2.23	8.52	2.23	**4.327**
90%	30.10	30.13	30.19	304.9	288.6	283.5	**5.770**	1.71	1.80	1.88	1.80	6.38	12.87	11.17	**10.14**

Tabel 4. Percentage of voltage swell and voltage harmonics

Swell Scn	**Source Voltage (Volt)**			**Load Voltage (Volt)**			**Sag (%)**	**Source Voltage TH(%)**				**Load Voltage THD (%)**			
	A	**B**	**C**	**A**	**B**	**C**		**A**	**B**	**C**	**Avg**	**A**	**B**	**C**	**Avg**
MPPT Fuzzy Mamdani															
110%	340.3	340.3	340.3	310.3	310.3	310.3	**0.021**	0.17	0.17	0.17	0.17	0.37	0.37	0.37	**0.370**
120%	371.4	371.4	371.4	310.3	310.3	310.4	**0.032**	0.16	0.16	0.16	0.16	0.37	0.37	0.37	**0.370**
130%	402.4	402.4	402.4	310.4	310.4	310.4	**0.054**	0.14	0.14	0.14	0.14	0.37	0.37	0.37	**0.370**
140%	433.4	433.4	433.4	310.4	310.4	310.4	**0.054**	0.13	0.13	0.13	0.13	0.37	0.37	0.35	**0.364**
150%	464.5	464.5	464.5	310.4	310.3	310.4	**0.042**	0.12	0.12	0.12	0.12	0.38	0.37	0.35	**0.367**
160%	495.5	495.5	495.5	310.4	310.4	310.5	**0.064**	0.12	0.12	0.12	0.12	0.35	0.37	0.35	**0.357**
170%	526.5	526.5	526.5	310.4	310.4	310.6	**0.075**	0.11	0.11	0.11	0.11	0.36	0.37	0.38	**0.370**
180%	557.5	557.5	557.5	310.5	310.7	311.1	**0.172**	0.10	0.10	0.10	0.10	0.39	0.41	0.48	**0.427**
190%	588.6	588.6	588.6	311.4	312.8	314.8	**0.892**	0.10	0.10	0.10	0.10	1.16	1.72	1.90	**1.594**
MPPT Fuzzy Sugeno															
110%	340.3	340.3	340.3	310.3	310.3	310.3	**0.021**	0.17	0.17	0.17	0.17	0.37	0.37	0.36	**0.367**
120%	371.4	371.4	371.4	310.3	310.4	310.4	**0.043**	0.16	0.16	0.16	0.16	0.37	0.36	0.37	**0.367**
130%	402.4	402.4	402.4	310.3	310.4	310.2	**0.021**	0.14	0.14	0.14	0.14	0.37	0.37	0.35	**0.364**
140%	433.4	433.4	433.4	310.3	310.3	310.3	**0.021**	0.13	0.13	0.13	0.13	0.37	0.37	0.34	**0.360**
150%	464.5	464.5	464.5	310.4	310.3	310.4	**0.043**	0.12	0.12	0.12	0.12	0.37	0.37	0.35	**0.363**
160%	495.5	495.5	495.5	310.4	310.4	310.5	**0.065**	0.12	0.12	0.12	0.12	0.37	0.37	0.36	**0.367**
170%	526.5	526.5	526.5	310.4	310.4	310.6	**0.075**	0.11	0.11	0.11	0.11	0.37	0.37	0.39	**0.377**
180%	557.5	557.5	557.5	310.5	310.8	311.3	**0.204**	0.10	0.10	0.10	0.10	0.39	0.58	0.69	**0.554**
190%	588.6	588.6	588.5	311.3	313.4	315.9	**1.064**	0.10	0.10	0.10	0.10	1.49	2.11	2.66	**2.087**





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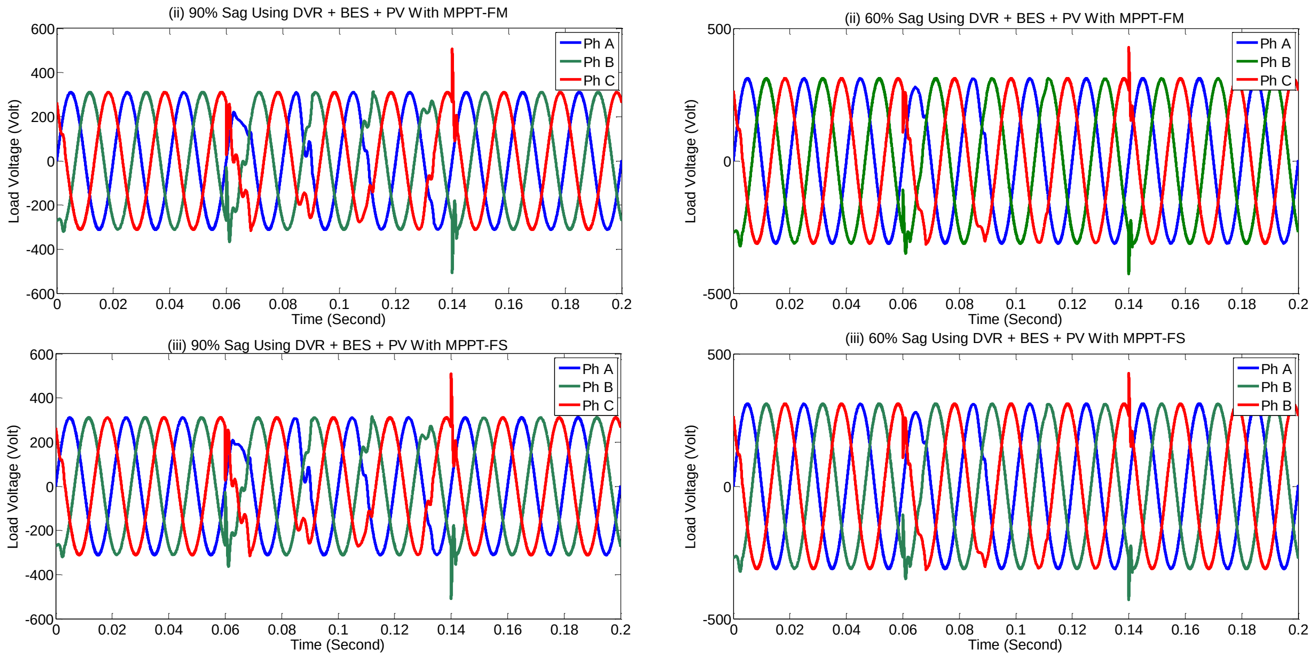
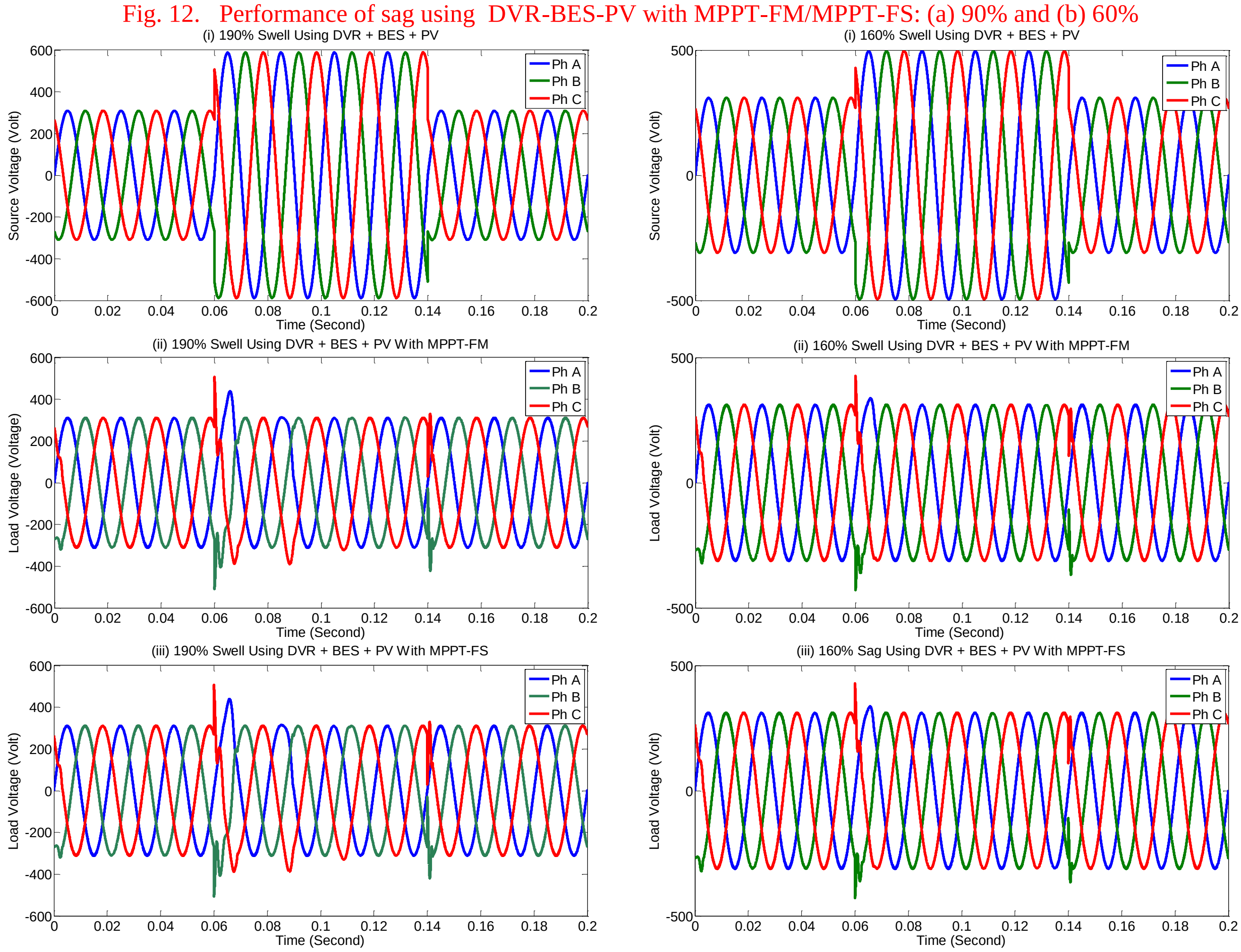


(a) 90% Sag Using DVR-BES-PV System (b) 60% Sag Using DVR-BES-PV System

Fig. 12. Performance of sag using DVR-BES-PV with MPPT-FM/MPPT-FS: (a) 90% and (b) 60%



(a) 190% Swell Using DVR-BES-PV System (b) 160% Swell Using DVR-BES-PV System

Fig. 13. Performance of swell using DVR-BES-PV with MPPT-FM/MPPT-FS: (a) 190% and (b) 160%

Fig. 14 and Fig. 15 show percentage of load voltage sag and load voltage swell in nine disturbances scenario using DVR-BES-PV system with MPPT-FM/MPPT-FS.

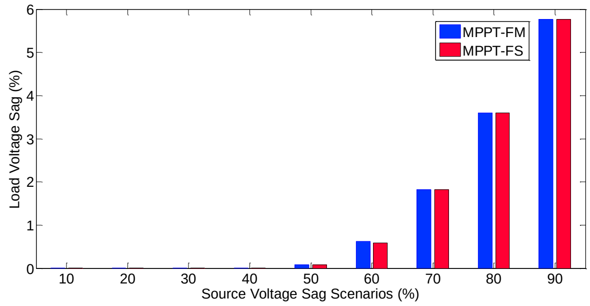


Figure 14. Percentage of load voltage sag

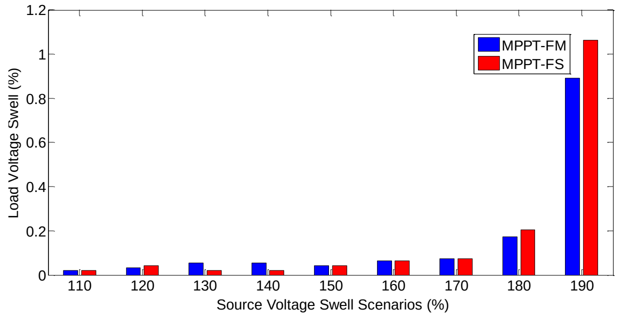


Figure 15. Percentage of load voltage swell

Fig. 12.a.i. shows that in 90% sag on source bus, DVR-BES-PV system using MPPT-FM at t = 0.06 s to t = 0.14 s, average of V_S falls from 310,234 V to 30.14 V. During the disturbance, PV is able to generate power to charge BES and injecting full average of compensation voltage through injection transformer by series active filter in DVR so that average of V_L in Fig. 12.a.(ii) remains stable at 292.334 V and then results percentage of sag and average THD voltage in load bus of 5.759% and 10.32%. By the same prosedur, implementation of MPPT-FS on DVR-BES-PV system results percentage sag and average THD voltage in load bus as 5.770 % and 10.14% as shown in Figure 12.a.(iii). Furthermore, for 10% to 80% voltage sag disturbances, the nominal of percentage of sag and average THD of load voltage are shown in Table 3.

Fig. 13.a.(i) shows that in 190% swell on source bus, DVR-BES-PV system using MPPT-FM at t = 0.06 s to t = 0.14 s, average of V_S rises from 310,234 V to 588.6 V. During the disturbance, PV is able to generate power to charge BES and injecting full average of compensation voltage with opposite polarities through injection transformer by series active filter in DVR so that average of V_L in Fig. 13.a.(ii) remains stable at 313 V and then results percentage of sag and average voltage THD in load bus of 0.892% and 1.594 %. By the same prosedur, implementation of MPPT-FS on DVR-BES-PV system results percentage swell and average THD voltage in load bus as 1.064 % and 2.087 % as shown in Figure 13.a.(iii). Furthermore, for 110% to 180% voltage swell disturbances, the nominal of percentage of swell and average THD of load voltage are shown in Table 4.

Table 3 and Fig. 14 show that for voltage sag disturbances scenario on source bus, the 3P3W system using DVR-BES-PV with MPPT-FM/MPPT-FS, the higher percentage drop of voltage sag on source bus, then percentage of voltage sag on load bus is also higher. The MPPT-FM is able to result a smaller percentage of voltage sag than MPPT-FS. In 90% voltage sag on source bus, MPPT-FM is able to result percentage of load voltage sag of 5.759%, lower than MPPT-FS of 5.770%. Reviewed from harmonics mitigation, MPPT-FM is able to result an average voltage THD higher than MPPT-FS. In 90% voltage sag on source bus, MPPT-FM is able to results an average THD of load voltage of 10.32%, higher than MPPT-FS of 10.14%.

Table 4 and Fig. 15 show that for voltage swell disturbances scenario on the source bus in 3P3W system using DVR-BES-PV with MPPT-FM/MPPT-FS method, the higher percentage increase in voltage swell on source bus, then percentage of voltage swell on load bus is also higher. The MPPT-FM method is able to result a smaller percentage of voltage swell than MPPT-FS. In 190% swell voltage on source bus, MPPT-FM method is able to result a percentage of load voltage swell of 0.892%, lower than MPPT-FS of 1.064%. Reviewed from harmonics mitigation, MPPT-FM method is able to result an average of THD voltage smaller than the MPPT-FS. In 190% voltage swell on source bus, MPPT-FM method is able to result an average THD of load voltage of 1.594%, smaller than the MPPT-FS of 2.087%. The average THD of load voltage using MPPT-FM/MPPT-FS in nine swell voltage disturbances scenario on source bus is smaller than voltage sag and its value already has met the limits prescribed in IEEE 519.

Fig. 16 and Fig. 17 show spectra of harmonic load voltage on phase A for 90% sag using MPPT-FM and MPPT-FS.

Fig. 18 shows performance of an average THD of load voltage in nine voltage sag disturbances scenario using DVR-BES-PV system with MPPT-FM/MPPT-FS. Fig. 19 also shows the same performance for voltage swell.

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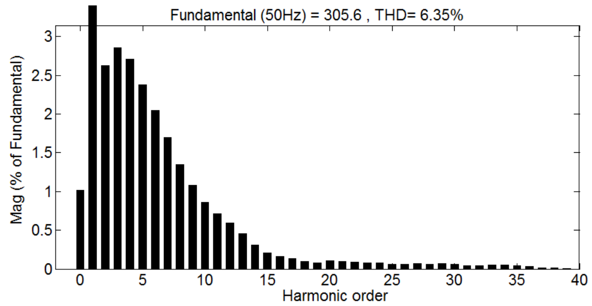

Figure 16. Spectra of harmonic load voltage on phase A for 90% sag using DVR-BES-PV with MPPT-FM

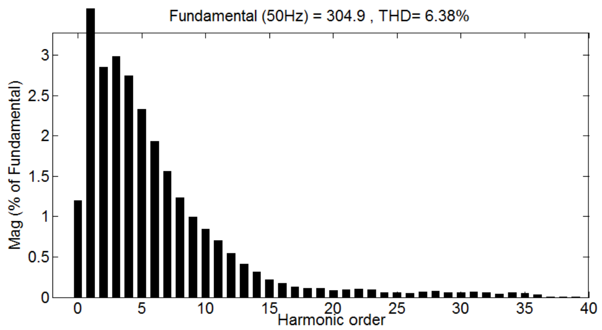

Figure 17. Spectra of harmonic load voltage on phase A for 90% sag using DVR-BES-PV with MPPT-FS

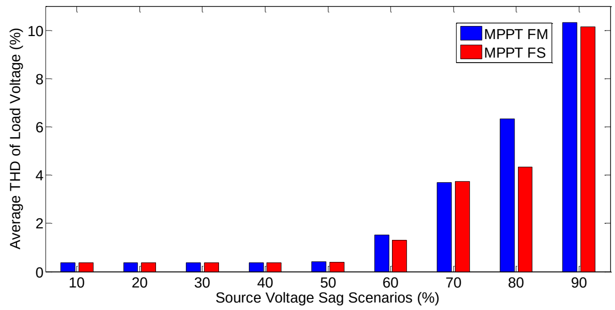

Figure 18. Performance of average THD load voltage for voltage sag

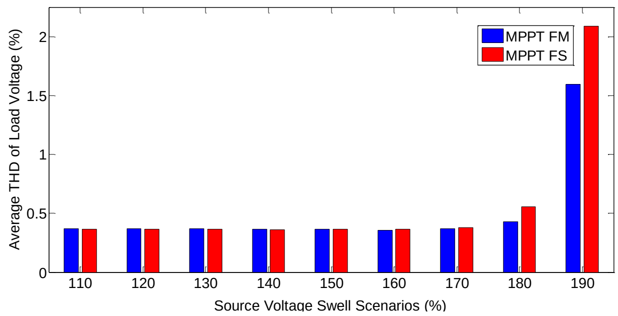

Figure 19. Performance of average THD load voltage for voltage swell

Fig. 18 shows that in the 3P3W system using DVR-BES-PV with MPPT-FM/MPPT-FS method, the higher percentage drop of voltage sag on source bus, then average THD of load voltage is also higher. The MPPT-FM method is able to result an average THD of load voltage THD higher than MPPT-FS method. Fig. 19 shows that in the 3P3W system using DVR-BES-PV with MPPT-FM/MPPT-FS method, the higher percentage increase of voltage swell on source bus, then an average THD of load voltage is also higher. The MPPT-FM method is able to result an average THD of load voltage smaller than MPPT-FS method. The average THD of load voltage using MPPT-FM/MPPT-FS in nine swell voltage disturbances on the source bus, is smaller than sag voltage and its value has met the limits prescribed in IEEE 519.

4. Conclusion

Comparative performance analysis between MPPT-FM and MPPT-FS as controller on PV output power using DVR-BES-PV system connected to 3P3W distribution network have been discussed. The combination of DVR-BES-PV system using two methods is used in order to mitigate voltage sag/swell and harmonics on load bus. The UVTG is used to control series active filter in DVR when it injects compensation voltage during voltage sag/swell disturbance. The PV is used as an alternative DC voltage source to charge BES when its capacity decreases and provides active power needed to compensate for sag/swell.

In nine sag/swell disturbances scenario, the higher percentage drop of sag/increase of swell voltage on source bus, then percentage of sag/swell voltage on load bus is also higher. In the same disturbances and scenarios, the higher percentage drop of sag/increase of swell voltage on source bus, then average THD of load voltage is also higher. The MPPT-FM is able to produce a smaller percentage of voltage sag/swell than MPPT-FS. In nine disturbances scenario, both of MPPT-FM and MPPT-FS are able to result percentage of sag/swell on load voltage under IEEE 1159. In voltage sag, MPPT-FM is able to result an average THD of load voltage THD higher than MPPT-FS. Otherwise in voltage swell, MPPT-FM is able to result an average THD of load voltage smaller than MPPT-FS. The average THD of load voltage using MPPT-FM/MPPT-FS in nine voltage swell disturbances scenario on source bus, is smaller than voltage sag and its value has met the limits prescribed in IEEE 519.

Nevertheless, the average THD of load voltage in 90% sag scenario (deep voltage sag) using MPPT-FM/MPPT-FS has exceeded the limit prescribed in IEEE 519. The implementation of advanced Fuzzy Method i.e. Fuzzy Type 2, Fuzzy Sliding Mode, or both combination for controlling

MPPT on PV connected to DVR-BES system is proposed as future work to overcome this problem.

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Appendix

Three phase grid: RMS voltage = 380 volt (L-L), frequency = 50 Hz, line source impedance R_s = 0.1 Ohm, line source inductance L_s = 15 mH; Series active filter: series inductance L_{se} = 0.015 mH, Series transformer: kVA rating = 10 kVA, frequency 50 Hz, N_1/N_2 = 1:1; Sensite Load: load resistance R_L = 60 Ohm, load inductance L_L = 0.15 mH, line load resistance R_c = 0.4 Ohm, line load inductance L_c = 15 mH; Battery energy storage: Type = nickel metal hibrid, DC voltage = 650 V, capacity = 200 Ah, initial SOC, 100%, inductance L_1 = 6 mH, capacitance C_1 = 200 μF; PV array active power = 0.6 kW, temperature = 25^0 C, irradiance = 1000 W/m^2; MPPT-FM model: FIS = mamdani, composition = max-min; input membership function: delta voltage (ΔV) = trapmf, trimf, delta power (ΔP) = trapmf, trimf; output membership function: delta duty cycle (ΔD) = trapmf, trimf, defuzzyfication = centroid; MPPT-FS model: FIS = sugeno, composition = max-min; input membership function: delta voltage (ΔV) = trapmf, trimf, delta power (ΔP) = trapmf, trimf; output membership function: delta duty cycle (ΔD) = constant [0,1], defuzzyfication = wtaver.

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Comparative Performance of Mitigation Voltage Sag/Swell and Harmonics Using DVR-BES-PV System with MPPT-Fuzzy Mamdani/MPPT-Fuzzy Sugeno

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Abstract: This paper presents comparative performance between Maximum Power Point Tracking-Fuzzy Mamdani (MPPT-FM) and MPPT-Fuzzy Sugeno (FS) methods as controller on Photovoltaic (PV) output power using Dynamic Voltage Restorer-Battery Energy Storage-PV (DVR-BES-PV) system connected to three phase three wire (3P3W) distribution network. The combination of DVR-BES-PV system using two methods is used in order to mitigate voltage sag/swell and harmonics on load bus. The PV is used as an alternative DC voltage source to charge BES when its capacity decreases and provides active power needed to compensate for sag/swell. In nine sag/swell disturbances scenario, MPPT-FM is able to give better performance in percentage of sag/swell on load voltage than MPPT-FS. In 90% voltage sag, MPPT-FM is able to result percentage of voltage sag on load bus of 5.759% smaller than MPPT-FS of 5.770%. Then, in 190% voltage swell, MPPT-FM is able to result percentage of voltage swell on load bus of 0.892% smaller than MPPT-FS of 1.064%. Both methods are also able to result percentage of sag/swell on load voltage under IEEE 1159. In voltage sag, MPPT-FM is able to result an average Total Harmonics Distortion (THD) of load voltage higher than MPPT-FS. Otherwise in voltage swell, MPPT-FM is able to result an average THD of load voltage smaller than MPPT-FS. In 90% voltage sag, MPPT-FM is able to result average THD of load voltage of 10.32% higher than MPPT-FS of 10.14%. Otherwise, in 190% voltage swell, MPPT-FM is able to result average THD on load bus of 1.594% smaller than MPPT-FS of 2.087%. The average THD of load voltage using MPPT-FM/MPPT-FS in nine voltage swell disturbances scenario on source bus, is smaller than voltage sag and it has met limit of IEEE 519. This research is simulated using Matlab/Simulink environment.

Keywords: MPPT-FM, MPPT-FS, Sag/Swell, Harmonics, THD, DVR, BES, PV.

1. Introduction

The diminishing of fossil energy sources and increasing concerns about environmental impacts have caused renewable energy (RE) sources i.e. PV and wind to develop into alternative energy of power generation. The electrical power produced by PV is direct current (DC), so it requires an inverter before it is operated and connected to distribution system (grid). The disadvantage of PV is beside able to supply power to grid, it also generates harmonics due to presence of voltage source inverter (VSI) type filter as a medium to convert DC to AC voltage so that it can reduce power quality. On the other hand, with increasing sensitive load penetration, causing power quality problems in modern distribution systems has increased significantly. The most serious and frequent disturbances in grid voltage are sag, swell, and short circuit. The sag is a decrease in rms voltage between 10-90% which lasts from one half cycle to one minute. The swell is an increase in the source rms voltage in a short time interval whose values range from 1.1 pu to 1.8 p.u from nominal source voltage. The device that is capable of effectively and comprehensively overcoming sag/swell disturbance is DVR. Research on sag compensation using DVR with unit vector template generation (UVTG) method has been done [1]. DVR is able to compensate for balanced and unbalanced sag voltage and inject the desired voltage component to quickly repair a number of interference anomalies at the source voltage to keep load voltage balanced and constant at nominal value.

The comparative analysis of three compensation techniques i.e. phase-by-method compensation, pre-dip compensation method (called large voltage difference compensation), and intelligent phase compensation method has been investigated [2]. A model for DVR control independently has been proposed [3]. The three of three phase harmonics filters (double tuned) were used to migrate harmonics generated by a voltage source converter (VSC). The low DVR rating was able to compensate for sag, swell, and reduce THD voltage on load bus according to IEEE-519. DVR performance on sag voltage and load voltage harmonics using Sinusoidal Pulse control Width Modulation (SPWM) and Space Vector Pulse Width Modulation (SVPWM) have been done [4]. The Synchronous Reference Frame (SRF) method has been used to detect sag and generate modulation signals. The load voltage THD using the SVPWM method was smaller than SPWM.

The grid integration system connected PV system with self supported DVR has been proposed [5]. The system was called a "six-port converter," whole consists of nine semiconductor switches, reduced from 12 previous semiconductors. The configuration was able to operate in different modes based on grid conditions and PV power. The research were conducted on normal grid mode, interference mode, sag mode, and non-active PV mode. PV based DVR model to overcome sag/swell voltage and outages in single phase low voltage housing distribution systems have been proposed [6]. The simulation shows that DVR-based PV with fuzzy logic controller (FLC) is able to provide better dynamic performance in overcoming voltage variations. DVR was operated in standby, active, bypass, power saver mode. DVR performance to mitigate sag voltage and reduce the THD of load voltage has been investigated [7]. The sag compensation on balanced and unbalanced disturbances conditions with variations in source voltage level sag uses PI and FLC method respectively on series active filter of DVR control. The simulation showed that FLC was able to maintain load voltage constant at nominal value and reduce load voltage THD better than PI.

Efficient FLC based on the power management scheme on the DVR in mitigating a number of voltage disturbances has been proposed [8]. The simulation showed that proposed model was efficiently able to maintain DVR output power below the predetermined value and reduce disturbance according to the priority given. The design and analysis of dynamic FLC on DVR is presented and expanded to perform fast error detection. The combination of DVR control methods using FLC and modulation of PWM carriers in an inverter circuit to detect voltage disturbances quickly has been investigated [9]. The proposed model is able to achieve superior performance for balanced and unbalanced sag/swell voltage mitigation. The start and end times of sag/swell voltage can be quickly detected and without oscillation. Fast switching capabilities can also be used in static transfer switches to improve power system reliability. Analysis of sag/swell voltage compensation using DVR and PV systems supported by energy storage elements (battery) has been carried out [10]. The PV system uses MPPT control with an incremental conductance (IC) algorithm as a RE source, which functions to inject reactive power during disturbance. Otherwise the energy storage (battery) element was used to improve system reliability. Integration of solar PV, battery, and DVR during dynamic disturbance conditions in distribution system has been done [11]. The solar PV system using boost converter was implemented using MPPT with IC algorithm. The PV system was supplied in two ways i.e. to meet load demands and maintain the DC link voltage of DVR in voltage sources converter VSC. The sensitive load and grid voltage were balanced by injecting voltage in series with distribution line. The DVR consists of injection transformers, filter circuits, three-phase series active filters, DC source voltage, and energy storage. The energy storage commonly used is DC-link capacitor. The disadvantage of this device has limited energy storage capacity. In order to overcome these problems, BES supplied by PV is used to mitigate sag/swell and harmonics on low voltage distribution network. This combination is called DVR-BES-PV system and installed on three phase three wire (3P3W) distribution network to maintain voltage on sensitive load. The advantage of BES has a larger storage capacity than capacitor. Moreover, PV is used as an alternative DC voltage source to charge BES when its capacity decreases and provides active power needed to compensate for sag/swell. The UVTG method is used to control series active filter in DVR when it injects compensation voltage during voltage sag/swell disturbance. The PV also helps with the self charging process of the system during uninterrupted condition (standby mode).

Table 1. Abbreviation

Symbol	Description
MPPT	Maximum Power Point Tracking
FM	Fuzzy Mamdani
FS	Fuzzy Sugeno
FIS	Fuzzy Inference System
MFs	Membership Functions
FLC	Fuzzy Logic Controller
THD	Total Harmonics Distortion
DVR	Dynamic Voltage Restorer
BES	Battery Energy Storage
PV	Photovoltaic
RE	Renewable Energy
UVTG	Unit Vector Template Generation
PWM	Pulse With Modulation
3P3W	Three Phase Three Wire
PCC	Point Common Coupling
P and O	Perturb and Observe
IC	Incremental Conductance
AI	Artificial Intelligent

Because of movement of sun, PV panel angle, and irradiance variation reaching the panel, sunlight absorbed and power generated by PV panel is not always constant. If this condition occurs then VI characteristic will change and MPP will move. To overcome this problem, MPPT method has been developed. MPPT is looking for independent maximum power based on environmental conditions following movement of sun, radiation and temperature to keep PV terminal voltage constant at its maximum value. The conventional MPPT methods that has been developed are Perturb and Observer (P and O) and Incremental Conductance (IC) method [12]. In this paper, FLC method as a part of artificial intelligent (AI) is used for determining MPPT in PV panel. The fuzzy set theory is a new method of controlling MPPT in obtaining peak of power point. The MPPT is implemented to obtain MPP operation voltage point faster with less overshoot and it also can minimize voltage fluctuation after MPP has been recognized. The fuzzy inference system (FIS) used in this research are FM and FS respectively.

This paper proposes and compares two methods i.e. FM and FS as MPPT control on PV. The PV is connected to 3P3W of 380 V and 50 Hz on low voltage distribution line through DVR-BES system. The nominal percentage of sag voltage disturbances scenarios is nine disturbances started from 10% to 90%. The swell voltage are the same number started from 110% to 190%. So that the total number of voltage sag/swell scenario using both methods are 18 disturbances scenario. The combination of the DVR-BES-PV system uses two methods connected to a 3P3W system is used in order to maintain the voltage at sensitive load remain constant. This research are performed on the percentage of sag/swell load voltage, average THD of source voltage, and average THD of load voltage in each MPPT methods and disturbances scenario. Furthermore the results were compared and validated with IEEE 1159 and IEEE 519. This paper is presented as follow. Section 2 describes proposed model of DVR-BES-PV, modelling of PV, UVTG control, sag/swell, harmonics, as well as MPPT-FM and MPPT-FS. Section 3 shows the results and the discusions about performance of percentage and average THD load voltage of sag/swell. Finally, this paper in concluded in Section 4.

2. Research method

2.1 Proposed method

Fig. 1 shows DVR proposed model using BES supplied by PV. The proposed DVR model is located between source or point common coupling (PCC) bus and load bus which it is connected to sensitive load. The PCC bus is then connected to a 3P3W of 380 Volt 50 Hz low voltage distribution line. The DVR consists of injection transformers, filter circuit, active filter series, DC voltage sources, and energy storage. The energy storage which is commonly used is DC link capacitor. The disadvantage of this device has limited energy storage capacity. The series active filter on DVR is controlled by UVTG method to mantain magnitude of voltage between PCC bus and load bus remain constant, balanced, and distortion free. The UVTG method is also used to generate trigger pulses in PWM circuit of six pulses by the active series filter, so as able to generate injection voltage to compensate for sag/swell voltage on load bus. Table 1 shows abbreviation in this paper.

This paper proposes model of DVR-BES system supplied by 0.6 kW PV system. The PV generator produces an output voltage and is an input for the DC/DC boost converter. There are two FLC method proposed in MPPT of PV system i.e. MPPT FM and MPPT-FS respectively. The MPPT-FM/MPPT-FS helps single phase PV generate MPP in DVR-BES-PV system output. The DC output voltage of the PV is relatively low and then it is raised by a DC/DC boost converter at the appropriate voltage level in order to generate active power for BES charging process. The BES has a larger storage capacity than capacitor, otherwise PV are used as an alternative DC voltage source to charge BES when its capacity decreases. The PV also provides active power to compensate for sag/swell voltage. The PV also helps self charging process of BES during uninterrupted conditions (standby mode). Fig. 2 shows PV system using MPPT-FM/MPPT-FS method connected to DC load.

The analysis of the proposed model is investigated by determination of nine sag/swell disturbances scenario on source bus in the 3P3W system using the DVR-BES-PV. Each sag/swell disturbances on source bus uses MPPT-FM and MPPT-FS respectively. The nominal percentage of sag voltage disturbance are 10%, 20%, 30%, 40%, 50%, 60%, 70%, 80%, and 90%. Whereas, swell voltage disturbances are 110%, 120%, 130%, 140%, 150%, 160%, 170%, 180%, and 190%. So that the total number of sag/swell voltage scenarios using MPPT-FM and MPPT-FS each is 18 disturbances scenario. The combination of DVR-BES-PV system which uses MPPT-FM/MPPT-FS is installed on a 3P3W system to maintain voltage in sensitive load constant. The analysis of this paper is performed on percentage of sag/swell and average THD of load voltage in each MPPT method and disturbances scenario. Then, the results are compared and validated with IEEE 1159 for voltage disturbance standards and IEEE 519 for voltage harmonic standards. Simulation and analysis of this paper using Matlab/Simulink. Parameters for the proposed model are shown in Appendix.

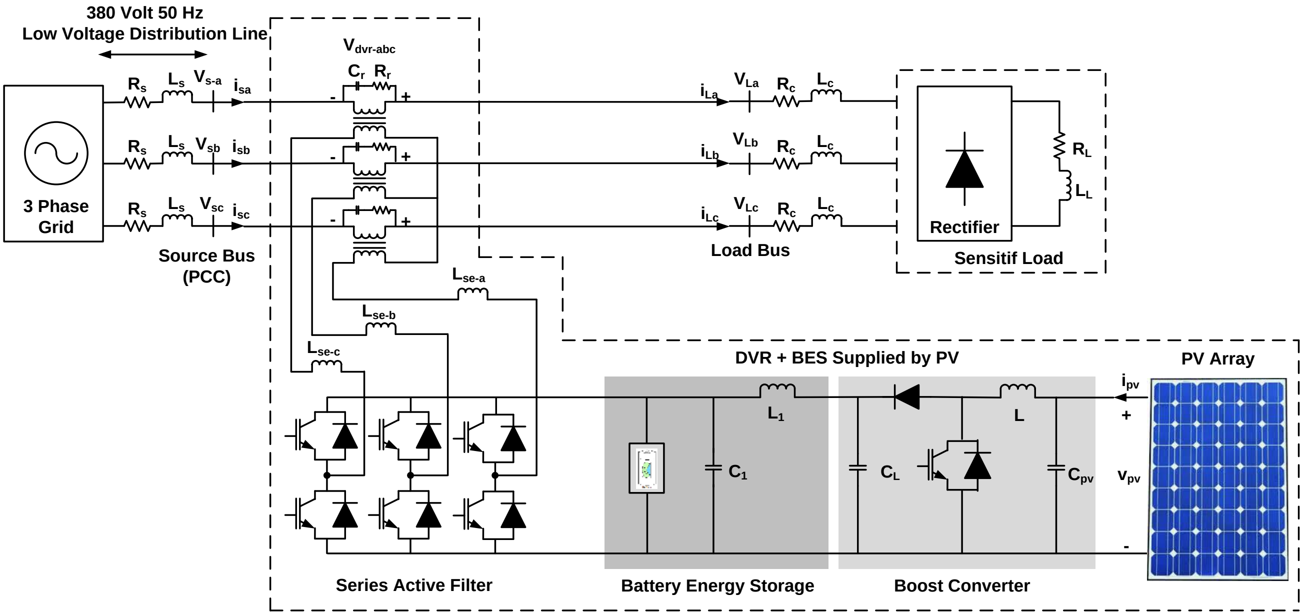

Figure. 1 Proposed model of DVR using BES supplied by PV system

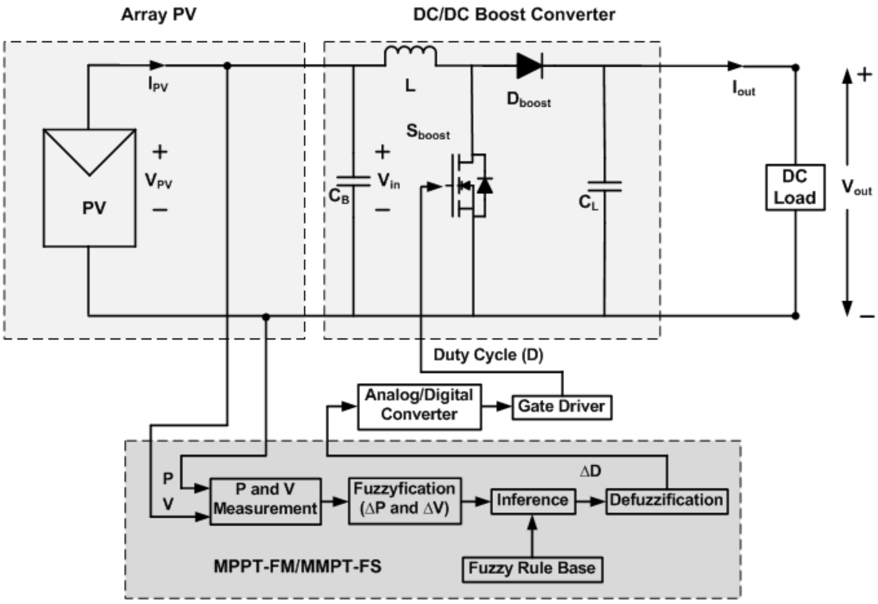

Figure. 2 PV system using MPPT-FM/MPPT-FS method connected to DC load

2.2 Modelling of PV array

Fig. 3 shows the equivalent circuit of a solar panel. A solar panel is composed by several PV cells that have series, parallel, or series-parallel external connections [13]. The V-I characteristic of a solar panel is showed in Eq. (1):

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

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 Eq. (2) and Eq. (3):

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

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

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 the variations of atmospheric conditions. By using Eq. (4) and Eq. (5) which are derived from PV model equations, short circuit current and open circuit voltage can be calculated in different atmospheric conditions.

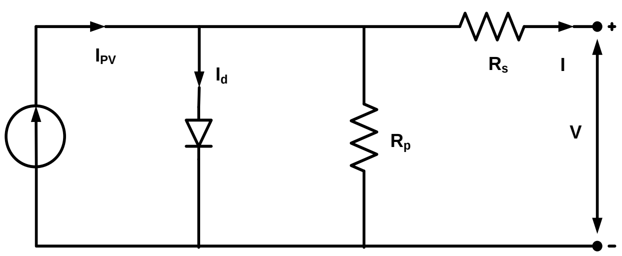

Figure. 3 Equivalent circuit of solar panel

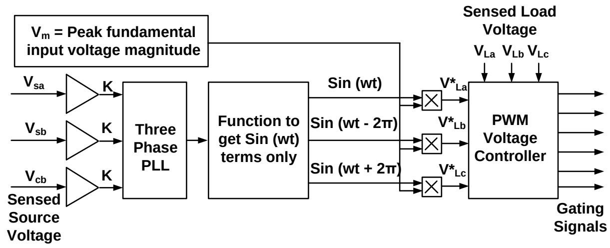

Figure. 4 UVTG control of series active filter

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

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

2.3 UVTG control on series active filter

The main function of series active filter is the sensitive load protection against a number of voltage disturbances at source bus. The control strategy algorithm of the source and load voltage in series active filter is shown in Fig 4. It extracts the UVTG from the distorted input supply. Furthermore, the templates are expected to be ideal sinusoidal signal with unity amplitude. The distorted supply voltages are measured and divided by peak amplitude of fundamental input voltage V_m given in Eq. (6) [14].

$$V_m = \sqrt{\frac{2}{3}(V_{sa}^2 + V_{sb}^2 + V_{sc}^2)} \quad (6)$$

A three phase locked loop (PLL) is used in order to generate sinusoidal unit vector templates with a phase lagging by the use of sinus function. The reference load voltage signal is determined by multiplying the unit vector templates with the peak amplitude of the fundamental input voltage V_m. The load reference voltage *(V_{La}^*, V_{Lb}^*, V_c^*)* is then compared to the sensed load voltage *(V_{La}, V_{Lb}, V_{Lc})* by a PWM controller used to generate the desired trigger signal on series active filter.

2.4 Voltage sag/swell

The voltage sag is defined as a decrease in the value of rms voltage between 10-90% which goes on from one half cycle to one minute. The voltage sag can affect to the phase or amplitude. The most voltages sag occurs caused by a single phase to ground short circuit. An unbalanced short circuit can trigger an unbalanced phase and shift it from its nominal value. The starting of motor with high power also can generate voltage sag. The amplitude of the voltage sag depends on several factors i.e. type, location, and impedance disturbance. The voltage sag in each busbar is different depends on location of disturbance. The duration of sag is determined by duration of protection clearing time i.e. the extent to which voltage sag is able to be removed. The voltage swell is an increase in source rms voltage in short time intervals whose value ranges from 1.1 pu to 1.8 p.u from nominal source voltage. Although the duration time of voltage sag/swell is short, the interference can affect sensitive loads such as the computers, the programmable logic controllers (PLCs) and the variable speed drives (VSDs) on motor and simultaneously reducing efficiency of these devices. The DVR is a special power electronics device used to reduce voltage sag/swell. The DVR is able to protect sensitive loads that may be drastically affected by voltage fluctuations in the distribution system [15]. The recommended standard of practice on monitoring voltage sag/swell as the part of electric power quality parameters is IEEE 1159-1995 [16]. This standard presents definition and table of voltage sag/swell base on categories (instantaneous, momentary, temporary) typical duration, and typical magnitude. The typical residential utility power after sag/swell disturbance is in the range of +/-5% from the nominal value [17]. The percentage of voltage sag is formulated in Eq. (7) [18] and with the same procedure, the authors propose Eq. (8) for percentage of voltage swell.

$$Sag(\%) = \frac{Vpre\ sag - Vsag}{Vpre\ sag} \quad (7)$$

$$Swell(\%) = \frac{|Vpre\ swell - Vswell|}{Vpre\ swell} \quad (8)$$

2.5 Voltage harmonics

Harmonics of power systems are low frequency phenomena characterized by waveform distortion, which introduces harmonic frequency components. Voltage and current harmonics have an undesirable effect on the operation of power systems and power system components [19]. In general, current and voltage waves form pure sinusoidal. The prominent problem in the distribution system is voltage harmonics waves generated by source of a distorted power system and non-sinusoidal currents due to the presence of sensitive/ non-linear loads. Harmonics is a periodic steady state wave that occurs due to interaction between sine wave forms at fundamental frequency with other waves where the wave is a multiple of fundamental frequency. The most common harmonics index, which is related to voltage waveforms, is THD which is defined as root mean square (rms) value of harmonics expressed as a percentage of fundamental component, as stated in Eq. 9 [20].

$$THD_V = \frac{\sqrt{\sum_{n=2}^{N} V_n^2}}{V_1} \times 100\% \quad (9)$$

Where V_n is a single frequency r.m.s voltage at the harmonic n, N is maximum harmonic order to be considered, and V_1 is fundamental line to neutral rms voltage. THD standard most often used in electric power systems is IEEE 519. According to IEEE 519, voltage harmonic distortion in power systems 69 kV and below is limited to 5% THD with each individual harmonics limited by 3% [21].

2.6 MPPT-FM and MPPT-FS

The initial research is to determine value of duty cycle (D) with a variable step to control DC/DC boost converter circuit using MPPT algorithm on PV power output. MPPT has been developed. MPPT searches for the maximum power independent based on environmental conditions, follows changes in solar radiation and temperature, as well as maintains PV output voltage remains constant at maximum value. In this paper FLC method is proposed as MPPT control in PV panel. The fuzzy inference system (FIS) used in this research are FM and FS respectively.

The difference between FM and FS is how to determine the output crips generated from fuzzy inputs. The FM uses a technique of fuzzy output defuzzification, while FS uses weighted average to compute output crips. The ability to express and interpret on FM output is lost in FS, because the consequents of rules are not fuzzy. However FS has a better processing time because weighted average replaces defuzzification process which takes a relatively long time. Because the basic nature of rules that can be interpreted and intuitively, FM can be widely used especially for decision support applications. The FM has an output membership functions (MFs), while FS has no output MFs [22].

MPPT-FLC with FM and FS FIS method respectively is applied by determining input variables, namely fuzzy control output of voltage *(V)* and power *(P)* of PV, seven linguistic variables fuzzy sets, fuzzy operating system block (fuzzification, fuzzy rule base, and defuzzification), function delta voltage *(ΔV)* and delta power (ΔP) during fuzzification, a table fuzzy rule base, crisp values to determine delta duty-cycle *(ΔD)* in defuzzification phase with variable step to control DC/DC boost converter circuit. Fig. 5 shows MPPT-FLC using Mamdani/Sugeno FIS.

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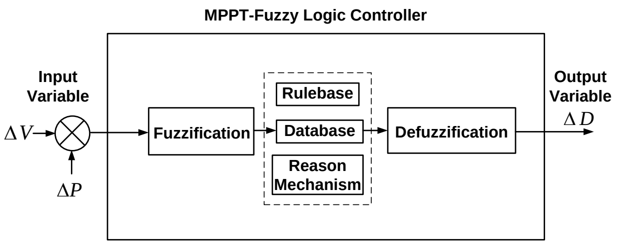


Figure. 5 MPPT-fuzzy Mamdani/MPPT fuzzy Sugeno

In the fuzzification phase shown in Fig. 5, a number of input variables ΔV and ΔP are calculated and converted into a linguistic variable based on the subset *ΔV* and *ΔP* called MFs. The input of ΔV and *ΔP* are designed to use seven variable fuzzy sets i.e. *PB* (Positive Big), *PM* (Positive Medium), PS (Positive Small), Z (Zero), *NS* (Negative Small), *NM* (Negative Medium), and *NB* (Negative Big). The delta voltage *(ΔV)* and delta power *(ΔP)* are proposed as input variables. While output variable is duty cycle change value *(ΔD)*. The input MFs of MPPT-FM and MPPT-FS are same in Max-Min but output MFs of them is different. MPPT-FM has MFs in Max-Min but MPPT-FS has MFs in constant [0,1]. The MFs of MPPT-FM input and output are presented with triangular and trapezoidal. The value of *ΔV* range from -10 to 10, ΔP from -10 to 10, and *ΔD* from -5 to 5. The output MFs of MPPT-FS is *ΔD* [0,1] from -5 to 5. The delta voltage and delta power for MPPT-FM/MPPT-FS are showed in Fig. 6 and Fig. 7. While delta duty cycle for MPPT-FM and MPPT-FS are showed in Fig. 8 and Fig. 9. Fig. 10 and Fig. 11 show surface view of MFs of MPPT-FM and MPPT-FS respectively.

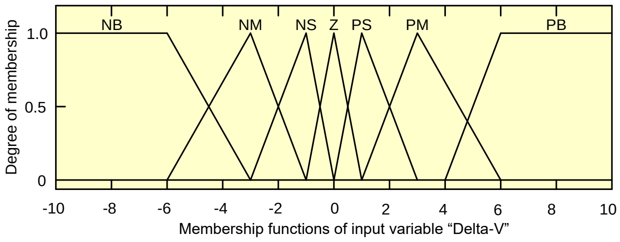


Figure. 6 Input MFs of MPPT-FM/MPPT-FS (ΔV)

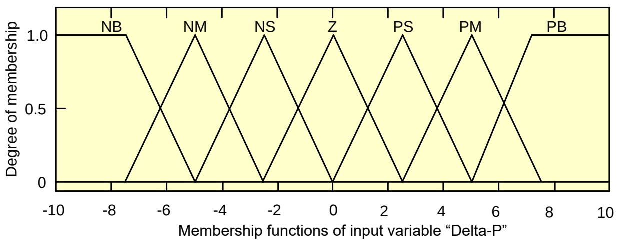


Figure. 7 Input MFs of MPPT-FM/MPPT-FS (ΔP)

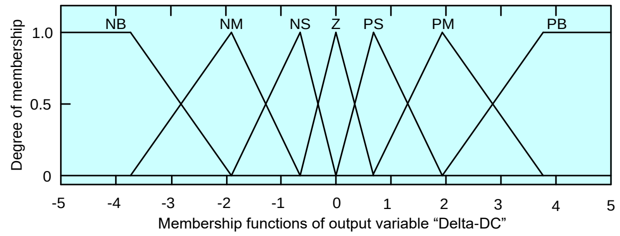


Figure. 8 Output MFs of MPPT-FM (ΔD)

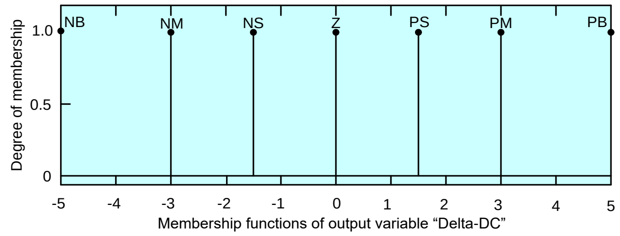


Figure. 9 Output MFs of MPPT-FS (ΔD)

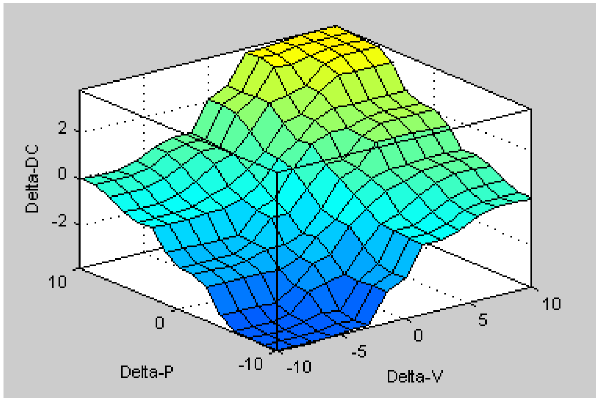


Figure 10. MFs surface view of MPPT-FM

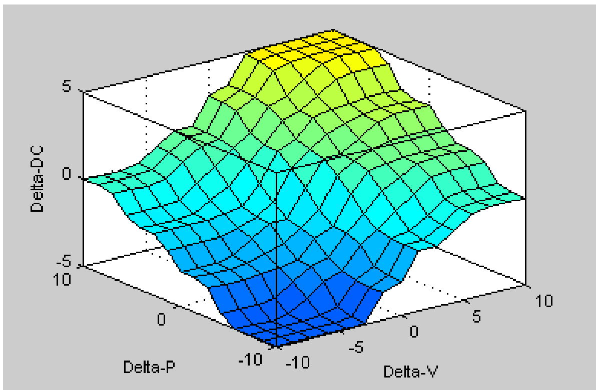


Figure. 11 MFs surface view of MPPT-FS

The limit of input and output MFs, determined by prior knowledge of parameter variations. The FIS consists of three parts, namely rule base, database, and reasoning mechanism as shown in Fig. 5. After determine ΔV and ΔP, then both are converted into linguistic variables and use them as input functions for MPPT-FM/MPPT-FS. The output value is ΔD is generated using block inference and fuzzy rules as shown in Table 2.

Table 2. Fuzzy Rule Base

ΔV / ΔP	NB	NM	NS	Z	PS	PM	PB
PB	Z	PS	PS	PM	PM	PB	PB
PM	NS	Z	PS	PS	PM	PM	PB
PS	NS	NS	Z	PS	PS	PM	PM
Z	NM	NS	NS	Z	PS	PS	PM
NS	NM	NM	NS	NS	Z	PS	PS
NM	NB	NM	NM	NS	NS	Z	PS
NB	NB	NB	NM	NM	NS	NS	Z

Finally defuzzyfication block operates to change value of ΔD is raised from linguistic variables into numeric variables back. Then, the numeric variables become an inputs signal for the IGBT switch of DC/DC boost converter to determine MPPT value for PV connected to DVR-BES and 3P3W system.

3. Result and discussion

The proposed model is analyzed through the determination of nine sag/swell voltage disturbance scenarios on source bus of 3P3W using DVR-BES-PV system. Each disturbances scenario on source bus uses MPPT-FM and MPPT-FS Methods. The nominal percentage of voltage sag/swell disturbances are nine so the total are 18 scenarios. The combination of DVR-BES-PV system circuit with MPPT-FM/MPPT-FS method is used to maintain voltage at sensitive load bus. By using Matlab/Simulink, the model then is run based on desired scenario to obtain source voltage *(V_S)* and load voltage *(V_L)* curves, percentage of voltage sag *(%)*, and percentage of voltage swell *(%)* using Eq. (7) and Eq. (8) [18] with average pre-sag/swell voltage equal as 310,234 V.

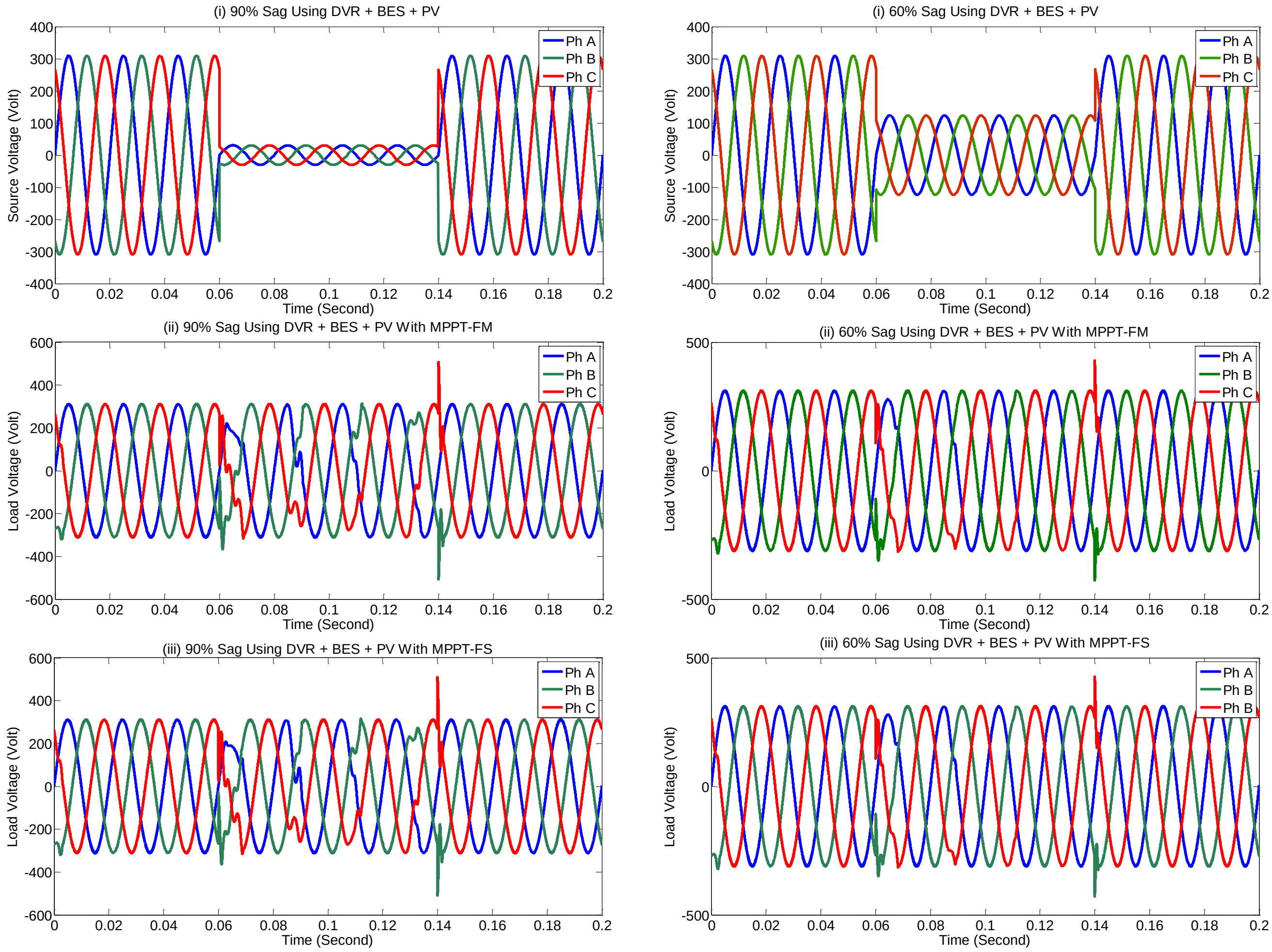
Furthermore, source voltage THD and load voltage THD in each phase are determined by using fast fourier transform (FFT) analysis base on the curve with Eq. 9 [20]. Then, the average THD of source voltage and load voltage are calculated from both of THD values in each phase previously. The total duration simulation occurs for 0.2 seconds with duration of sag/swell voltage disturbance between 0.06-0.14 second. The THD voltage in each phase is determined for one cycle starting at t = 0.1 seconds. The next step, percentage of sag/swell load voltage *(%)*, average THD of source voltage *(%)*, and average THD of load voltage (%) on each MPPT control methods and scenarios are presented in Table 3. By using the same procedure for swell voltage disturbances, the parameters and simulation results are also shown in Table 4. Fig. 12 and Fig. 13 present performance of sag and swell voltage using DVR-BES-PV with MPPT-FM/MPPT-FS.

Table 3. Percentage of voltage sag and voltage harmonics

Sag Scn	**Source Voltage (Volt)**			**Load Voltage (Volt)**			**Sag (%)**	**Source Voltage THD (%)**				**Load Voltage THD (%)**			
	A	**B**	**C**	**A**	**B**	**C**		**A**	**B**	**C**	**Avg**	**A**	**B**	**C**	**Avg**
MPPT Fuzzy Mamdani															
10%	278.3	278.3	278.3	310.2	310.2	310.2	**0.011**	0.21	0.21	0.21	0.21	0.37	0.37	0.37	**0.370**
20%	247.3	247.3	247.3	310.2	310.2	310.2	**0.011**	0.23	0.23	0.23	0.23	0.37	0.37	0.37	**0.370**
30%	216.2	216.2	216.2	310.2	310.3	310.2	**0.011**	0.27	0.27	0.27	0.27	0.38	0.36	0.36	**0.367**
40%	185.2	185.2	185.2	310.2	310.2	310.2	**0.011**	0.31	0.31	0.31	0.31	0.37	0.36	0.35	**0.360**
50%	154.2	154.2	154.2	310.2	309.9	309.9	**0.075**	0.37	0.37	0.38	0.37	0.38	0.42	0.41	**0.404**
60%	123.2	123.2	123.2	310.1	307.4	307.4	**0.623**	0.47	0.46	0.47	0.47	0.38	2.09	2.07	**1.514**
70%	92.13	92.16	92.17	309.9	301.7	302.2	**1.816**	0.61	0.60	0.62	0.61	0.43	5.35	5.27	**3.684**
80%	61.11	61.14	61.18	308.2	295.6	293.4	**3.600**	0.88	0.89	0.94	0.91	2.46	8.51	8.00	**6.324**
90%	30.10	30.13	30.19	305.6	288.4	283.1	**5.759**	1.72	1.80	1.90	1.81	6.35	13.14	11.46	**10.32**
MPPT Fuzzy Sugeno															
10%	278.3	278.3	278.3	310.2	310.2	310.2	**0.011**	0.21	0.21	0.21	0.21	0.37	0.37	0.37	**0.370**
20%	247.3	247.3	247.3	310.2	310.2	310.2	**0.011**	0.23	0.23	0.23	0.23	0.37	0.37	0.37	**0.370**
30%	216.2	216.2	216.2	310.2	310.2	310.2	**0.011**	0.27	0.27	0.27	0.27	0.38	0.38	0.36	**0.374**
40%	185.2	185.2	185.2	310.2	310.2	310.2	**0.011**	0.31	0.31	0.31	0.31	0.38	0.36	0.34	**0.360**
50%	154.2	154.2	154.2	310.1	310.0	309.9	**0.076**	0.37	0.37	0.38	0.37	0.38	0.37	0.39	**0.380**
60%	123.2	123.2	123.2	310.0	307.7	307.6	**0.581**	0.47	0.46	0.47	0.47	0.40	1.75	1.73	**1.294**
70%	92.13	92.16	92.17	309.9	301.6	302.2	**1.826**	0.61	0.60	0.63	0.61	0.44	5.41	5.34	**3.730**
80%	61.11	61.14	61.18	308.1	295.6	293.5	**3.600**	0.88	0.89	0.94	0.91	2.23	8.52	2.23	**4.327**
90%	30.10	30.13	30.19	304.9	288.6	283.5	**5.770**	1.71	1.80	1.88	1.80	6.38	12.87	11.17	**10.14**

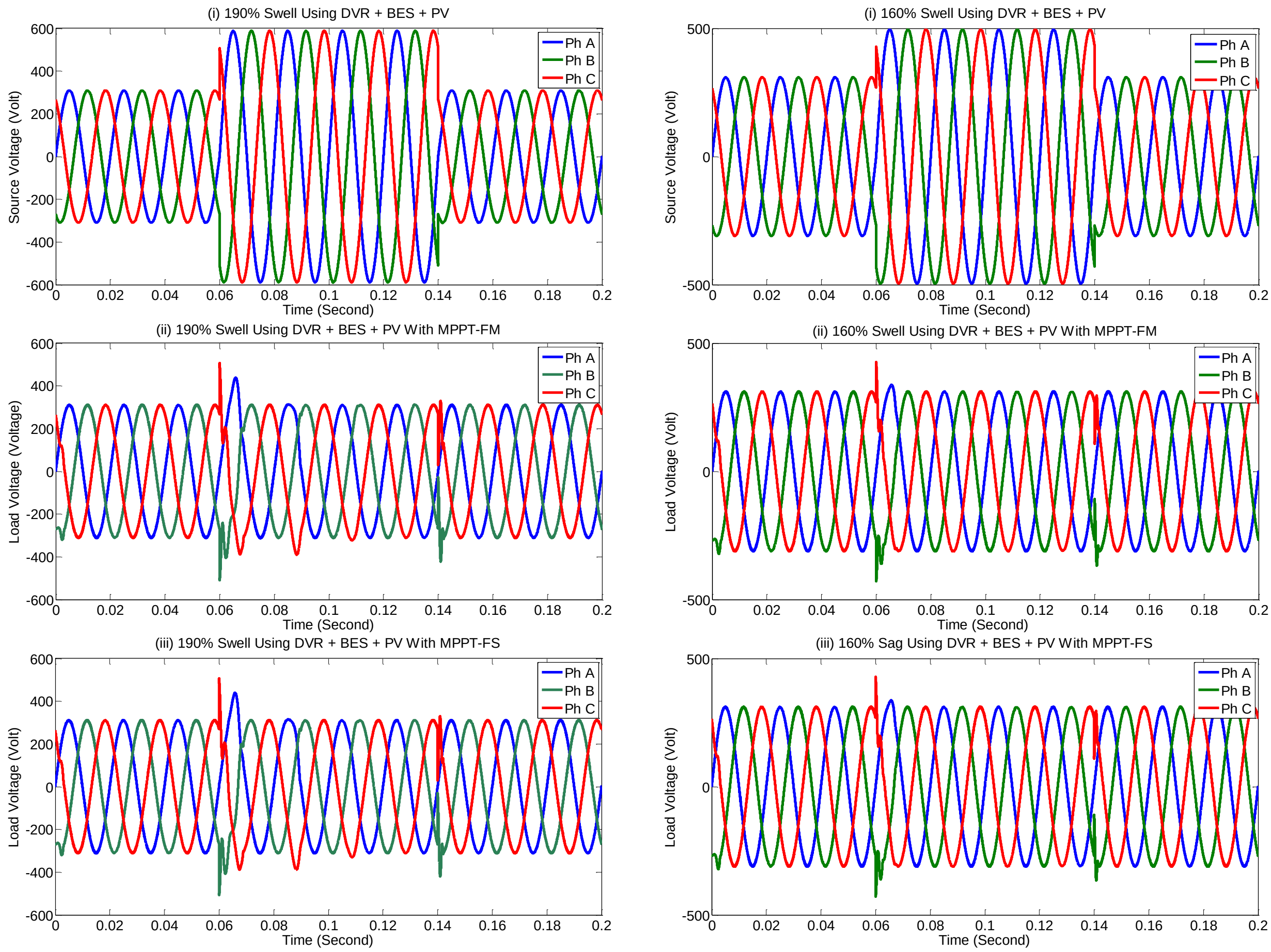
Table 4. Percentage of voltage swell and voltage harmonics

Swell Scn	Source Voltage (Volt)			Load Voltage (Volt)			Sag (%)	Source Voltage TH(%)				Load Voltage THD (%)			
	A	B	C	A	B	C		A	B	C	Avg	A	B	C	Avg
MPPT Fuzzy Mamdani															
110%	340.3	340.3	340.3	310.3	310.3	310.3	**0.021**	0.17	0.17	0.17	0.17	0.37	0.37	0.37	**0.370**
120%	371.4	371.4	371.4	310.3	310.3	310.4	**0.032**	0.16	0.16	0.16	0.16	0.37	0.37	0.37	**0.370**
130%	402.4	402.4	402.4	310.4	310.4	310.4	**0.054**	0.14	0.14	0.14	0.14	0.37	0.37	0.37	**0.370**
140%	433.4	433.4	433.4	310.4	310.4	310.4	**0.054**	0.13	0.13	0.13	0.13	0.37	0.37	0.35	**0.364**
150%	464.5	464.5	464.5	310.4	310.3	310.4	**0.042**	0.12	0.12	0.12	0.12	0.38	0.37	0.35	**0.367**
160%	495.5	495.5	495.5	310.4	310.4	310.5	**0.064**	0.12	0.12	0.12	0.12	0.35	0.37	0.35	**0.357**
170%	526.5	526.5	526.5	310.4	310.4	310.6	**0.075**	0.11	0.11	0.11	0.11	0.36	0.37	0.38	**0.370**
180%	557.5	557.5	557.5	310.5	310.7	311.1	**0.172**	0.10	0.10	0.10	0.10	0.39	0.41	0.48	**0.427**
190%	588.6	588.6	588.6	311.4	312.8	314.8	**0.892**	0.10	0.10	0.10	0.10	1.16	1.72	1.90	**1.594**
MPPT Fuzzy Sugeno															
110%	340.3	340.3	340.3	310.3	310.3	310.3	**0.021**	0.17	0.17	0.17	0.17	0.37	0.37	0.36	**0.367**
120%	371.4	371.4	371.4	310.3	310.4	310.4	**0.043**	0.16	0.16	0.16	0.16	0.37	0.36	0.37	**0.367**
130%	402.4	402.4	402.4	310.3	310.4	310.2	**0.021**	0.14	0.14	0.14	0.14	0.37	0.37	0.35	**0.364**
140%	433.4	433.4	433.4	310.3	310.3	310.3	**0.021**	0.13	0.13	0.13	0.13	0.37	0.37	0.34	**0.360**
150%	464.5	464.5	464.5	310.4	310.3	310.4	**0.043**	0.12	0.12	0.12	0.12	0.37	0.37	0.35	**0.363**
160%	495.5	495.5	495.5	310.4	310.4	310.5	**0.065**	0.12	0.12	0.12	0.12	0.37	0.37	0.36	**0.367**
170%	526.5	526.5	526.5	310.4	310.4	310.6	**0.075**	0.11	0.11	0.11	0.11	0.37	0.37	0.39	**0.377**
180%	557.5	557.5	557.5	310.5	310.8	311.3	**0.204**	0.10	0.10	0.10	0.10	0.39	0.58	0.69	**0.554**
190%	588.6	588.6	588.5	311.3	313.4	315.9	**1.064**	0.10	0.10	0.10	0.10	1.49	2.11	2.66	**2.087**



(a) (b)

Figure. 12 Performance of sag using DVR-BES-PV with MPPT-FM/MPPT-FS: (a) 90% sag using DVR-BES-PV system and (b) 60% sag using DVR-BES-PV system



(a) (b)

Figure. 13 Performance of swell using DVR-BES-PV with MPPT-FM/MPPT-FS: (a) 190% swell using DVR-BES-PV system and (b) 160% swell using DVR-BES-PV system

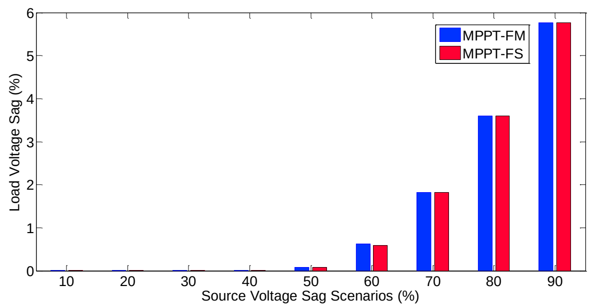


Figure. 14 Percentage of load voltage sag

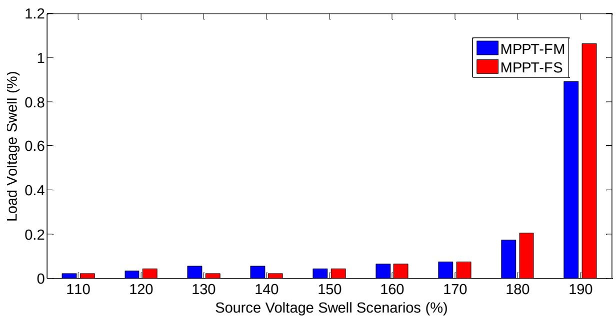


Figure. 15 Percentage of load voltage swell

Fig. 14 and Fig. 15 show percentage of load voltage sag and load voltage swell in nine disturbances scenario using DVR-BES-PV system with MPPT-FM/MPPT-FS.

Fig. 12.a.i. shows that in 90% sag on source bus, DVR-BES-PV system using MPPT-FM at t = 0.06 s to t = 0.14 s, average of V_S falls from 310,234 V to 30.14 V. During the disturbance, PV is able to generate power to charge BES and injecting full average of compensation voltage through injection transformer by series active filter in DVR so that average of V_L in Fig. 12.a.(ii) remains stable at 292.334 V and then results percentage of sag and average THD voltage in load bus of 5.759% and 10.32%. By the same procedure, implementation of MPPT-FS on DVR-BES-PV system results percentage sag and average THD voltage in load bus as 5.770 % and 10.14% as shown in Fig. 12.a.(iii). Furthermore, for 10% to 80% voltage sag disturbances, the nominal of percentage of sag and average THD of load voltage are shown in Table 3.

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Fig. 13.a.(i) shows that in 190% swell on source bus, DVR-BES-PV system using MPPT-FM at t = 0.06 s to t = 0.14 s, average of V_S rises from 310,234 V to 588.6 V. During the disturbance, PV is able to generate power to charge BES and injecting full average of compensation voltage with opposite polarities through injection transformer by series active filter in DVR so that average of V_L in Fig. 13.a.(ii) remains stable at 313 V and then results percentage of sag and average voltage THD in load bus of 0.892% and 1.594 %. By the same procedure, implementation of MPPT-FS on DVR-BES-PV system results percentage swell and average THD voltage in load bus as 1.064 % and 2.087 % as shown in Fig. 13.a.(iii). Furthermore, for 110% to 180% voltage swell disturbances, the nominal of percentage of swell and average THD of load voltage are shown in Table 4.

Table 3 and Fig. 14 show that for voltage sag disturbances scenario on source bus, the 3P3W system using DVR-BES-PV with MPPT-FM/MPPT-FS, the higher percentage drop of voltage sag on source bus, then percentage of voltage sag on load bus is also higher. The MPPT-FM is able to result a smaller percentage of voltage sag than MPPT-FS. In 90% voltage sag on source bus, MPPT-FM is able to result percentage of load voltage sag of 5.759%, lower than MPPT-FS of 5.770%. Reviewed from harmonics mitigation, MPPT-FM is able to result an average voltage THD higher than MPPT-FS. In 90% voltage sag on source bus, MPPT-FM is able to results an average THD of load voltage of 10.32%, higher than MPPT-FS of 10.14%.

Table 4 and Fig. 15 show that for voltage swell disturbances scenario on the source bus in 3P3W system using DVR-BES-PV with MPPT-FM/MPPT-FS method, the higher percentage increase in voltage swell on source bus, then percentage of voltage swell on load bus is also higher. The MPPT-FM method is able to result a smaller percentage of voltage swell than MPPT-FS. In 190% swell voltage on source bus, MPPT-FM method is able to result a percentage of load voltage swell of 0.892%, lower than MPPT-FS of 1.064%. Reviewed from harmonics mitigation, MPPT-FM method is able to result an average of THD voltage smaller than the MPPT-FS. In 190% voltage swell on source bus, MPPT-FM method is able to result an average THD of load voltage of 1.594%, smaller than the MPPT-FS of 2.087%. The average THD of load voltage using MPPT-FM/MPPT-FS in nine swell voltage disturbances scenario on source bus is smaller than voltage sag and its value already has met the limits prescribed in IEEE 519.

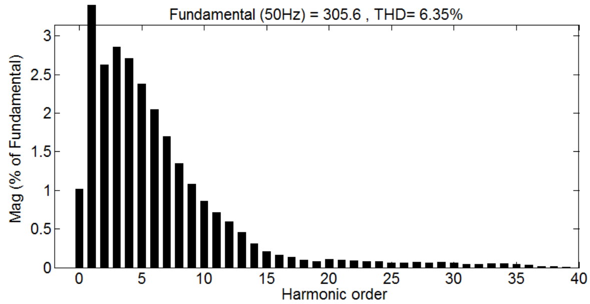

Figure. 16 Spectra of harmonic load voltage on phase A for 90% sag using DVR-BES-PV with MPPT-FM

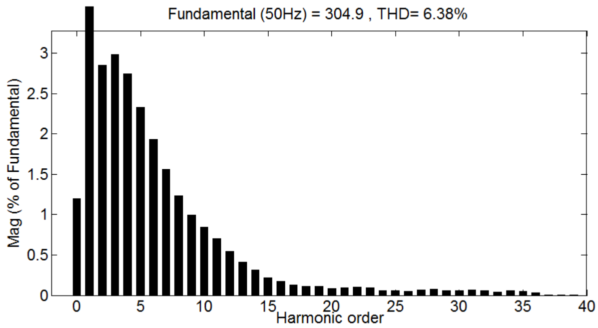

Figure. 17 Spectra of harmonic load voltage on phase A for 90% sag using DVR-BES-PV with MPPT-FS

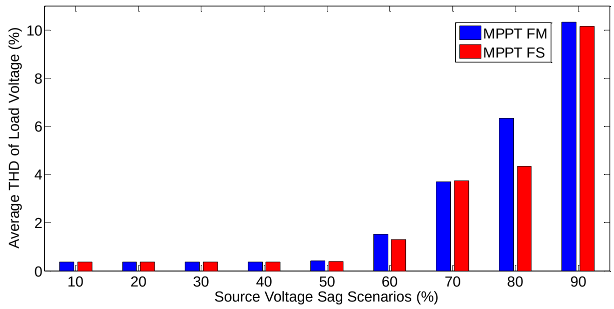

Figure. 18 Performance of average THD load voltage for voltage sag

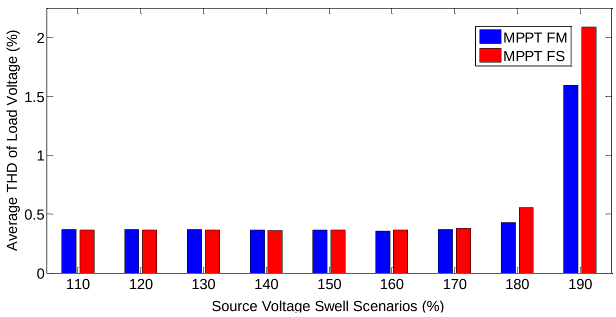

Figure. 19 Performance of average THD load voltage for voltage swell

Fig. 16 and Fig. 17 show spectra of harmonic load voltage on phase A for 90% sag using MPPT-FM and MPPT-FS.

Fig. 18 shows performance of an average THD of load voltage in nine voltage sag disturbances scenario using DVR-BES-PV system with MPPT-

FM/MPPT-FS. Fig. 19 also shows the same performance for voltage swell.

Fig. 18 shows that in the 3P3W system using DVR-BES-PV with MPPT-FM/MPPT-FS method, the higher percentage drop of voltage sag on source bus, then average THD of load voltage is also higher. The MPPT-FM method is able to result an average THD of load voltage THD higher than MPPT-FS method. Fig. 19 shows that in the 3P3W system using DVR-BES-PV with MPPT-FM/MPPT-FS method, the higher percentage increase of voltage swell on source bus, then an average THD of load voltage is also higher. The MPPT-FM method is able to result an average THD of load voltage smaller than MPPT-FS method. The average THD of load voltage using MPPT-FM/MPPT-FS in nine swell voltage disturbances on the source bus, is smaller than sag voltage and its value has met the limits prescribed in IEEE 519.

4. Conclusion

Comparative performance analysis between MPPT-FM and MPPT-FS as controller on PV output power using DVR-BES-PV system connected to 3P3W distribution network have been discussed. The combination of DVR-BES-PV system using two methods is used in order to mitigate voltage sag/swell and harmonics on load bus. The UVTG is used to control series active filter in DVR when it injects compensation voltage during voltage sag/swell disturbance. The PV is used as an alternative DC voltage source to charge BES when its capacity decreases and provides active power needed to compensate for sag/swell.

In nine sag/swell disturbances scenario, the higher percentage drop of sag/increase of swell voltage on source bus, then percentage of sag/swell voltage on load bus is also higher. In the same disturbances and scenarios, the higher percentage drop of sag/increase of swell voltage on source bus, then average THD of load voltage is also higher. The MPPT-FM is able to produce a smaller percentage of voltage sag/swell than MPPT-FS. In nine disturbances scenario, both of MPPT-FM and MPPT-FS are able to result percentage of sag/swell on load voltage under IEEE 1159. In voltage sag, MPPT-FM is able to result an average THD of load voltage THD higher than MPPT-FS. Otherwise in voltage swell, MPPT-FM is able to result an average THD of load voltage smaller than MPPT-FS. The average THD of load voltage using MPPT-FM/MPPT-FS in nine voltage swell disturbances scenario on source bus, is smaller than voltage sag and its value has met the limits prescribed in IEEE 519.

Nevertheless, the average THD of load voltage in 90% sag scenario (deep voltage sag) using MPPT-FM/MPPT-FS has exceeded the limit prescribed in IEEE 519. The implementation of advanced Fuzzy Method i.e. Fuzzy Type 2, Fuzzy Sliding Mode, or both combination for controlling MPPT on PV connected to DVR-BES system is proposed as future work to overcome this problem.

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Appendix

Three phase grid: RMS voltage = 380 volt (L-L), frequency = 50 Hz, line source impedance R_s = 0.1 Ohm, line source inductance L_s = 15 mH; Series active filter: series inductance L_{se} = 0.015 mH, Series transformer: kVA rating = 10 kVA, frequency 50 Hz, N_1/N_2 = 1:1; Sensite Load: load resistance R_L = 60 Ohm, load inductance L_L = 0.15 mH, line load resistance R_c = 0.4 Ohm, line load inductance L_c = 15 mH; Battery energy storage: Type = nickel metal hibrid, DC voltage = 650 V, capacity = 200 Ah, initial SOC, 100%, inductance L_1 = 6 mH, capacitance C_1 = 200 μF; PV array active power = 0.6 kW, temperature = 25^0 C, irradiance = 1000 W/m^2; MPPT-FM model: FIS = mamdani, composition = max-min; input membership function: delta voltage (ΔV) = trapmf, trimf, delta power (ΔP) = trapmf, trimf; output membership function: delta duty cycle (ΔD) = trapmf, trimf, defuzzyfication = centroid; MPPT-FS model: FIS = sugeno, composition = max-min; input membership function: delta voltage (ΔV) = trapmf, trimf, delta power (ΔP) = trapmf, trimf; output membership function: delta duty cycle (ΔD) = constant [0,1], defuzzyfication = wtaver.

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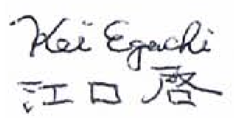

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Dear Amirullah Amirullah,

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Author(s): Agus Kiswantono, Eko Prasetyo, Amirullah Amirullah

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