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/ 40 /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. Mereview makalah jurnal internasional bereputasi berjudul THREE LEVEL H BRIDGE GRID CONNECTED INVERTER WITH MULTIFUNCTIONAL CAPABILITY BASED ON THE CONSERVATIVE POWER THEORY dari Journal of Engineering Science and Technology (JESTEC), Publisher: Taylor's University Malaysia Tahun 2021, Terindeks Scopus Q2.
2. Telah melakukan korespondensi email dengan editor/pengelola jurnal dalam rangka mereview substansi materi makalah jurnal dalam selang waktu yang telah ditentukan sebelumnya. 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

Paper ID EE20301 /Requesting paper review for JESTEC, First round of Review Process/

20 pesan

Jestec <Jestec@taylors.edu.my> 5 Februari 2021 pukul 21.25

Dear Dr.

Greetings from the Editorial Board of JESTEC.

The following attached manuscript titled

THREE LEVEL H BRIDGE GRID CONNECTED INVERTER WITH MULTIFUNCTIONAL CAPABILITY BASED ON THE CONSERVATIVE POWER THEORY

has been submitted to JESTEC for consideration for publication, and I am writing to request that you, as an expert in its topic area, review it and make a recommendation regarding its acceptability.

I hope that you will agree to review this manuscript, in which case you will have 2-3 weeks (from the date of this email) to complete the review.

If you would like to have more than 4 weeks to complete the review, could you please indicate the time frame within which you expect to return the review report.

I appreciate your contribution in maintaining the quality and value of JESTEC, and look forward to your response.

Best regards

Some quick guidelines to our respected reviewers

We would appreciate if you take note that whenever appropriate, papers are evaluated on the basis of the following seven criteria. Please try not to focus on the editorial issues/mistakes as too many of them may lead to the author's frustration. We want the authors, when we revise their paper, to focus on our comments/concern related to the seven above-mentioned criteria.

1. **Research question**: why the authors do this research and what is its importance and application.

2. **Novelty**: a paper gives new ideas, derivations, applications that has been not studied before or little- or not in depth-studied.
3. **Literature review**: to identify the research gap with recent references from 2010 onwards.
4. **Research methodology**: analytical, numerical or experimental or mixed. What is the contribution of the authors, assumptions and/or approximations used, description of apparatus and its limitations, steps of experiments, etc.
5. **Quality of results**: and the depth and logic of the discussion.
6. **Insight** conveyed and recommendations that might be used by others for future work.
7. **English:** used effectively to communicate the ideas and easy to understand with least or no grammatical error or typos.

Assoc. Prof. Dr. Abdulkareem Sh. Mahdi Al-Obaidi, CEng MIMechE

Executive Editor, Journal of Engineering Science & Technology

http://jestec.taylors.edu.my

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2 lampiran

Review Report - 2017.docx
62K

EE20301.docx
1062K

Amirullah Ubhara Surabaya <amirullah@ubhara.ac.id> 6 Februari 2021 pukul 09.27
Kepada: Jestec <Jestec@taylors.edu.my>
Cc: Amirullah Ubhara Surabaya <amirullah@ubhara.ac.id>
Bcc: Amirullah Ubhara Surabaya <amirullah@ubhara.ac.id>

Dear

Assoc. Prof. Dr. Abdulkareem Sh. Mahdi Al-Obaidi, CEng MIMechE

Executive Editor, Journal of Engineering Science & Technology

http://jestec.taylors.edu.my

It is okay I would review this paper at least in a week.

Dr. Amirullah

Universitas Bhayangkara Surabaya

Surabaya Indonesia

[Kutipan teks disembunyikan]

Jestec <Jestec@taylors.edu.my> 6 Februari 2021 pukul 10.40
Kepada: Amirullah Ubhara Surabaya <amirullah@ubhara.ac.id>

Dear Dr.

Thank you in advance for the support and accepting the review invitation.

Best regards

Abdulkareem

[Kutipan teks disembunyikan]

Amirullah Ubhara Surabaya <amirullah@ubhara.ac.id> 8 Februari 2021 pukul 11.14
Kepada: Jestec <Jestec@taylors.edu.my>
Cc: Amirullah Ubhara Surabaya <amirullah@ubhara.ac.id>
Bcc: Amirullah Ubhara Surabaya <amirullah@ubhara.ac.id>

Dear

Assoc. Prof. Dr. Abdulkareem Sh. Mahdi Al-Obaidi, CEng MIMechE

Executive Editor, Journal of Engineering Science & Technology

Here I send you:

1. Point of paper review ID 20301.

2. Review form paper ID 20301.

Dr. Amirullah

Universitas Bhayangkara Surabaya

Surabaya Indonesia

https://www.scopus.com/authid/detail.uri?authorId=57053422400

https://publons.com/researcher/4182659/amirullah-amirullah/

[Kutipan teks disembunyikan]

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2 lampiran

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Jestec <Jestec@taylors.edu.my> 8 Februari 2021 pukul 12.16
Kepada: Amirullah Ubhara Surabaya <amirullah@ubhara.ac.id>

Dear Dr.

Thank you for your kind email.

We confirm that we received your review report.

We will reply you later with some details.

Best regards

JESTEC Editor

http://jestec.taylors.edu.my

[Kutipan teks disembunyikan]

Amirullah Ubhara Surabaya <amirullah@ubhara.ac.id> 8 Februari 2021 pukul 12.35
Kepada: Jestec <Jestec@taylors.edu.my>
Cc: Amirullah Ubhara Surabaya <amirullah@ubhara.ac.id>
Bcc: Amirullah Ubhara Surabaya <amirullah@ubhara.ac.id>

Dear Prof.

Thank you very much.

Dr. Amirullah

Universitas Bhayangkara Surabaya

Surabaya Indonesia

https://www.scopus.com/authid/detail.uri?authorId=57053422400

https://publons.com/researcher/4182659/amirullah-amirullah/

Dr. Amirullah

[Kutipan teks disembunyikan]

Amirullah Ubhara Surabaya <amirullah@ubhara.ac.id> 11 Februari 2021 pukul 06.25
Kepada: Jestec <Jestec@taylors.edu.my>
Cc: Amirullah Ubhara Surabaya <amirullah@ubhara.ac.id>
Bcc: Amirullah Ubhara Surabaya <amirullah@ubhara.ac.id>

Dear Prof,

I need the certificate review as a reviewer of this paper below:

THREE LEVEL H BRIDGE GRID CONNECTED INVERTER WITH MULTIFUNCTIONAL CAPABILITY BASED ON THE CONSERVATIVE POWER THEORY

I would be happy if you respond to this request.

Dr. Amirullah

Universitas Bhayangkara Surabaya

Surabaya Indonesia

https://www.scopus.com/authid/detail.uri?authorId=57053422400

https://publons.com/researcher/4182659/amirullah-amirullah/

[Kutipan teks disembunyikan]

Jestec <Jestec@taylors.edu.my> 11 Februari 2021 pukul 21.29
Kepada: Amirullah Ubhara Surabaya <amirullah@ubhara.ac.id>

Dear Dr.

I would like to express on behalf of the Review panel our sincere thanks for your effort shown in reviewing this paper. We highly appreciate this effort and support and hope that we may call upon you again to review future manuscripts.

Kindly accept the attached appreciation letter.

Best regards

Assoc. Prof. Dr. Abdulkareem Sh. Mahdi Al-Obaidi, CEng MIMechE

Executive Editor, Journal of Engineering Science & Technology

http://jestec.taylors.edu.my

From: Amirullah Ubhara Surabaya <amirullah@ubhara.ac.id>
Sent: Monday, February 08, 2021 12:15 PM

[Kutipan teks disembunyikan]

[Kutipan teks disembunyikan]

AL_Amirullah Ubhara Surabaya_2.pdf
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Amirullah Ubhara Surabaya <amirullah@ubhara.ac.id> 12 Februari 2021 pukul 07.59
Kepada: Jestec <Jestec@taylors.edu.my>
Cc: Amirullah Ubhara Surabaya <amirullah@ubhara.ac.id>
Bcc: Amirullah Ubhara Surabaya <amirullah@ubhara.ac.id>

Dear Prof.

Thanks a lot for sending me a certificate.

Dr. Amirullah
Universitas Bhayangkara Surabaya
Surabaya Indonesia

https://www.scopus.com/authid/detail.uri?authorId=57053422400

https://publons.com/researcher/4182659/amirullah-amirullah/

[Kutipan teks disembunyikan]

Amirullah Ubhara Surabaya <amirullah@ubhara.ac.id> 12 Februari 2021 pukul 08.01
Kepada: reviews@publons.com
Cc: Amirullah Ubhara Surabaya <amirullah@ubhara.ac.id>

Bcc: Amirullah Amirullah <amirullah.ubhara.surabaya@gmail.com>

[Kutipan teks disembunyikan]

Amirullah Ubhara Surabaya <amirullah@ubhara.ac.id> 12 Februari 2021 pukul 08.11
Kepada: reviews@publons.com
Cc: Amirullah Ubhara Surabaya <amirullah@ubhara.ac.id>
Bcc: Amirullah Ubhara Surabaya <amirullah@ubhara.ac.id>

Dear Publons Admin,

Here I send you the certificate as a reviewer on JESTEC.

Dr. Amirulah

https://www.scopus.com/authid/detail.uri?authorId=57053422400

https://publons.com/researcher/4182659/amirullah-amirullah/

[Kutipan teks disembunyikan]

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Jestec <Jestec@taylors.edu.my> 21 Mei 2021 pukul 23.22
Kepada: Amirullah Ubhara Surabaya <amirullah@ubhara.ac.id>

Dear Dr.

Your Reviewer number is: 1

The paper you earlier reviewed has been revised according to your comments/concern.

Could you kindly have a look at the revised paper and check whether the author(s) addressed all your comments/concern.

We appreciate receiving your feedback before or latest by **4/6/2021**

Attached for your reference, please find

- the original paper
- your review report
- the revised paper and
- the outlining how the author(s) addressed your and other reviewers' comments.

Thank you

Assoc. Prof. Dr. Abdulkareem Sh. Mahdi Al-Obaidi, CEng MIMechE

Executive Editor, Journal of Engineering Science & Technology http://jestec.taylors.edu.my

---

From: Amirullah Ubhara Surabaya <amirullah@ubhara.ac.id>
Sent: Monday, February 08, 2021 12:15 PM

[Kutipan teks disembunyikan]

[Kutipan teks disembunyikan]

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4 lampiran

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Review Report 1.docx
45K

EE20301 R1.docx
1691K

Amirullah Ubhara Surabaya <amirullah@ubhara.ac.id> 23 Mei 2021 pukul 08.21
Kepada: Jestec <Jestec@taylors.edu.my>
Cc: Amirullah Ubhara Surabaya <amirullah@ubhara.ac.id>
Bcc: Amirullah Ubhara Surabaya <amirullah@ubhara.ac.id>

Dear Dr.

It is okay please give me a week cheeking this revised manuscript.

Dr. Amirullah
Universitas Bhayangkara Surabaya
Surabaya Indonesia

[Kutipan teks disembunyikan]

Jestec <Jestec@taylors.edu.my> 23 Mei 2021 pukul 21.05
Kepada: Amirullah Ubhara Surabaya <amirullah@ubhara.ac.id>

Sure, Dr.

Thank you for the support

Best regards

JESTEC Editor

[Kutipan teks disembunyikan]

Amirullah Ubhara Surabaya <amirullah@ubhara.ac.id> 23 Mei 2021 pukul 21.30
Kepada: Jestec <Jestec@taylors.edu.my>
Cc: Amirullah Ubhara Surabaya <amirullah@ubhara.ac.id>
Bcc: Amirullah Ubhara Surabaya <amirullah@ubhara.ac.id>

Dear Dr.

Here I send you the final recommendation of the revised manuscript.

Dr. Amirullah
Universitas Bhayangkara Surabaya
Surabaya Indonesia

[Kutipan teks disembunyikan]

Revision_2_Jestec_outlining of Review Report_v3_Oke.docx
52K

Jestec <Jestec@taylors.edu.my> 23 Mei 2021 pukul 21.59
Kepada: Amirullah Ubhara Surabaya <amirullah@ubhara.ac.id>

Dear Dr.

Thank you for your time in reviewing the said paper.

We highly appreciate your support and commitment.

[Kutipan teks disembunyikan]

Amirullah Ubhara Surabaya <amirullah@ubhara.ac.id> 24 Mei 2021 pukul 05.54
Kepada: Jestec <Jestec@taylors.edu.my>
Cc: Amirullah Ubhara Surabaya <amirullah@ubhara.ac.id>
Bcc: Amirullah Ubhara Surabaya <amirullah@ubhara.ac.id>

Dear Dr.

You are welcome.

Dr. Amirullah
Universitas Bhayangkara Surabaya
Surabaya-Indonesia

[Kutipan teks disembunyikan]

Amirullah Ubhara Surabaya <amirullah@ubhara.ac.id> 5 September 2022 pukul 11.26
Kepada: Jestec <Jestec@taylors.edu.my>
Cc: Amirullah Ubhara Surabaya <amirullah@ubhara.ac.id>
Bcc: Amirullah Ubhara Surabaya <amirullah@ubhara.ac.id>

Dear Abdulkareem Sh. Mahdi Al-Obaidi, Ph.D.
Associate Professor, School of Computer Science and Engineering
Executive Editor, Journal of Engineering Science & Technology
Taylor's University

I have reviewed two papers in the Journal of Engineering Science & Technology. I need your information, how many articles do I have to check so that my name and affiliation are included in the reviewer list in https://jestec.taylors.edu.my/reviewers.html?

I need the name displayed on this link for recognition from the Ministry of Education, Culture, Research and Technology of the Republic of Indonesia.

Thanks a lot for your help.

Dr. Amirullah
Department of Electrical Engineering
Faculty of Engineering
Universitas Bhayangkara Surabaya

Surabaya East-Java Indonesia

Pada tanggal Jum, 5 Feb 2021 pukul 21.26 Jestec <Jestec@taylors.edu.my> menulis:
[Kutipan teks disembunyikan]

Jestec <Jestec@taylors.edu.my> 8 September 2022 pukul 20.03
Kepada: Amirullah Ubhara Surabaya <amirullah@ubhara.ac.id>

Dear Dr.

One more please

Best regards

JESTEC Editor

http://jestec.taylors.edu.my

From: Amirullah Ubhara Surabaya <amirullah@ubhara.ac.id>
Sent: Monday, September 05, 2022 12:27 PM
To: Jestec <Jestec@taylors.edu.my>
Cc: Amirullah Ubhara Surabaya <amirullah@ubhara.ac.id>
Subject: Re: Paper ID EE20301 /Requesting paper review for JESTEC, First round of Review Process/

Dear Abdulkareem Sh. Mahdi Al-Obaidi, Ph.D.

[Kutipan teks disembunyikan]
[Kutipan teks disembunyikan]

Amirullah Ubhara Surabaya <amirullah@ubhara.ac.id> 9 September 2022 pukul 08.04
Kepada: Jestec <Jestec@taylors.edu.my>
Cc: Amirullah Ubhara Surabaya <amirullah@ubhara.ac.id>
Bcc: Amirullah Amirullah <amirullah.ubhara.surabaya@gmail.com>

Dear Dr. Abdulkareem Sh. Mahdi Al-Obaidi

Thanks a lot for your information.
[Kutipan teks disembunyikan]
[Kutipan teks disembunyikan]

Lampiran 2

Bukti Pendukung

Journal of Engineering Science and Technology
Vol. XX, No. Y (Year) PPP - QQQ

THREE LEVEL H BRIDGE GRID CONNECTED INVERTER WITH MULTIFUNCTIONAL CAPABILITY BASED ON THE CONSERVATIVE POWER THEORY

Abstract

This article presents use of single stage transformer less cascaded multilevel converter for smart grid application with nonlinear loads. The salient feature of the presented scheme is the use conservative power theory based control strategy for multifunctional operation modes besides injecting its available energy. This scheme does not use any reference frame transformation. Multifunction capability makes proposed system one of the best choice for medium and high power applications with increased reliability. Effectiveness of proposed scheme is verified through simulation results,.

Keywords: Multifunctional inverter, Cascade h-bridge, Low voltage ride through, Ant islanding, conservative power theory

1. Introduction

Renewable energy resources (RES) like solar, wind are becoming most popular sources of electricity production worldwide. This leads to use of power electronics, increase in renewable energy generation as well as micro grid control. Multilevel topology utilization in distributed generation is being preferred to the conventional full bridge invertors because multilevel topology has several advantages especially when the applications involve high power processing. Use of different digital control algorithms makes it possible to operate these inverter for multifunctional mode without using extra circuitry [1]. Generally, the available types of PV systems use conventional three phase inverter which injects real power to the grid at many points in the distribution network while multilevel inverters have many advantages over conventional two level inverters, have less total harmonics distortion (THD), less switching losses, improved power quality, low electromagnetic interference (EMI), modularity and low voltage stress of electronic components [2], [3]. The use of a cascaded multilevel converter for flexible power conditioning in grid connected applications was presented in [4] based on instantaneous power theory (pq). A synchronous reference frame theory based current control strategy for grid-connected inverters is presented by [5], to provide a sinusoidal current into the utility grid, for nonlinear load conditions. In [6], a CPT-based multifunctional control strategy for grid connected solar inverters is developed. A single-phase Asymmetrical Cascaded H-Bridge Multilevel Inverter (ACHMI), control for multifunctional operation in micro grid systems with nonlinear loads was presented by [7]. In this voltage regulation of load in autonomous mode, based on two different voltage control technique was proposed. Cascaded multilevel converter for power conditioning application in smart-grid was proposed by [8]. In this study control of a 7-level shunt active power filter CHMI with individual H-bridge DC-link in voltage regulation was presented and selective compensation based on CPT algorithm. In all the above mentioned references the compensator aims harmonic compensation, reactive power compensation, power factor improvement and have their own features and validity. However, there are several other functionalities to be addressed like islanding detection LVRT/HVRT. These functionalities for the future smart PV inverters can contribute to reduced cost of energy and thus enable more cost-effective PV installations. To accomplish some smart features, a multifunctional Compensator is developed in this study, which can be configured in the PV inverter and capable to perform different operation modes while flexibly change from one to another mode during operation. Inverter is also exposed to various transient conditions such as change in load demands, response during weak grid conditions, response during grid voltage distortions, effect of system parameters variation.

Paper is organized in following manner system description presented in section II. Conservative power theory application for three-phase circuits is explained in section III and its implementation for anti-islanding and LVRT detection is presented in Section IV. Simulation results and its discussion presented in Section V. The last part is the conclusions presented in section VI.

System configuration

In this study conservative power theory based photovoltaic (PV) array supported by three level cascaded inverter is proposed. Propose system is single stage transformer less application which not only improves system efficiency but also reduced weight and size of overall system .The Inverter is not only able to inject real power produced by PV array but also compensate harmonics and reactive power whenever it is demanded in the distribution system. The cascaded H-bridge multilevel inverter is used as STATCOM in night time when no solar power is there and inverter is idle and entire capacity of inverter is utilized for STATCOM operation. Apart from these functions proposed multifunction inverter is able to detect islanding event and LVRT. Capability of proposed inverter is also checked for critical system disturbances which is discussed in coming section. Entire inverter capacity is released to provide grid support for transient disturbing conditions. This solar PV inverter returns to its normal operation after the grid support need is fulfilled. Fig.1 shows the complete diagram of proposed multifunctional smart solar inverter. Three phase three level H bridge PV inverter is connected to 415V distribution system, equivalent model having impedance parameters (Z_g). Three phase diode bridge rectifier with R-L as output is acting as non-linear load is connected at PCC. Lf and R_f are modelled as filter inductance and resistance to mitigate harmonics generated by the inverter. Here I_{abc} and $I_{loadabc}$ are inverter and load current sensed and provided to controller. V_{pabc} is three phase PCC voltage. The d.c voltage controller output, from H-bridge cells, is multiplied by the PCC voltage (v_{pccabc}), this results in additional current reference ($ipabc*$) which will be added to the reference of the disturbance currents ($i_{fabc}{}^*$). The resulting current reference ($i_{abc}{}^*$) is given to the current controller output of the active filter. The main objective of the grid-connected three level H bridge system is to provide simultaneous functionalities based on the CPT for injecting active power, compensating harmonics of the nonlinear load, and supporting reactive power demand of load, unity power factor operation and enabling a smooth transition between grid-connected and islanding modes of operation. System parameters used for simulation is given in table 1

2. Control strategy

The conservative power theory was first developed by Tenti et al [9].CPT works on time domain and this is successfully applied to single- and poly-phase system with or without neutral conductor. The t theory proposes by Tenti is decompositions of power and current in the stationary frame, the terms which are directly related to electrical characteristics, such as: average power transfer, reactive energy, unbalanced loads and nonlinearities. In conservative power theory based converter are presented by [7] [8]. Main quantities used in CPT-based compensation methodologies are defined in set of real, continuous and periodic quantities T (time period), Fundamental frequency (f=1/T), angular frequency (ω = 2π) .Voltage (v) and Current (i) vectors measured at a given network port (phase variables are indicated with subscript “m) The instantaneous power was defined by the scalar product by the scalar product

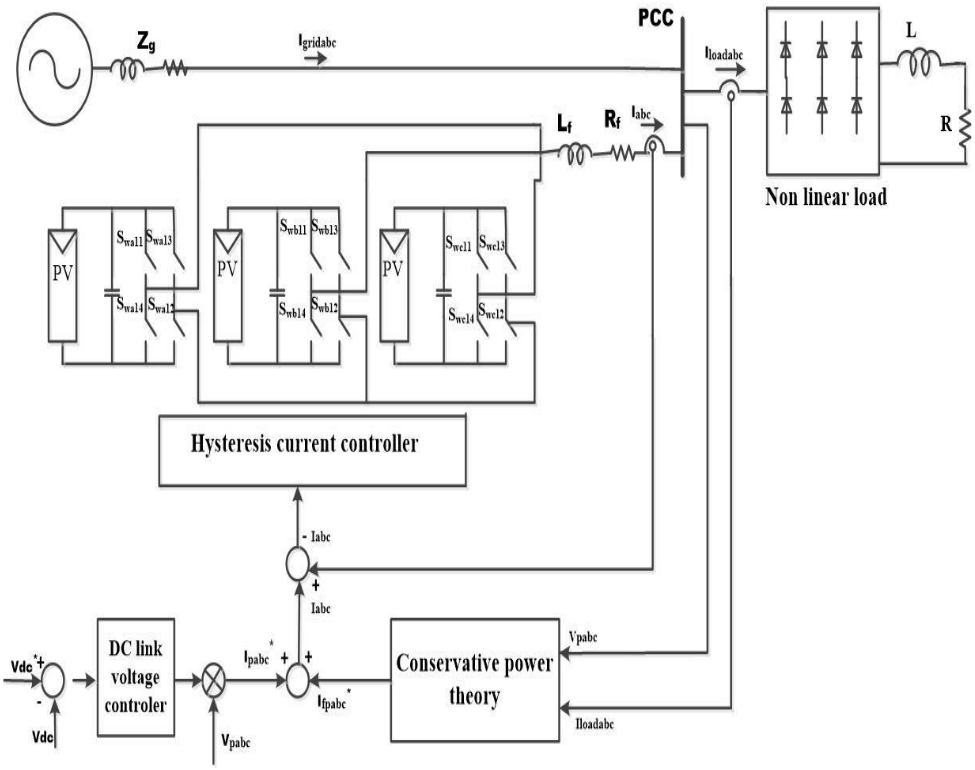

Fig. 1 block diagram of proposed system

$$P= v \circ i=\left|v_a\, v_b\, v_c\right| . \begin{vmatrix} i_a \\ i_b \\ i_c \end{vmatrix} \quad \text{or}$$

$$P\,(t) = \underline{v} \,.\, \underline{i} = \sum_{k=0}^{m} = v_m\, i_m \qquad (1)$$

While the **i**nstantaneous reactive energy was defined

$$P\,(t) = \underline{v} \,.\, \underline{i} = \sum_{k=0}^{m} = v_m\, i_m \qquad (2)$$

While the **i**nstantaneous reactive energy was defined

$$w = \hat{v} \circ i = [\hat{v}_a \;\; \hat{v}_b \;\; \hat{v}_c\,] \circ \begin{vmatrix} i_a \\ i_b \\ i_c \end{vmatrix} \quad \text{or}$$

$$W\,(t) = \underline{\hat{v}} \,.\; \underline{i} = v_m\, i_m \qquad (3)$$

Where $\hat{v}$ is defined as the vector containing the unbiased integrals of the phase voltages. In other words, this quantity $\hat{v}$ is calculated by the difference between the time integral and its average value, as shown below:

$\hat{v}_m = v_{\int m} - \hat{v}_{\int m} \; v_{\int m} = \int_0^T v_m(\tau)\, d\tau$

$\hat{v}_{\int m} = \frac{1}{T}\int_0^T v_m\,(\tau)\, d\tau$

Where according to theory phase voltages are measured with respect to a virtual reference point, in the case of three-phase three-wire circuits, and with respect to the neutral conductor, in the case of single or three-phase four-wire circuits. In this theory, active power is the average power transferred (converted into work), and its definition is identical to that of conventional active power. Reactive energy, in turn, is a new definition that represents the average energy stored in the multiphase grid in generic conditions, including waveform distortions and unbalances. Both P and W satisfy Tellegen's Theorem and are therefore conservative in any grid, regardless of voltage and current waveform. Here term P coincides, at any moment, with conventional active power P conv = V I cosϕ. Conversely, reactive energy is related to conventional reactive power through the fundamental frequency (ω), so that W = Q conv/ω = V I sinϕ/ω. Thus, conventional reactive power is associated with the frequency of the electrical grid, whereas the reactive energy proposed by the CPT is independent of frequency, making it interesting for systems with possible frequency variations, such as micro-grids. From a practical perspective, it is sufficient to calculate for the average value by means of frequency adaptive algorithms or simply low-pass filters, so that both the active power and the reactive energy are immune to variations in mains frequency. Based on these definitions, the phase currents were decomposed into the following subcomponents: balanced active currents, balanced reactive currents, unbalanced ac the corresponding average values of (4) and (5) are the Active power

$$P = \bar{p} = (\underline{v}\;.\;\underline{i}\;) = \frac{1}{T}\int_0^T . \underline{v}\;.\;\underline{i}\; dt = \sum_{m=1}^{M} P_m \quad (4)$$

And Reactive Energy

$$W = \bar{p} = (\;\underline{\hat{v}}\;.\;\;\underline{i}\;\;) = \frac{1}{T}\int_0^T \hat{v}\;.\;\underline{i}\;\; dt = \sum_{m=1}^{M} W_m \quad (5)$$

Where ($\hat{v}$) is the unbiased integral of the voltage vector. Based on the above definitions the phase currents are decomposed into three basic current components. Active phase currents are defined by

Where (G_m) is the equivalent phase conductance

Reactive phase currents are given by

$$i_{am} = \frac{(v_m i_m)}{\|v_m\|2}\; v_m = \frac{P_m}{v_m^2} V_m \;\; = G_m V_m \quad (6)$$

$$i_{rm} == \frac{(\widehat{v_m} i_m)}{\|v_m\|2}\; \hat{v}_m = \frac{Wm}{Vm}\, 2\, \widehat{v_m} \;\; = B_m \hat{v}_m \quad (7)$$

Where (B_m) is the equivalent phase reactivity

Void phase currents are the remaining current terms.

$$\underline{i}_{vm} = \underline{i}_m - \underline{i}_{am} - \underline{i}_{rm} \quad (8)$$

Which do not convey any active power or reactive energy. The active and reactive phase currents can be further decomposed into balanced and unbalanced terms.

$$\underline{i}^b_{am} = \frac{(v,i)}{\|v\|2} \underline{v}_m = \frac{P}{v^2} \underline{v}_m = G^b \underline{v}_m \quad (9)$$

the balanced active currents have been defined as These currents represent the minimum portion of the phase currents which could be associated with a balanced equivalent circuit, responsible for conveying the total active power (P) in the circuit, under certain voltage conditions.

The balanced reactive currents have been defined as:

$$\underline{i}^b_{rm} = \frac{(\hat{v},i)}{\|\hat{\underline{v}}\|2} \hat{\underline{v}}_m = \frac{W}{\hat{v}^2} v_m = B^b \hat{\underline{v}}_m \quad (10)$$

They represent the minimum portion of the phase currents which could be associated with a balanced equivalent circuit responsible for conveying the total reactive energy (W) in the circuit. The unbalanced active currents are calculated by the difference between

$$i^u_{am} = i_{am} - i^b_{am} = (G_m\text{-}G^b)v_m \quad (11)$$

In the same way, the unbalanced reactive currents are

$$i^u_{rm} = i_{rm} - i^b_{rm} = (B_m\text{-}B^b)\hat{v}_m \quad (12)$$

Thus the total unbalance phase currents are defined as in (13)

$$I^u_m = I^u_{am} + I^u_{rm} \quad (13)$$

Therefore, the measured current vector can be split as

$$\underline{i} = \underline{i}_a{}^b + \underline{i}_r{}^b + \underline{i}_a{}^u + \underline{i}_r{}^u \quad (14)$$

For example, the unbalanced currents components or void currents can be used to compensate, selectively or not, for load unbalances and/or nonlinearities. Likewise, the reactive energy (or power) can be compensated in any multiphase system, by definition given previously all the current components are orthogonal to each other so that their RMS value represents as follows.

$$I = \sqrt{I^{b}_{a}{}^2 + I^{b}_{r}{}^2 + I^{u}_{a}{}^2 + I^{b}_{r}{}^2 + I_v{}^2} \quad (15)$$

Similarly, apparent power (A) can be defined by

$A = \|v\|.\ \|i\|$ or

$$A=\|v\|.\sqrt{{I_a^b}^2+{I_r^b}^2+{I_a^u}^2+{I_r^b}^2+{I_v}^2} \quad (16)$$

$$A=\sqrt{P^2+Q^2+N_a^2+N_r^2+D^2}$$

Where P= Vi_a^bactive power;

Q = $V\mathbf{I_r^b}$ is reactive power;

Na = $V\mathbf{I_a^u}$ is unbalanced active power;

N_rr = $V\mathbf{I_r^u}$ is unbalanced reactive power and

D = $V\mathbf{I_v}$ is distortion power

CPT also defined the global power factor (λ). This is affected not only by the circulation of reactive power (Q) but also by load unbalances (N) and nonlinearities (D). $\lambda=\frac{P}{A}$ Thus some of the portions of Eq. (15) can be applied for power conditioning purposes irrespective of the circuit's voltage and current waveforms, provided these quantities are periodic. Here three level H Bridge is controlled to regulate the DC-link voltages of each H-bridge cell provided by MPPT, and also compensate nonlinear load current disturbing effects. Since proposed system is single stage no dc-dc boost converter is used here so MPPT is also incorporated in control. The voltage controller output, from H-bridge cells, is multiplied by the PCC voltage (V_{pccabc}), which results an additional current reference ($ipabc*$) and this reference is added to the disturbance currents (i_{fabc}*) and result of this is current reference (i_{abc}*) which is given to the hysteresis current controller for switching. Thus, this multifunctional inverter can also act as power factor controlled rectifier during transient load conditions and as a current compensator under steady state conditions. It is important to note here that there is no need for any reference frame transformation or synchronization algorithm to provide the reference signals .The proposed three level H Bridge is designed in the abc frame based on frequency response requirements. Proposed three level H Bridge is shown in Fig. 1, simulation parameter are provided in Table I. The PCC voltages (v_{pccabc}) is controlled by grid.

2.1. Anti-Islanding Concepts and Implementations for multilevel inverter using CPT

To implement anti-islanding and LVRT capability in proposed multilevel multifunctional inverter simultaneously GE AI scheme proposed by [12]. This scheme is based on positive feedback concept and these concepts are implemented in this work for grid connected multilevel inverter.

Figure 2 shows the voltage feedback scheme applied in three phase three level inverter using DQ control from V_d to I_d^* here V_d is passed by a band-pass filter (BPF), a gain, and a limiter, and becomes a current variation I_{dd} adding to the I_d*

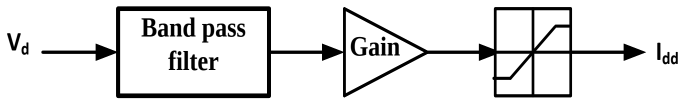

Fig.2 AI voltage feedback block

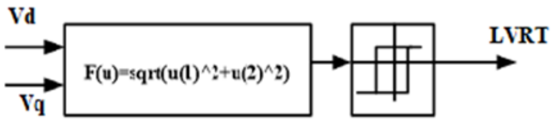

Fig.3 the LVRT implementation block

Before giving reference of d axis current $I_d^*$and q axis current $I_q^*$for generation of PWM signal for hysteresis controller for enabling the inverter for islanding detection as well as fault ride through capability. Following subsystem which is shown in figure 4 explain these capabilities. With this block inverter will differentiate between the islanding events from the LVRT event. Here under voltage trip is disabled and increased the limit for overvoltage trip to see the islanding operation and low voltage ride through of inverter. Corresponding references are generated by comparing the threshold limits set between islanding event and low voltage ride through.

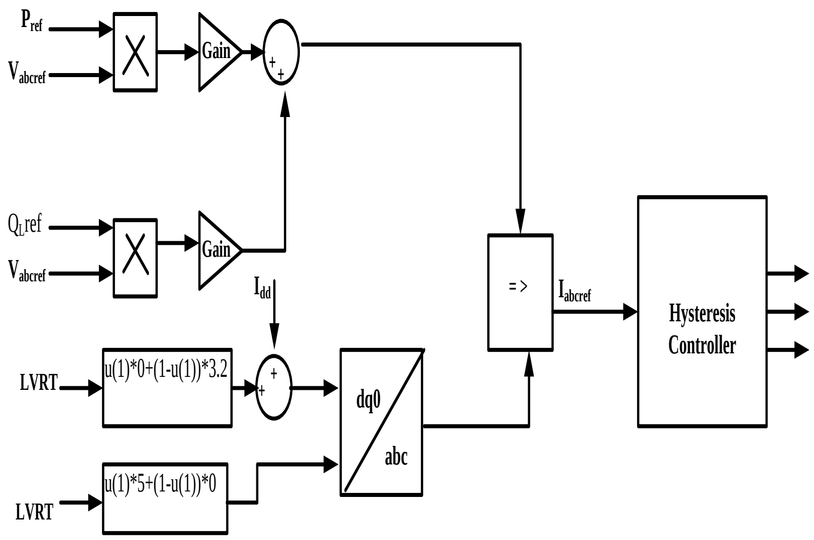

Fig.5 Current controller for generation of current reference in cpt control

3. Simulation results and discussion

In this section performance of three phase three level inverter is evaluated for multiple functionality.in matlab Simulink based on block diagram shown in fig.1 and simulation parameter is given in table 1. The main aim is to investigate the performance of the multilevel multifunctional inverter, controlled by means of CPT based compensation for active power integration, harmonics free current injection, reactive support and power factor control. Fig. 2(a) and three shows the dc link voltage and fig. (b) Shows all three PV panel voltages and MPPT voltages. Fig.3 (a) shows the line voltage of three level

Table 1 Simulation Parameter

Voltage	**440V**
Frequency	50Hz
Open circuit voltage of each cell	45.78V
Short circuit current of each cell	5.75A
No of cell in each module	60
Series connected modules per string	10
Parallel connected module	1
Irradiance(G)	500~700
Temperature	25^0C~35^0C
Source resistance	1x10-3Ω
Source inductance	1x10-7mH
Three-Phase Diode Bridge Rectifier With RL as output	R=180Ω,L =11.20mH

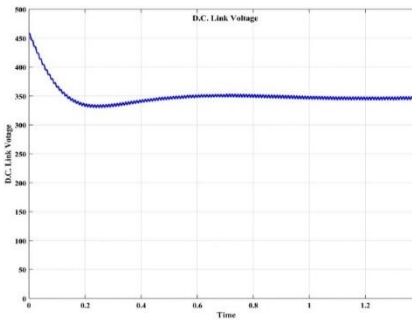

Fig. 6 (a)DC link voltage

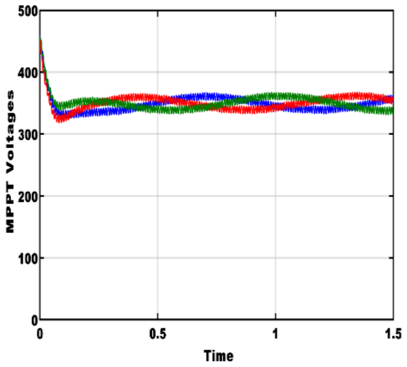

Fig.6(b) MPPT & PV Voltages

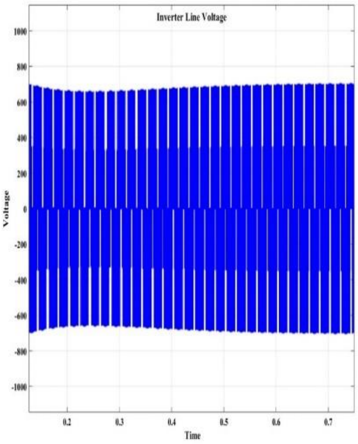

Fig.7(a) Line voltage of inverter

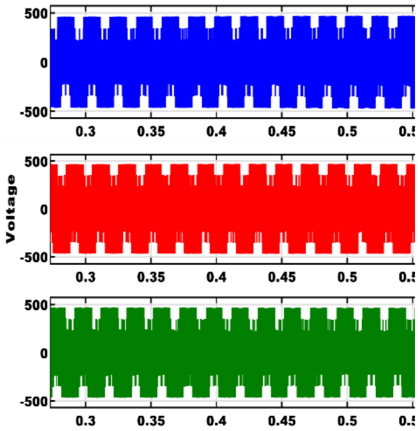

Fig. 7(b) Phase voltages

Fig. 8 shows the waveforms of grid current in a transition. When the time t = 1 s the solar radiation is altered from 500W/m^2 to 700W/m^2. This has the effect of changing the amplitude of the current of the inverter and of the grid.

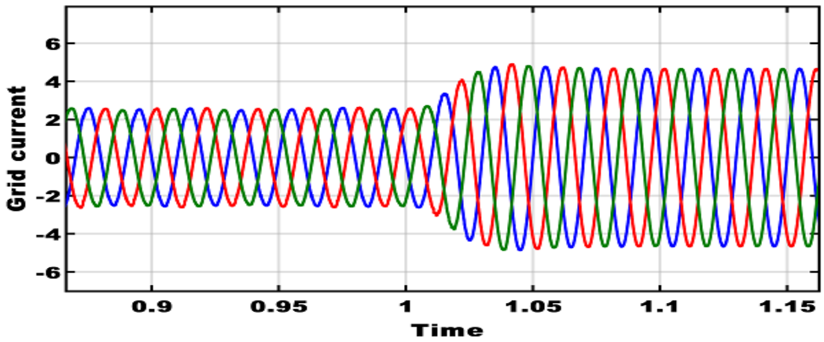

Fig. 8 Grid current for varying irradiation/temperature

From Fig. 9(a) and (b) we observe that the active and reactive power flow in the electric power system is established from Eq. (17) and (18) respectively

$$P_i+P_l+P_g=0 \quad (17)$$

$$Q_i+Q_l+Q_g=0 \quad (18)$$

Proposed inverter is capable of supplying active and reactive power demand of load day time i.e. PV mode.at time t = 1sec. when irradiance increases inverter current increases so power of inverter also increases accordingly. Active and reactive power inverter, load, grid is shown by fig. 19(a) and 9(b). From Fig. 5, it is clear that the inverter fully compensates the reactive power of the load while feeding it with the required active power. Therefore the absorbed active power of the grid is decreased. At night time when there is no solar power inverter become idle .to increase utilization factor of system same inverter will act as STATCOM mode.fig.10(a) and (b) shows active and reactive power of inverter , load and grid it is clear from fig. 10 inverter is successfully supplying reactive power demand of load and grid

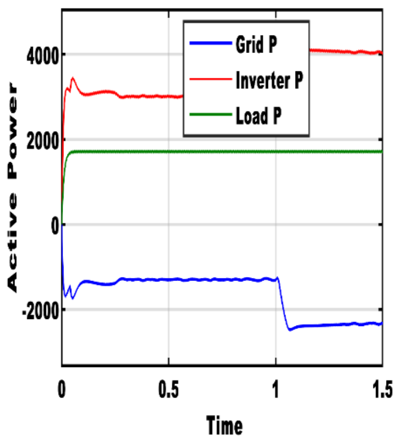

Fig.9(a) Active power of inverter, load, grid in PV mode

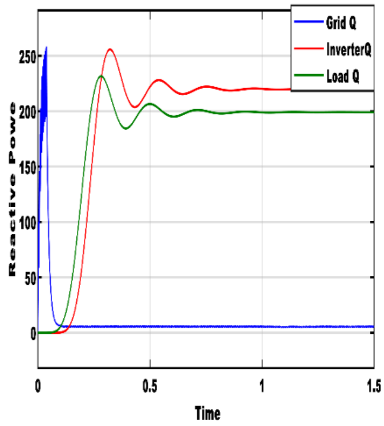

Fig.9(b) Reactive power of inverter, load, grid in PV mode

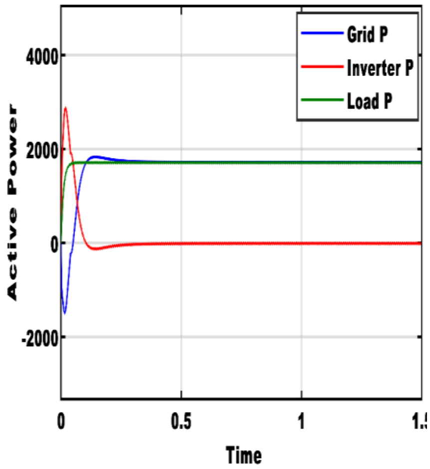

Fig. 10(a) Active power of inverter, load, grid in STATCOM mode

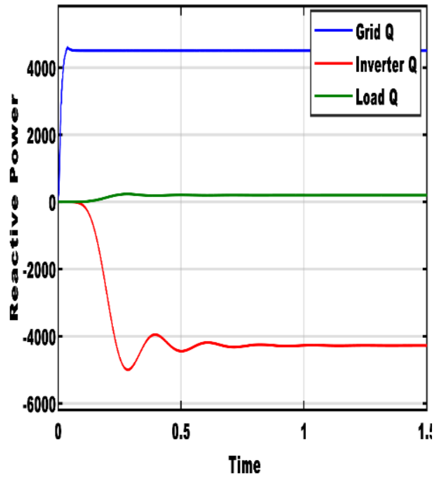

Fig.10(a) Reactive power of inverter, load, grid in STATCOM mode

Fig.11 (a) shows the grid, inverter, load current while fig. 11(b) shows grid current THD which well below 5% IEEE standard requirement. Proposed inverter is capable of compensating harmonics of non-linear load successfully using CPT based compensation.

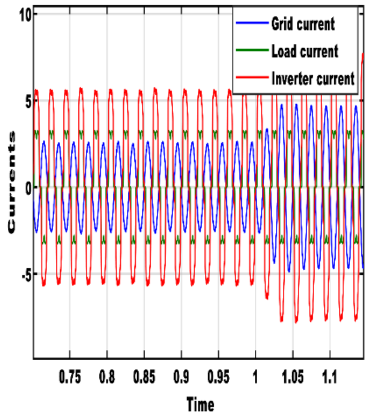

Fig.11(a) Inverter, load, grid current waveforms

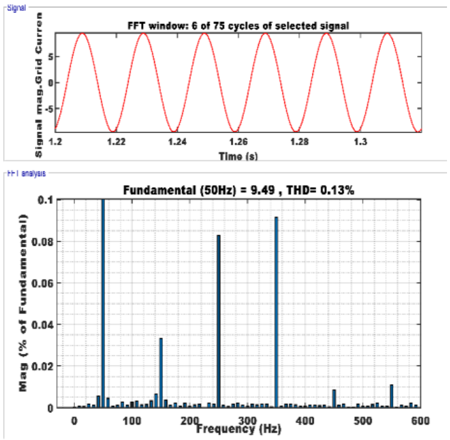

Fig. 11(b) grid current THD

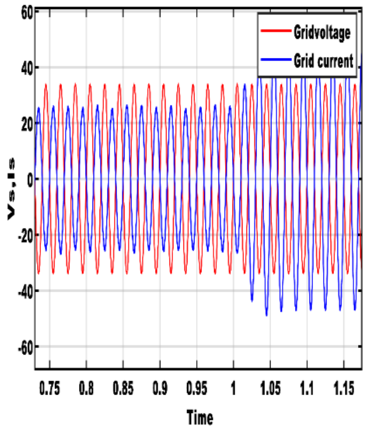

Fig.12 (a) Grid voltage and current in PV mode

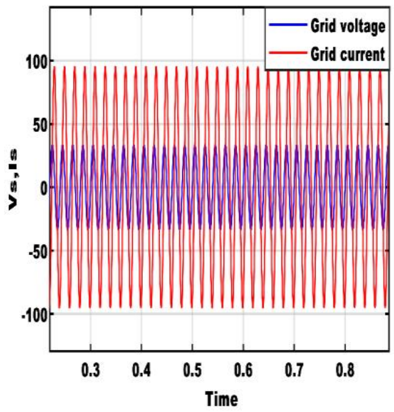

Fig.12 (b) Grid voltage and current in STATCOM mode

Fig. 12(a) and (b) shows the voltage (V_{sa}) and current of the grid (I_{sa}) for the phase a. It is observed that the current and voltage are in phase opposition because here grid is absorbing surplus power supplied by inverter this shows the power factor correction operation of inverter. While in STATCOM mode all the reactive power of the load compensated by the PV system therefore grid voltage and currents are in same phase. This angle is generated because the grid changes from the active power absorption operation in PV mode to the active power feeding operation in STATCOM mode.

Figures 13 shows grid voltage (Vs) grid current (Is) and inverter current (I_{inv}). It is clear from figures that system monitors the grid status, acts to synchronize and ride through with fault for time limit prescribed by regulations and come back to service again. Proposed system also detect islanding within 4msec, which is well below standard time limit of 2sec.

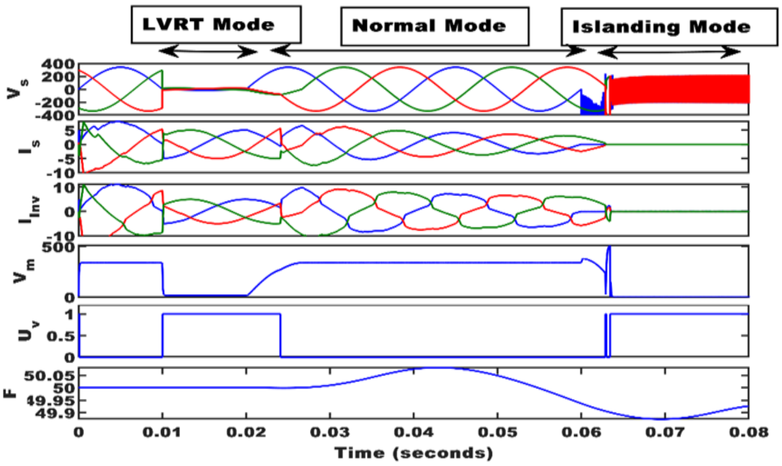

Fig.13 Grid voltage Vs, Grid current Is, Inverter current I_{inv} LVRT voltage, Detection signal and Frequency

4. Conclusion

This paper has presented a multifunctional multilevel inverter for grid connected solar PV. Objective here is to compensate various disturbing current components using the Conservative Power Theory. Multilevel inverters has many advantages, e.g., the modularity and increased reliability in the system configuration and the use of independent DC link voltages. These characteristics make this topology an ideal choice for medium and high power applications. Also, this control strategy regulates the output current by tracking references provided by CPT, without implementing any type of coordinate transformation .There are multiple operation that proposed inverter can perform apart from active power injection. The Low Voltage Ride Through (LVRT) performance with ant islanding capability of the proposed smart inverter is investigated through matlab simulation All function has its own current reference that is obtained by means of the CPT. Simulation results demonstrated the efficacy of the multifunctional multilevel inverter to operate in all modes of operation a contributing to the improvement of the quality, reliability, efficiency and stability of the electrical system. Therefore, proposed system have promising application potential.

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REVIEW FORM

Title of paper: THREE LEVEL H BRIDGE GRID CONNECTED INVERTER WITH MULTIFUNCTIONAL CAPABILITY BASED ON THE CONSERVATIVE POWER THEORY

For sections A & B, please tick a number from 0 to 5, where 0 = strongly disagree and 5 = strongly agree.

A. Technical aspects

	0	1	2	3	4	5
1. The paper is within the scope of the Journal.	☐	☐	☐	☐	☑	☐
2. The paper is original.	☐	☐	☐	☐	☑	☐
3. The paper is free of technical errors.	☐	☐	☐	☑	☐	☐

B. Communications aspects

	0	1	2	3	4	5
1. The paper is clearly readable.	☐	☐	☐	☑	☐	☐
2. The figures are clear & do clearly convey the intended message.	☐	☐	☐	☑	☐	☐
3. The length of the paper is appropriate.	☐	☐	☐	☐	☑	☐

C. Comments to the authors (You may use another sheet of paper.)

A. Abstract: Objective, method, significant findings with quantitative results (not qualitative result), conclusion, use abbreviation in keywords after explained them all in the abstract **(Page 1).**

B. Many abbreviations in this paper do not explain the meaning. Please make an abbreviation table in this manuscript to explain all the meanings of the abbreviations. For example CPT, CHMI, LVRT/HVRT, (2) Apart from being tabular, all the meanings of the abbreviations must be explained in the manuscript previously **(Page 2).**

C. In section paragraph, please replace Section I, II, III, and IV with Section 1, 2, 3, and 4 (Follow the format templates in this manuscript) **(Page 2).**

D. What is number section of system configuration title? **(Page 3).**

E. Many equations in this paper do not use microsoft equation (italic format), please revise them all. For example: Zg, Ipabc*, Vpccabc*, Iabc*, et. al **(Page 3).**

F. (1) Figure 1, 2, 3, 4, and 5 is unclear (blurred), please copy them directly from Word Drawing or Visio to this paper, do not use the print screen menu or paintbrush. (2) Please add Fig 1 with a flow-chart diagram to show the reader more understand the explaining of your proposed model i.e. active power, reactive power on grid, load, and inverter and THD voltage and current in selected case (PV mode and STATCOM mode) as well as Grid voltage Vs, Grid current Is, Inverter current I_{inv} LVRT voltage in selected case (LVRT, Normal, and Islanding Mode) Explain also the diagram in single paragraph (4). **(Page 4).**

G. (1) Write all equations (Eq. 1 to Eq. 16) in a single equation using Microsoft Equation. Do not be in a separate form (one-part uses a typed word but the other part uses the Microsoft equation). (2) Write all equations also in a single equation using Microsoft Equation on all paragraph of this manuscript **(Page 4).**

H. (1) Make Table 1 according to the paper template guidelines, (2) Write the parameters in the first column and the design values in the second column (in the top row of this table) **(Page 9)**

I. (1) Make Fig 6(a) and Fig 6(b) vertically (do not horizontaly), (2) Adjust the y-axis so that the image is clearer if it's still unclear use the zoom menu to plot the image in the middle of the simulation (t = 0.75 s). (3) Both figures are unclear (blurred), please copy them directly from Matlab Figure to this paper, do not use the print screen menu or paintbrush. **(Page 9).**

J. (1) Make Fig 7 (a) and Fig 7 (b) vertically (do not horizontaly), (2) Set the x-axis the same for all images (t = 0 s to t = 1.5 s) (3) Use the zoom menu to plot the image in the middle of the simulation (t = 0.75 s) to show detail the simulation in both figures, (4) Both figures are unclear (blurred), please copy them directly from Matlab Figure to this paper, do not use the print screen menu or paintbrush. **(Page 10).**

K. Set the x-axis simulation in Fig. 8 same as with all figures (t = 0 s to t = 1.5 s), (2) Both figures are unclear (blurred), please copy them directly from Matlab Figure to this paper, do not use the print screen menu or paintbrush **(Page 10).**

L. Make Fig 9a, 9b, 10a, 10b, 11a, 11b, 12a, 12b in vertical model (not in horizontally), (2) Eight figures are unclear (blurred), please copy them directly from Matlab Figure to this paper, do not use the print screen menu or paintbrush. **(Page 11).**

M. (1) Please explain more detail the results of your proposed model i.e. active power, reactive power on grid, load, and inverter and THD voltage and current in selected case (PV mode and STATCOM mode) base on Fig 9a, 9b, 10a, 10b, 11a, 11b, 12a, 12b, (2) Plot and mention of significant nominal values and analyse them combined with all figures results **(Page 12).**

N. (1) The y-axis in Fig. 13 is too tight, please widen this axis so that the figure is clearer, (2) This figure is unclear (blurred), please copy them directly from Matlab figure to this paper, do not use the print screen menu or paintbrush, (3) Please explain more detail the results of Grid voltage Vs, Grid current Is, Inverter current I_{inv} LVRT voltage in selected case (LVRT, Normal, and Islanding Mode) and plot and mention of significant nominal values base three modes and analyse them combined with this figure results. (4) What are the novelty and contribution of your proposed method to make the reader sure that this paper has a significant contribution as well as illustrate them in a table base on the previous researcher in references. **(Page 13).**

O. This paper only describes the best performances of your proposed method, please add this section (conclusion) with future work to assistant the readers that your research has some weaknesses and eligible to continue **(Page 13).**

P. Add your references up to a minimum of 20 references and analyse additional references also in introduction section **(Page 13).**

D. Recommendation (Tick one)

1. Accepted without modifications. ☐
2. Accepted with minor corrections. ☐
3. Accepted with major modification. ☑
4. Rejected. ☐

E. Comments to the editors (These comments will not be sent to the authors)

OUTLINING HOW THE ISSUES ARE ADDRESSED

Title of paper: THREE LEVEL H BRIDGE GRID CONNECTED INVERTER WITH MULTIFUNCTIONAL CAPABILITY BASED ON THE CONSERVATIVE POWER THEORY

1. Address all the concerns/recommendations of the reviewers.
2. All amendments made are to be highlighted in red color in the revised paper.

Reviewer # 1

Final Recommendation	Accepted without modification	Accepted with minor corrections	Accepted with major modification	Rejected
Please tick	☑	☐	☐	☐

Comments	Addressed (Y/N)	Reply/Action taken
Abstract: Objective, method, significant findings with quantitative results (not qualitative result), conclusion, use abbreviation in keywords after explained them all in the abstract	Y	Keywords changed, abstract change according to comments.
Many abbreviations in this paper do not explain the meaning. Please make an abbreviation table in this manuscript to explain all the meanings of the abbreviations. For example, CPT, CHMI, LVRT/HVRT, (2) Apart from being tabular, all the meanings of the abbreviations must be explained in the manuscript previously	Y	Abbreviation table made at end,
In section paragraph, please replace Section I, II, III, and IV with Section 1, 2, 3, and 4	Y	Roman numbers are changed with number 1,2,3
What is number section of system configuration title?	Y	Title number is changed appropriately
Many equations in this paper do not use Microsoft equation (italic format), please revise them all. For example: Zg, Ipabc*, Vpccabc*, Iabc*, et. al	Y	All equation are revised and rewrite in Microsoft equation (italic format)
Figure 1, 2, 3, 4, and 5 is unclear (blurred), please copy them directly from Word Drawing or Visio to this paper, do not use the print screen menu or paintbrush. (2) Please add Fig 1 with a flow-chart diagram to show the reader more understand the explaining of your proposed model i.e. active power, reactive power on grid, load, and inverter and THD voltage and current in selected case (PV mode and STATCOM mode) as well as Grid voltage Vs, Grid current Is, Inverter current Iinv LVRT voltage in selected case (LVRT, Normal, and Islanding Mode) Explain also the diagram in single paragraph (4). (Page 4).	Y	Flow chart made and figure changed according to comments. Explanation is also included
Write all equations (Eq. 1 to Eq. 16) in a single equation using Microsoft Equation. Do not be in a separate form (one-part uses a typed word but the other part uses the Microsoft equation). (2) Write all equations also in a single equation using Microsoft Equation on all paragraph of this manuscript	Y	All equations are changed to Microsoft word equations
Make Table 1 according to the paper template guidelines, (2) Write the parameters in the first column and the design values in the second column (in the top row of this table)	Y	Table changed as per template with corrections
(1) Make Fig 6(a) and Fig 6(b) vertically (do not horizontaly), (2) Adjust the y-axis so that the image is clearer if it's still unclear use the zoom menu to plot the image in the middle of the simulation (t = 0.75 s). (3) Both figures are unclear (blurred), please copy them directly from Matlab Figure to this paper, do not use the print screen menu or paintbrush	Y	All Figures are made vertically and zoom made in simulation time also changed from 0.75 sec

(1) Make Fig 7 (a) and Fig 7 (b) vertically (do not horizontaly), (2) Set the x-axis the same for all images (t = 0 s to t = 1.5 s) (3) Use the zoom menu to plot the image in the middle of the simulation (t = 0.75 s) to show detail the simulation in both figures, (4) Both figures are unclear (blurred), please copy them directly from Matlab Figure to this paper, do not use the print screen menu or paintbrush	Y	All Figures are made vertically and zoom made in simulation time also changed from 0.75 sec
Set the x-axis simulation in Fig. 8 same as with all figures (t = 0 s to t = 1.5 s), (2) Both figures are unclear (blurred), please copy them directly from Matlab Figure to this paper, do not use the print screen menu or paintbrus	Y	Figure changed and x axis keep from t=0 to 1.5
Make Fig 9a, 9b, 10a, 10b, 11a, 11b, 12a, 12b in vertical model (not in horizontally), (2) Eight figures are unclear (blurred), please copy them directly from Matlab Figure to this paper, do not use the print screen menu or paintbrush	Y	All Figures are made vertically
Please explain more detail the results of your proposed model i.e. active power, reactive power on grid, load, and inverter and THD voltage and current in selected case (PV mode and STATCOM mode) base on Fig 9a, 9b, 10a, 10b, 11a, 11b, 12a, 12b, (2) Plot and mention of significant nominal values and analyse them combined with all figures results	Y	Explanation in detailed is included
The y-axis in Fig. 13 is too tight, please widen this axis so that the figure is clearer, (2) This figure is unclear (blurred), please copy them directly from Matlab figure to this paper, do not use the print screen menu or paintbrush, (3) Please explain more detail the results of Grid voltage Vs, Gr id current Is, Inverter current I_{inv} LVRT voltage in selected case (LVRT, Normal, and Islanding Mode) and plot and mention of significant nominal values base three modes and analyse them combined with this figure results. (4) What are the novelty and contribution of your proposed method to make the reader sure that this paper has a significant contribution as well as illustrate them in a table base on the previous researcher in references	Y	Two show the events i.e LVRT, Islanding and normal mode so figure is made like this so that all quantities can present simultaneously. Detail. review table included and novelty of work in introduction part included.
This paper only describes the best performances of your proposed method, please add this section (conclusion) with future work to assistant the readers that your research has some weaknesses and eligible to continue	Y	Future scope included
Add your references up to a minimum of 20 references and analyse additional references also in introduction section	Y	More references added

(Please add more rows if needed)

Reviewer # 2

Final Recommendation Please tick	Accepted without modification	Accepted with minor corrections	Accepted with major modification	Rejected
	☐	☐	☐	☐

Comments	**Addressed (Y/N)**	**Reply/Action taken**
Control technique could have been explained better.	Y	Control technique explanation included
Validation of results should be incorporated. Simulation results are good, but the paper would be sounder with hardware results.	Y	Validation of simulation result is done through hardware result

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Reviewer # 3

Final Recommendation Please tick	Accepted without modification ☐	Accepted with minor corrections ☐	Accepted with major modification ☐	Rejected ☐

Comments	Addressed (Y/N)	Reply/Action taken
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Reviewer # 4

Final Recommendation Please tick	Accepted without modification ☐	Accepted with minor corrections ☐	Accepted with major modification ☐	Rejected ☐

Comments	Addressed (Y/N)	Reply/Action taken
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Reviewer # 5

Final Recommendation Please tick	Accepted without modification ☐	Accepted with minor corrections ☐	Accepted with major modification ☐	Rejected ☐

Comments	Addressed (Y/N)	Reply/Action taken
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Reviewer # 6

Final Recommendation Please tick	Accepted without modification ☐	Accepted with minor corrections ☐	Accepted with major modification ☐	Rejected ☐

Comments	Addressed (Y/N)	Reply/Action taken
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Reviewer # 7				
Final Recommendation Please tick	**Accepted without modification** ☐	**Accepted with minor corrections** ☐	**Accepted with major modification** ☐	**Rejected** ☐

Comments	Addressed (Y/N)	Reply/Action taken
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Reviewer # 8				
Final Recommendation Please tick	**Accepted without modification** ☐	**Accepted with minor corrections** ☐	**Accepted with major modification** ☐	**Rejected** ☐

Comments	Addressed (Y/N)	Reply/Action taken
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Reviewer # 9				
Final Recommendation Please tick	**Accepted without modification** ☐	**Accepted with minor corrections** ☐	**Accepted with major modification** ☐	**Rejected** ☐

Comments	Addressed (Y/N)	Reply/Action taken
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Reviewer # 10				
Final Recommendation	**Accepted without modification**	**Accepted with minor corrections**	**Accepted with major modification**	**Rejected**

Please tick ☐ ☐ ☐ ☐

Comments	Addressed (Y/N)	Reply/Action taken
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THREE LEVEL H BRIDGE GRID CONNECTED INVERTER WITH MULTIFUNCTIONAL CAPABILITY BASED ON THE CONSERVATIVE POWER THEORY

Abstract

This article presents use of single stage transformer less cascaded H bridge multilevel inverter for smart grid application with nonlinear loads to explore multifunctional capabilities. The salient feature of the presented scheme is the use conservative power theory-based control strategy for multifunctional operation modes besides injecting available solar energy. Presented system apart from injecting active power also accomplish the task of power factor correction, reactive power support, harmonics compensation, islanding detection and Low voltage ride through. Conservative power theory scheme does not use any reference frame transformation. Multifunction capability makes proposed system one of the best choices for distributed power generation with improved consistency. Capability and Efficiency of proposed scheme is verified through simulation and experimental results.

Keywords: Multilevel inverter, Multifunctional capability, Cascade h-bridge, Low voltage ride through, Islanding detection, conservative power theory

1. Introduction

Renewable energy resources (RES) like solar, Winds are becoming the most popular sources of electricity production worldwide. This leads to the use of power electronics, an increase in renewable energy generation as well as microgrid control. Multilevel topology utilization in distributed generation is being preferred to the conventional full-bridge invertors because multilevel topology has several advantages especially when the applications involve high power processing. The use of different digital control algorithms makes it possible to operate these inverters for a multifunctional mode without using extra circuitry [1]. Usually, the accessible type of PV systems uses conventional three-phase four leg inverter which supplies available real power to the network at numerous points in the power system while multilevel inverters have many more benefits over two-level inverters like reduced switching losses, decreased total harmonics distortion (THD), better power quality less electromagnetic interference EMI, modularity etc. [2], [3]. The application of a grid connected cascaded multilevel inverter for power conditioning was presented in [4] it was based on instantaneous power (pq) theory. Based on Synchronous reference frame theory to control grid-connected solar inverters is proposed in [5] so as to deliver a sinusoidal reference for grid, during nonlinear load connections. While in [6], a multifunctional inverter operations based on CPT-approach for grid-connected solar inverters is presented. "A single-phase Asymmetrical Cascaded H-Bridge Multilevel Inverter (ACHMI), control for multifunctional operation in micro grid systems with nonlinear loads" was presented by [7]. This paper proposed two technique for voltage control. "Cascaded multilevel converter for power conditioning in smart-grid" was presented in [8]. In this revision control of a 7-level shunt based active filter cascade H-bridge multilevel inverter (CHMI) through separate H-bridge DC-link in voltage regulation was accessible and selective compensation is done through CPT algorithm. In altogether the aforementioned orientations the compensator goals power factor improvement, reactive power and harmonics compensation, and have their own topographies and authority. Though, there are numerous other functionalities to be addressed like islanding discovery Low voltage ride through/ High voltage ride through (LVRT/HVRT). These functional for the prospect smart PV inverters can donate to abridged energy and therefore allow more cost beneficial PV connections. To complete some smart structures, a multifunctional compensator is established in this work that can be arranged in this solar inverter and accomplished to achieve dissimilar process modes while compliantly alteration from one to another mode throughout the process. The inverter is also exposed to numerous fleeting circumstances alterations such as load change, system parameter change, and its performance during weak grid conditions as well as grid voltage disturbance. The brief review of the state of the art on multi-functional inverter topologies for grid connected PV application and control strategies reported in the previous literature have been described in Table1.All these references have their own efficacy and legitimacy. However there are many functionality can be explore in grid connected applications. Novelty of this paper is that presented multilevel multifunctional compensator is capable to perform six different operations using CPT based selective compensation ie. Injecting active power and operating as active filter simultaneously, Operating exclusively as active filter, power factor correction, reactive power compensation, grid support during low voltage ride through, islanding detection. The choice for multilevel inverter is due to the advantage of using a reduced output filter and its capability to apply low-voltage semiconductor devices in grids.

Table1 Previous work comparison

Reference	**Work reported in the research article**	**Research gap**
Rajasekar.S et al [4]	Only Shunt active filter based on pq theory presented with simulation results is presented	Multifunctional capacities not explored, night time application not proposed. reliability issues not discussed
Trinh and H. Lee [5]	Advanced current control is presented with active filtering operation for	Selective compensation not explored. reliability issues not discussed
Marafão, F. P. et al. [6]	Active filtering with voltage control and load current compensation during disturbance is presented with experimental results	More operations can explore like reactive support etc reliability issues not discussed.
A. Mortezaei et al. [7][8]	CPT based multifunctional operation for asymmetric & symmetric CHB inverter is proposed	Utilization of DG is not included
Zhao et al[9].	Multifunctional UPS were proposed with functionality of UPS and good improvement in power quality	Selective compensation not explored. reliability issues not discussed
Kim, G.H., et al. [10]	PV system operations as active filter is proposed	Multifunctional capacities not explored. reliability issues not discussed
Sawant, R.R et al.[11]	p-q theory based multi-functional shunt compensator was presented. neutral current elimination in a three-phase four-wire system also included	Selective compensation and night time application not explored. reliability issues not discussed
R. k. Varma et al. [13}	dq theory-based PV-STATCOM for night time application was presented	Selective compensation not explored. reliability issues not discussed

Broadside is prearranged in the subsequent way system description presented in segment (system configuration) 2. Conservative power theory application for three-phase circuits is explained in section (control strategy) and its implementation for anti-islanding and LVRT discovery is presented in Segment 3. Imitation results and its conversation presented in Portion 4. The last part is the conclusions presented in section 5.

2. System configuration

In this work conservative power theory-based photovoltaic (PV) array maintained through a three-level cascaded inverter is recommended. Propose system is a single-stage transformer less application which not only improves system efficiency but also reduced the weight and size of the overall system .The Inverter is not only able to inject real power supplied by PV array but also compensate harmonics and reactive energy required by distribution networks. The proposed H-bridge inverter is use as Static synchronous compensator (STATCOM) in the time when no solar power is there and the inverter is idle and the whole volume of the inverter is utilized for STATCOM operation. Apart from these functions proposed multifunction inverter is capable to identify islanding actions and LVRT. Capability of the proposed inverter is also checked for critical system disturbances which are discussed incoming section. The whole inverter capability is free to afford grid provision for transient disturbing conditions. This solar PV inverter come back to its normal operation after the grid provision essential is satisfied. Fig.1 displays the complete diagram of the future multifunctional solar inverter. Three-level H bridge PV converter is connected to the 415V distribution network, (Z_g) is here equivalent impedance. The diode bridge rectifier with R-L load in its output is taken as non-linear load which is associated at PCC. L_f and R_f are modelled as filter inductance and resistance to mitigate harmonics generated by the inverter. Here I_{abc} and $I_{loadabc}$ are inverter and load current sensed and provided to the controller. V_{pccabc} is a three-phase PCC voltage. The output of d.c voltage controller, as of H-bridge cells, is multiplied through the PCC voltage (V_{pccabc}, this results in the supplementary reference current (i^*_{pabc}) this supplementary reference current is then add to the disruption currents (i^*_{fabc}). The current reference (i^*_{abc})is obtained now is added to the current controller for active filtering operation. The main objective of the grid-connected three-level H bridge scheme is to deliver concurrent functionalities established on the CPT for inoculating active power, recompensing harmonics of the nonlinear load, supporting reactive power demanded by load, unity power factor operation, and allowing safe transition between grid-connected mode of operation and islanding mode of system. System parameters used for simulation is given in table 1.Fig2,shows the flow chart of various operating mode of presented system Fig.2 shows the Flowchart of the presented inverter control during night time, daytime, LVRT and islanding mode. which is explained below. O denotes the specific operating mode.

1.Full PV mode

2Full STATCOM mode

3.LVRT mode

4.Islanding Mode

Both during night and day, active filtering and power factor correction will be priority. During daytime, the remaining inverter capacity after real power generation based on available solar insolation is computed at every time step. If at any time (day or night) due to any system disturbance Voltage falls below 80% of specified grid voltage inverter goes to LVRT mode it will stay connected and start supplying reactive support to system up to 1.2 sec. as per IEEE P1547 Standard after that it will ride through or trip. If any time grid is disconnected for maintenance or other reasons inverter will goes on islanding mode immediately. In night time operating mode is switched to Full-STATCOM mode. Active filtering performed with reactive power exchange up to the entire inverter capacity along with power factor correction.

.3. Control strategy

The conventional influence philosophy was developed by Tenti et al [9]. CPT works for time domain systems and this stands also successfully applied to single phase as well as poly-phase system for both system with neutral and without neutral. Tenti suggests the theory in which energy and current is decomposed into stationary frame. The term which are directly related to characteristics of electrical network, such as: reactive energy, average power transfer, nonlinearities and unbalanced loads. Conservative power theory-based converter are presented by [7] [8]. CPT-based compensation theory defined the all quantities which must be real, periodic and continuous variables such as Fundamental frequency (f=1/T), Time period (T), angular frequency (ω = 2π). The Voltage and Current vector are' v' and 'i 'respectively which are measured at a specific network port. The subscript 'm' is used for phase here Definitions of different operators used in following section is given in table 2 [9]. The voltage and current scalar product for all phases defines the instantaneous power here.

$$P(t) = \underline{v} \cdot \underline{i} = \sum_{k=0}^{m} = v_m \, i_m \quad (1)$$

Where subscript m use for no. of phases in multiphase system.

here the reactive energy(instantaneous) is defined as follows.

$$W = \hat{v} \circ i = [\widehat{v_a} \;\; \widehat{v_b} \;\; \widehat{v_c}] \circ \begin{vmatrix} i_a \\ i_b \\ i_c \end{vmatrix}$$

or

$$W(t) = \hat{v}\_ . \;\; \underline{i} = v_m \, i_m \quad (2)$$

Here the vector $\hat{v}$ is encircling the unbiased integrals for the particular phase voltages. However, the calculation of this amount $\hat{v}$ is obtained by average value of voltage and its time integral as follows:

$$\hat{v}_m = v_{\int m} - \hat{v}_{\int m}$$

$$v_{\int m} = \int_0^T v_m(\tau)\, d\tau \qquad (3)$$

$$\hat{v}_{\int m} = \frac{1}{T}\int_0^T v_m\,(\tau)\, d\tau$$

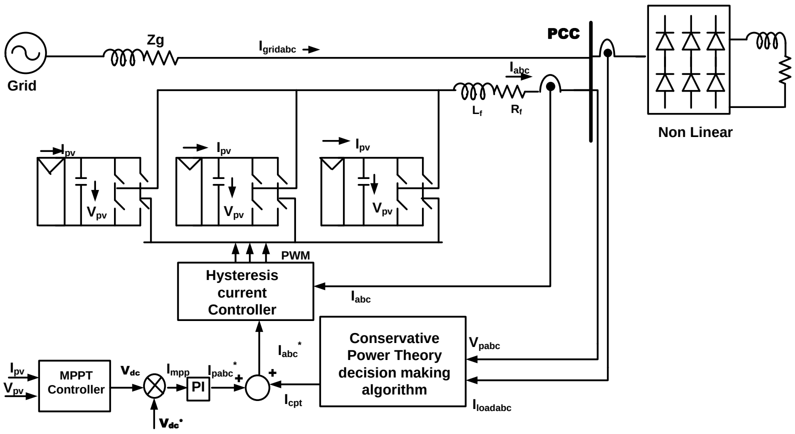


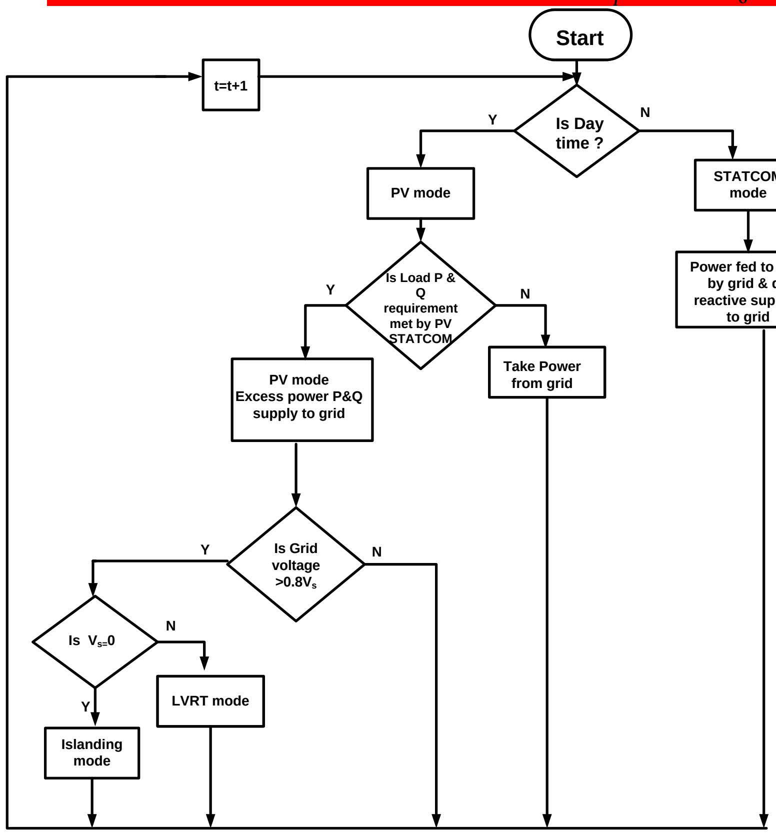
Fig.1 Block diagram of proposed system

In this method measurement of phase voltages in three-phase three-wire networks is done with respect to some exclusive reference point, and measured with respect to neutral in single phase circuits or four-wire circuits. Wherever rendering to this philosophy, active power is the power which will is actually converted in to the work, same as given in all traditional theories. Whereas Reactive energy is a new description specified here which signifies the average energy deposited in the polyphase grid in general situations, it moreover comprises unbalances and waveform distortions in the given system. If Both Power P and energy W placate Tellegen's Theorem actually these terms up till now are conventional quantities for particular grid, irrespective of waveform of voltage and current. Here at any instant the term P corresponds with general active power P*conv* = V I $cos\phi$. Contrariwise, reactive energy is correlated to general reactive power with given the fundamental frequency (ω), therefore W = Q $conv/\omega$ = V I $sin\phi/\omega$. It is unblemished there for general reactive energy is related through the frequency of the electrical network, whereas in conservative power theory the reactive energy is liberated of frequency, therefore it is precise useful on

Fig.2 Flow chart for multifunctional operation modes

behalf of schemes by likely frequency disparities, especially micro-grids. From a real-world point of opinion, it is passable to compute for the regular quantities by use of adaptive frequency procedures or basically low-pass filters, so that equally the active power as well as the reactive energy are unsusceptible to change in frequency. Established on descriptions accessible above, the phase currents are disintegrated in to the subsequent components: composed balance active currents$\underline{i}_{am}^{b}$, balance reactive currents $\underline{i}_{rm}^{b}$, [14]

$$P = \bar{p} = (\underline{v} \; . \; \underline{i}) = \frac{1}{T} \int_0^T \underline{v} \; . \; \underline{i} \; dt = \sum_{m=1}^{M} P_m \quad (4)$$



And reactive Energy [14]

$$W = \bar{p} = (\underline{\hat{v}} \; . \; \underline{i}) = \frac{1}{T} \int_0^T \hat{v} \; . \; \underline{i} \; dt = \sum_{m=1}^{M} W_m \quad (5)$$

In above equation unbiased integral of voltage vector is ($\hat{v}$). As given the descriptions accessible here three basic decomposed component of the phase currents are given by

Active phase currents i_{am} are distinct as

$$i_{am} = \frac{(v_m i_m)}{\|v_m\|2} v_m = \frac{P_m}{v_m^2} V_m = G_m V_m \quad (6)$$

Where (G_m) is the equal stage conductance

Reactive phase currents i_{rm} are specified by

$$i_{rm} == \frac{(\widehat{v_m} i_m)}{\|v_m\|2} \hat{v}_m = \frac{Wm}{Vm}{}_2 \widehat{v_m} = B_m \hat{v}_m \tag{7}$$

Where (B_m) is the equivalent phase reactivity

After subtracting active besides reactive current from total phase currents remaining currents are void current $\underline{i}_{vm}$ and given by

$$\underline{i}_{vm} = \underline{i}_m - \underline{i}_{am} - \underline{i}_{rm} \tag{8}$$

Void currents are those which ensure neither transfer of reactive energy nor active power. The active and reactive phase currents be able to supplementary divisions into unbalance and balance currents .Balance active current then is current given by

$$\underline{i}^b_{am} = \frac{(v,i)}{\|v\|2} \underline{v}_m = \frac{P}{v^2} \underline{v}_m = G^b \underline{v}_m \tag{9}$$

The balanced active currents take distinct as individual’s currents which symbolize the smallest part of the phase currents which stand related by a balanced circuits and in authority for resounding the total active power (P) in the circuit, for subjected to given specific voltages.

The balanced reactive currents are demarcated as:

$$\underline{i}^b_{rm} = \frac{(\hat{v},i)}{\|\hat{v}\|2} \underline{\hat{v}}_m = \frac{W}{\hat{v}^2} v_m = B^b \underline{\hat{v}}_m \tag{10}$$

These currents signify the least ration of the phase flows that are related with a balanced equal circuit and in authority for transmission the total reactive energy (W) in the given circuit. The subtraction of total active current and balance active current gives the unbalanced active currents

$$i^u_{am} = i_{am} - i^b_{am} = (G_m - G^b) v_m \tag{11}$$

In similar manner, the unbalanced reactive currents are designed as

$$i^u_{rm} = i_{rm} - i^b_{rm} = (B_m - B^b) \hat{v}_m \tag{12}$$

Therefor I^u_m which is total unbalance phase currents are definite by

$$I^u_m = I^u_{am} + I^u_{rm} \tag{13}$$

The current vector (measured) can be splited as following four parts

$$\underline{i} = \underline{i}_a{}^b + \underline{i}_r{}^b + \underline{i}_a{}^u + \underline{i}_r{}^u \quad (14)$$

However all the components of the current are orthogonal to each other (given by definitions previously) thus the RMS value are represented as follows.

$$I = \sqrt{I_a^b{}^2 + I_r^b{}^2 + I_a^u{}^2 + I_r^b{}^2 + I_v{}^2} \quad (15)$$

In the same way , apparent power (P_a)is defined as follows

$P_a = \|v\|.\|i\|$ or

$$P_a = \|v\|.\sqrt{I_a^b{}^2 + I_r^b{}^2 + I_a^u{}^2 + I_r^b{}^2 + I_v{}^2} \quad (16)$$

or

$$P_a = \sqrt{P^2 + Q^2 + N_a^2 + N_r^2 + D^2}$$

Where

Active power is $P = VI_a^b$

Reactive power is $Q = VI_r^b$

Unbalanced active power is $N_a = VI_a^u$

Unbalanced reactive power is $N_r = VI_r^u$

Distortion power is $D = VI_v$

Conservative power theory moreover distinct the global power factor (λ) which is affected by reactive power (Q) circulation, load unbalances (N) and nonlinearities (D) of the system. $\lambda = \frac{P}{A}$ Accordingly this theory many variables present in Eq. (15) can be utilized in power conditioning applications and these are independent of the circuit's current /voltage waveforms, only condition needed is that quantities must be periodic . The converter presented in this paper is controlled to maintain the constant DC-link voltages of each cell of multilevel bridge which is provided by MPPT algorithm apart from this proposed control also compensate the nonlinear load current. Since proposed system is single stage, no dc-dc boost converter is utilized here so MPPT is also incorporated in control. The output of voltage V_{pv} and current I_{pv} of each here H-bridge cells, is given to the P& O MPPT controller which will produce voltage (V_{dc}) this voltage is then compare with reference V_{dc}^* and generate current reference I_{mpp} this current passes through PI controller, which results an additional current reference (i_{pabc}*) and this reference is added to the compensating currents (i_{fabc}*) generated by CPT decision making algorithm and result of this is current reference (i_{abc}*)

which is given to the hysteresis current controller for switching. Thus, this multifunctional inverter can also work as power factor controller in sudden variable load conditions and also compensate nonlinear load current in steady state conditions. An important conclusion here is that there is no reference frame transformation is done here or any synchronization algorithm is used to obtain the reference signals. The parameters used in simulation are given in table 1.

3.1. Anti-Islanding Concepts and Implementations for multilevel inverter using CPT

To implement anti-islanding and LVRT capability in proposed multilevel multifunctional inverter simultaneously GE AI scheme proposed by [12]. This scheme is based on positive feedback concept and these concepts are implemented in this work for grid connected multilevel inverter.

Fig. no. 3 shows the voltage feedback scheme applied in three phase three level inverter using dq control technique (voltage is converted to dq using abc to dq block in matlab) from $V_d$to i_d^*here direct axis voltage V_d is passes through one band-pass filter (BPF) plus gain, and then one limiter and which results in a current dissimilarity I_{dd} and added directly to current reference.

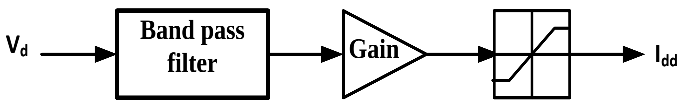


Fig.3 AI voltage feedback block

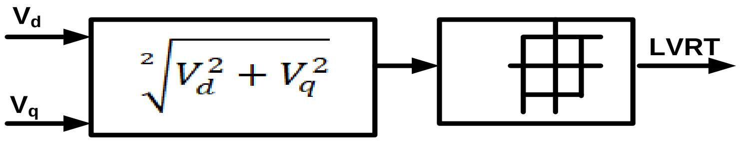


Fig.4 the LVRT implementation block

Before giving reference for generation of PWM signal for hysteresis controller for enabling the inverter for islanding detection as well as fault ride through capability. Following subsystem which is shown in fig.5explain these capabilities. With this block inverter will distinguished between the islanding events by the LVRT incident. Here under voltage trip is disabled and increased and the limit for overvoltage trip to see the islanding operation and low voltage ride through of inverter. Corresponding references are generated by comparing the threshold limits set between islanding event and low voltage ride through. Here P_{ref} and Q_{ref} are active and reactive power references and V_{abcref} is voltage reference in abc coordinate

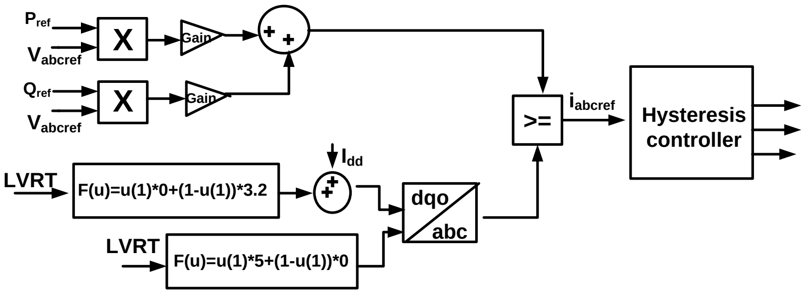


Fig.5 Current controller for generation of current reference in cpt control

Table 1 Simulation Parameter.

4. MATLAB Simulation results and its discussion

In this segment presentation of three phase three level inverter is evaluated on behalf of multiple functionalities in matlab Simulink based on block diagram shown in fig.1 and simulation parameters are given in table 1. The main aim is to examine the presentation of the multilevel multifunctional inverter, measured by means of CPT based compensation for active power integration, harmonics free current injection, reactive support and power factor control. Fig. 5 displays the line voltage and all three phase voltages are shown in Fig.6.It is clear from both figure that stepped out-put voltage of inverter reduces the harmonics significantly and out waveform become more close to sinusoidal All three PV panel voltages and MPPT voltages are shown in Fig.7

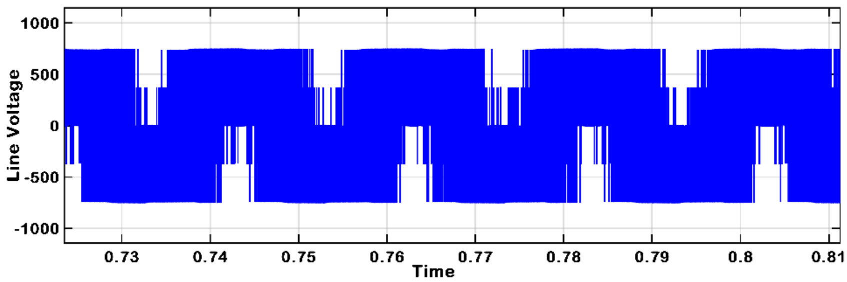


Fig. 5 Inverter Line Voltage Voltage

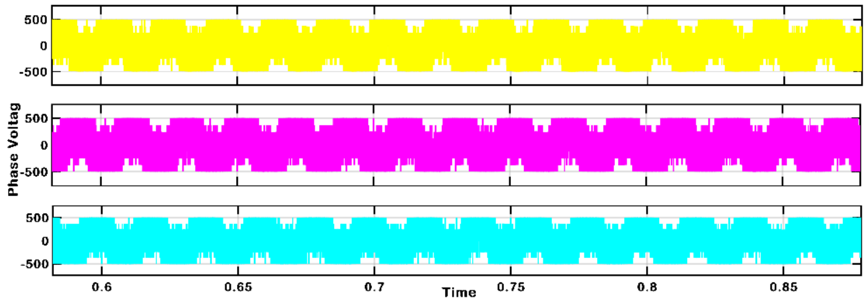


Fig. 6 Inverter Phase voltages of all three phase

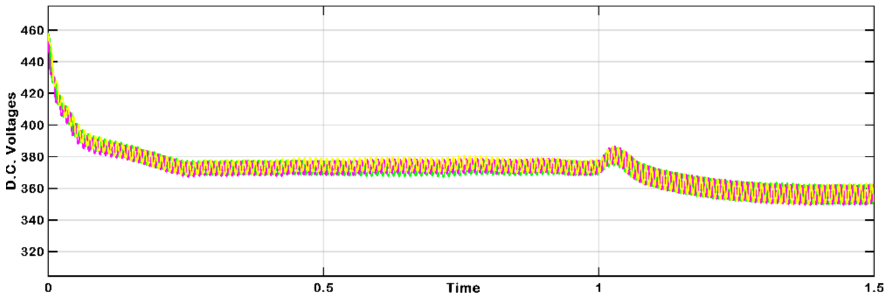


Fig. 7 PV panel and MPPT voltages of all three phases

Dynamic behavior of presented system is shown when it is subjected to variable irradiation temperature change At the time t = 1 s in simulation the solar irradiation is increased from 500W/m^2 to 700W/m^{2}and temperature from 25^o C to 30 ^{o} C inverter is now feeding more power to grid as load is constant this results in increase in the amplitude of the current of the inverter as well as the grid. Fig. 8 here shows the waveforms of grid current I_s transition at t=1 sec.

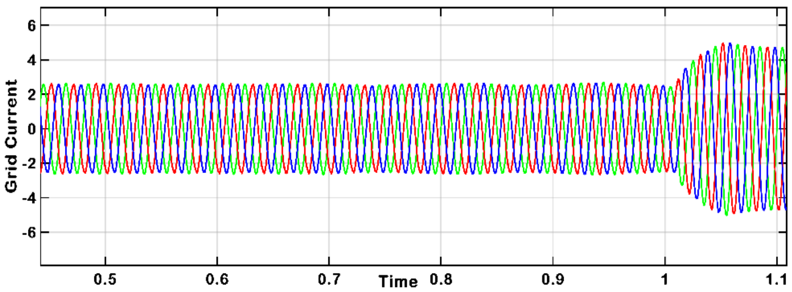


Fig. 8 Grid current for varying irradiation/temperature

The active and reactive power flow in the given electric power system is given by eq. (17) and (18) respectively which is clear from Fig. 9 and 10.

$$P_i + P_l + P_g = 0 \tag{17}$$

$$Q_i + Q_l + Q_g = 0 \tag{18}$$

Proposed inverter remains capable of supplying active and also reactive power demand of load during day time i.e. PV mode.at time t = 1sec. when irradiance increases inverter current increases so power of inverter also increases accordingly. This increase in power from solar pv leads to increment in grid power. Active and reactive powers of the grid, inverters, load, is shown by fig. 9 and 10 From Fig. 10, it is vibrant that the inverter completely compensate the reactive power demand of the load though supplying it with the essential active power. So the engrossed active power of the grid is reduced Here inverter capacity is made slightly higher then require load capacity so that apart from supplying required active power of load inverter also supplies reactive power with remaining capacity as explain in flow-chart. In the night when there is no solar irradiations inverter turn into idle, to increase utilization factor of system same inverter can be supposed to work in STATCOM mode.Fig.11 and 12 presents the performance of system in STATCOM mode. Active and reactive power of the grid, inverter and load in STATCOM mode of operation of proposed system is shown in these two figures, at this time active power demand of load is fulfil by grid and inverter is supplying entire load and grid reactive power demand it is clear from fig. 11 and 12 inverter is successfully supplying reactive power demand of load and grid at night time and act as fully STATCOM. In this way when there is no sunlight and PV is not producing any power inverter can be utilized as DSTATCOM and support grid for power quality operations.

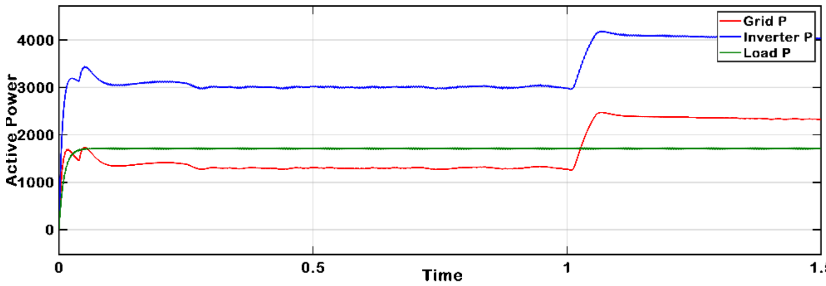


Fig 9 Active power of Grid , inverter and Load iv PV mode

Fig.14 shows the grid, current I_s inverter current I_{inv}, and load current I_l.It is clear from figure that amplitude of inverter current is more than both load current and grid current which means inverter is capable of supplying load demand as well as feeding excess power to grid. Dynamic performance is also evident from this figure as irradiation temperature set to more values inverter respond quickly and increase its current up to its remaining capacity. While fig. 15 shows grid current THD which is 1.99% well below 5% IEEE standard requirement. Proposed inverter is capable of compensating harmonics of non-linear load successfully using CPT based compensation and act as active filter Simulation results show effectiveness of the CPT based multilevel compensator for shunt APF function along with suppling real power and harmonic's free grid current injection.

The voltage (V_{sa}) and current of the grid (i_{sa}) are shown in Fig. 13(a) and 13(b) for the phase a. It is clear from the figures that the current and voltage are in phase opposition because grid is absorbing surplus power supplied by inverter which conforms the power factor correction operation of proposed PV inverter. While in STATCOM mode all load reactive power is compensated by inverter so grid currents and voltage are in same phase. This change in angle is due to the grid changes its mode from the active power absorption in PV mode to the active power supplying procedure in STATCOM mode

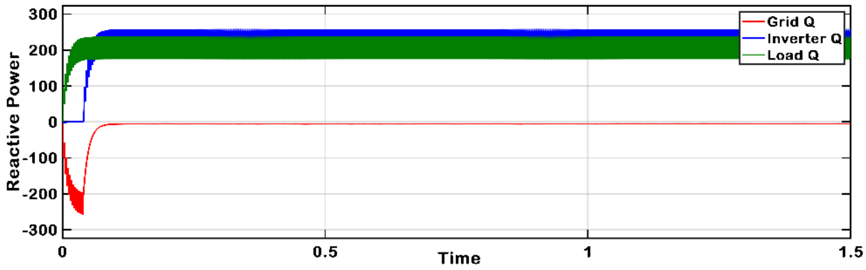


Fig 10 Reactive power of Grid , inverter and Load iv PV mode

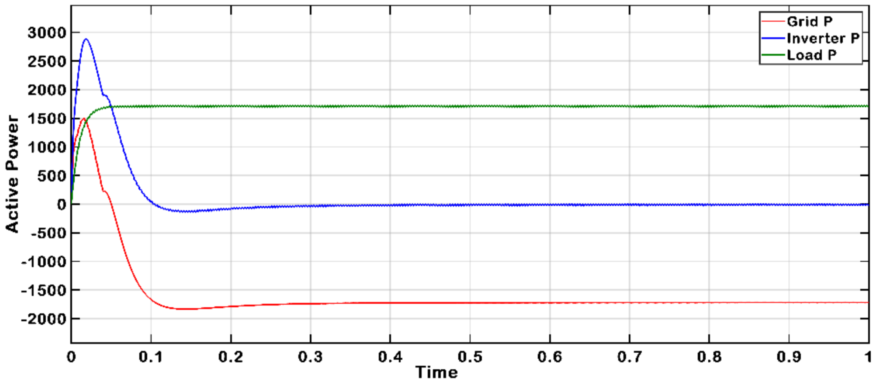


Fig 11 Active power of Grid , inverter and Load iv STATCOM mode

The Low Voltage Ride Through performance with islanding detection of the proposed inverter is investigated in figure 16. Performance is investigated when system is working in PV mode. Disturbance is created by creating short circuit at t=0.1 sec for 0.03 sec. After that normal operation is restore and then grid is disconnected to show anti-islanding capacity of presented inverter Figures 15 shows grid voltage (V_{sa}) grid current (i_{sa}) and inverter current i_{ca}) and load current (i_{la}) It is clear from figures that system monitors the grid status, acts to synchronize and ride through with fault for time limit prescribed by regulations and come back to service again. At time of low voltage ride through grid voltage is reduced to 80% of normal value inverter differentiate clearly between LVRT and islanding because inverter current is not zero actually at this point inverter is

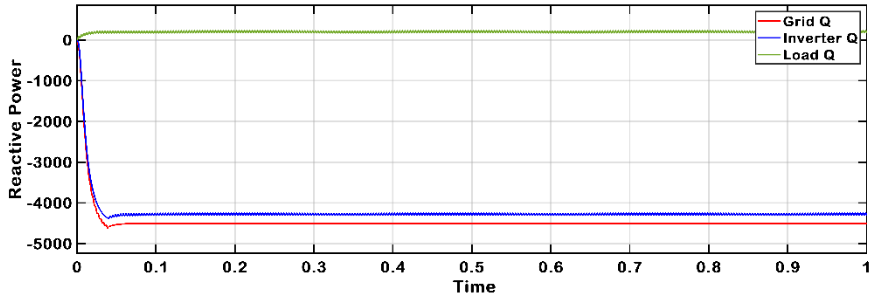


Fig 12 Reactive power of Grid, inverter and Load iv STATCOM mode

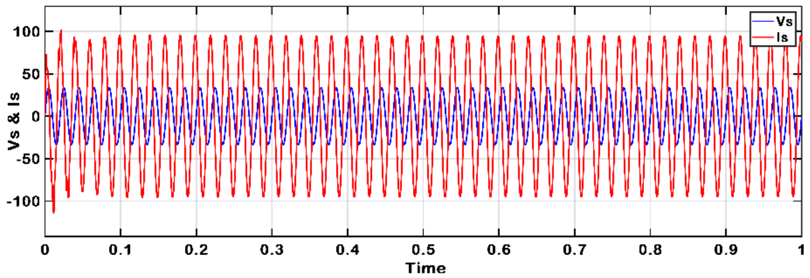


Fig 13(a)Power factor correction in PV mode

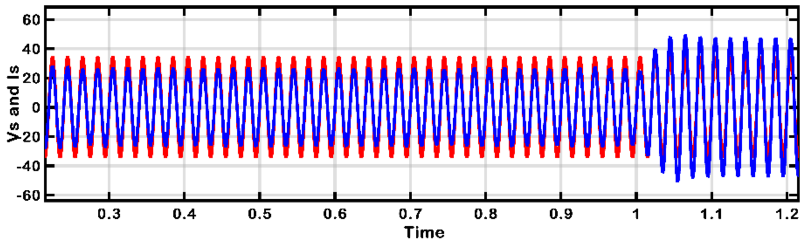


Fig 13(b) Power factor correction in STATCOM mode

supplying require reactive power and support to grid. which is clear from figure that inverter current with significant value at time of grid fallout invert stop feeding power and disconnected as its current became zero. This system also detect islanding within 4msec, which is well below standard time limit of 2sec.Detection signal used to check the LVRT in simulation is also shown in figure 16 and islanding because inverter current is not zero actually at this point inverter is supplying require reactive power and support to grid

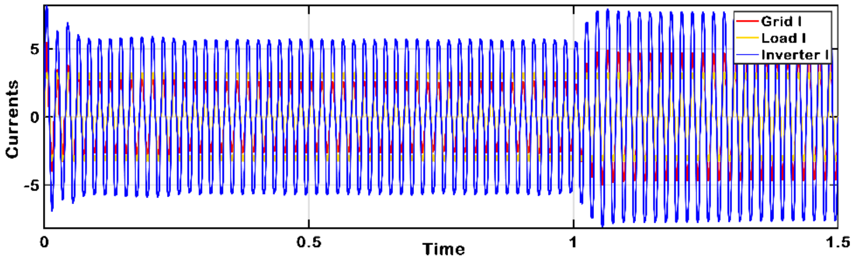


Fig 14 Grid current, Inverter current, Load current

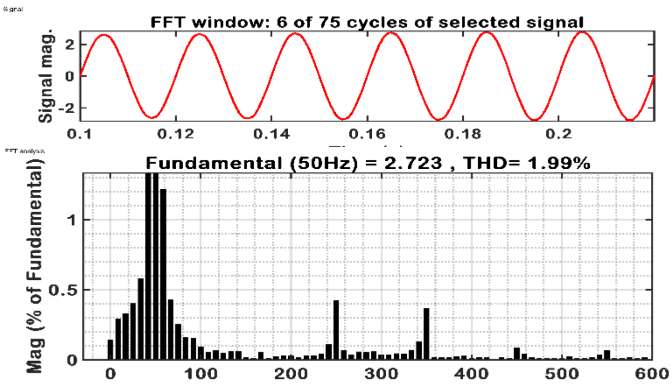


Fig 15 FFT analysis of grid current

4. Experimental setup and its results

To validate results presented in simulations hardware prototype of the presented system is developed in the laboratory which is shown in fig 17. three-phase grid supply of 230V 50 Hz reduced to 30V with varec. Three inductance of value 6mH are used as coupling inductors. Six PV panels (150Wp of Warree make) are used two in series for each phase. Three D.C. link voltages are kept between 65V to 70 V. Harmonic currents were generated by a three-phase diode bridge rectifier (IRI MDS100/16) as the non-linear load single phase four switch IGBT inverter module (NiTech make) each in all three phases is realized as H bridge inverter. NiTech make hall effect-based sensor cards are used to sense the DC-bus voltage, PV current. The grid voltage, the load current and grid currents are measured by NiTech make inductive current transformer. The Control technique is implemented through arm cortex STM32F407VGT microcontroller. Details of hardware is shown in table 2. Fig.18 shows grid voltage (V_{sa}) grid current (i_{sa}) and inverter current (i_{ca})and load current(i_{la}) in steady-state with non-linear load and active filtering operation.Fig.19 shows the dynamic performance of the presented system for varying load conditions in PV mode. It is clear from the diagram that the inverter is capable of compensating harmonics of nonlinear load all the time as grid current waveform is close to sinusoidal apart from that grid current and is in phase with the grid voltage that shows the power factor correction operation of the inverter.Fig.20 shows the islanding detection operation of the presented inverter it is clear from fig. as grid voltage/current reduced to <70% of its normal value inverter command voltage(V_d)dropped to zero value which causes the inverter to stop feeding to the grid. Presented simulation and experimental results validate the multifunctional operation of the proposed inverter with CPT control.

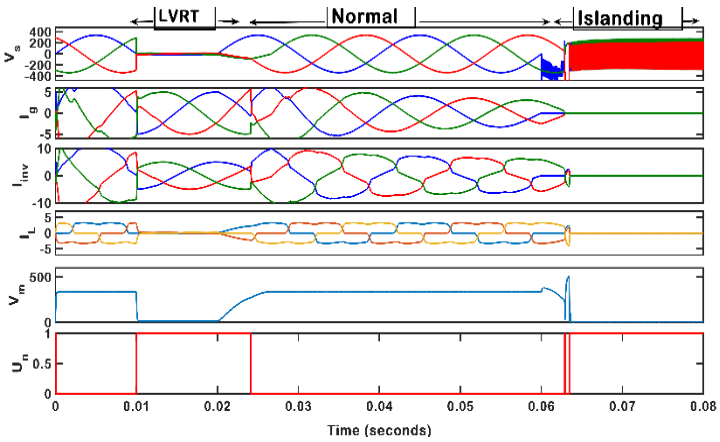


Fig.16 Grid voltage Vs, Grid current Is, Inverter current I_{inv}, load current, LVRT voltage, Detection signal

5. Conclusion

This broadsheet has presented a multifunctional multilevel inverter for grid connected solar PV. Objective here is to compensate various unwanted signals presents in wave forms with the help of Conservative power theory. Multilevel inverters has numerous advantages, e.g., the modular structure and more reliability in the system. These appearances make this topology a perfect choice for medium as well as high power requirements in power systems. Also, this control plan controls the output current through following positions providing by CPT, without applying any type of reference frame transformations. There are manifold operation that projected inverter can achieve apart from active power inoculation. The Low Voltage Ride through (LVRT) presentation with ant islanding capability of the proposed smart inverter is examined through matlab Simulink environment. All-purpose has its own present orientation that is gotten by resources of the CPT. Simulation and experimental results established the effectiveness of the multifunctional multilevel inverter to function in all manners of process a causal to the development of the quality, dependability, efficiency and constancy of the electrical system. So, recommended system have auspicious application probable.

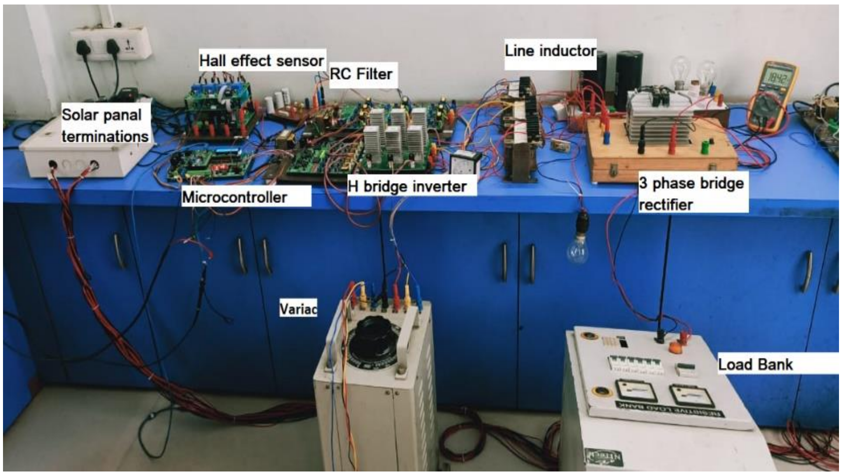


Fig.17 Experimental setup

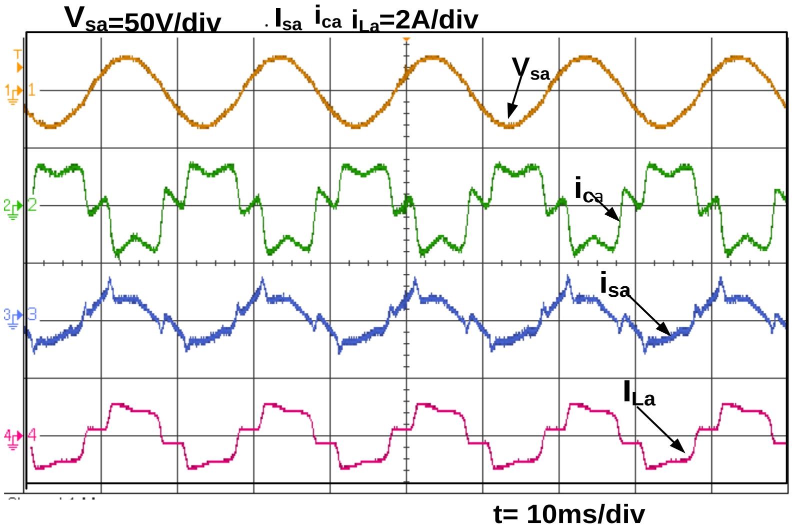


Fig.18 Grid voltage Vsa, Grid current Isa, Inverter current I_{ca}, load current I_{La}, steady state mode

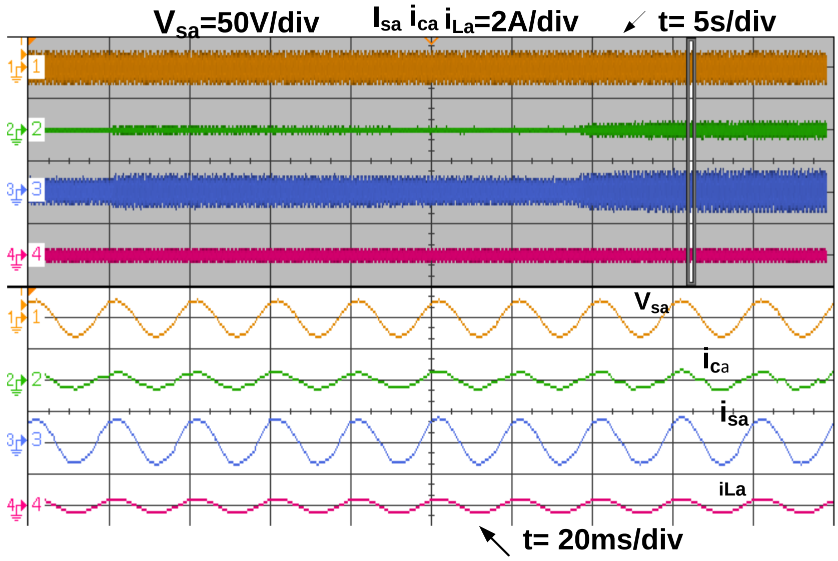


Fig.19 Dynamic performance of inverter grid tied system under nonlinear load in phase a

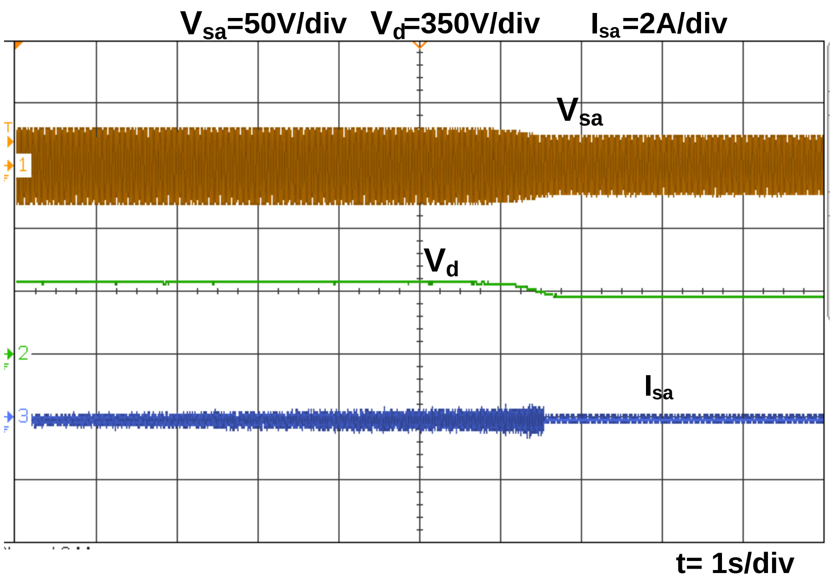


Fig.20 Islanding detection

6.Future scope

This paper explores three level multifunctional inverter for distribution grid application more level can be increase to use this system in medium and high voltage applications. Multifunctional compensator with battery storage capability can also include to make system more efficient and reliable.

Table 2 Simulation Parameter

Parameter	Design values
Voltage of grid	440V
Frequency of grid	50Hz
Each cell Open circuit voltage	45.7Volts
Each cell Short circuit current	5.7Ampere
No of cell in each module	60
Series connected modules in each string	10
Paralleled connected modules	1
Solar irradiance(G)(variable)	500~700
Module temperature(variable)	250C~350C
Source resistance	$1x10\text{-}^{3}\Omega$
Source inductance	$1x10\text{-}^{7}$mH
Three-Phase Diode Bridge Rectifier with RL in output	R=2X90Ω ,L=11X10-^{3}H

Table 3 Details ratings of experimental components

Parameter	Design values
Voltage of grid	440V
Frequency of grid	50Hz
Nominal Maximum Power (Pm) in Watts	150Wp
Each cell Open circuit voltage	44.3Volts
Each cell Short circuit current	4.51Ampere
Capacity of three phase inverter is	5KVA
Fixed frequency hysteresis at	20 KHz
DC-Link Capacitor (Single on each DC LINK)	4700mF 450V
RC Filter at PCC	R 10ohm/10 W, C=2.5mF/440V
PI controller value	K=0.3 & Ki=0.2
Three-Phase Diode Bridge Rectifier	IRI MDS100/16

Table 4 Definition of operators used [9]

Time derivative $\breve{x}=\frac{dx}{dt}$
Time integral $x_{\int} = \int_0^t x(\tau)d\tau$
Internal product $=\langle x\|y\rangle=\frac{x}{y}\int_0^t x.y\,dt$
Norm (rms value): $X=\|x\|=\sqrt{\langle x,x\rangle}$
Orthogonality $\langle x,y\rangle=0$

Abbreviations	
THD	Total harmonics distortion
EMI	electromagnetic interference
ACHMI	Asymmetrical Cascaded H-Bridge Multilevel Inverter
CHMI	Cascade H-bridge multilevel inverter (CHMI)
LVRT	Low voltage ride through
HVRT	High voltage ride through
CPT	Conservative power theory
STATCOM	Static synchronous compensator
PV	Photovoltaic
DG	Distributed generation

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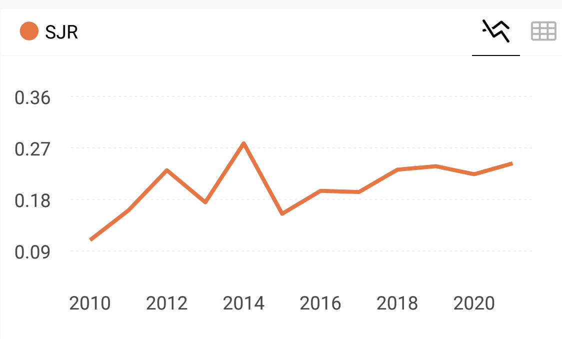

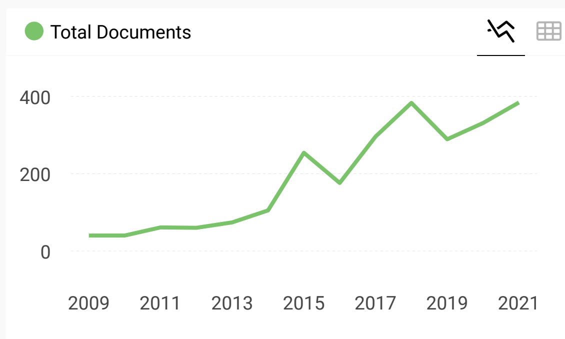

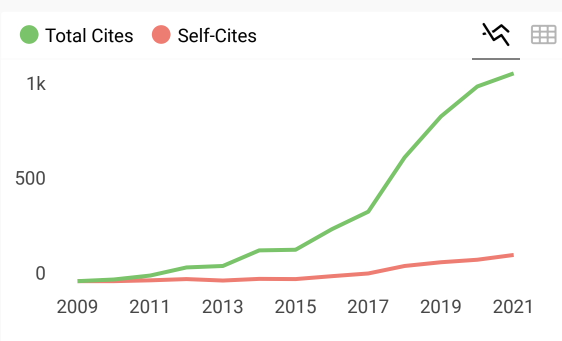

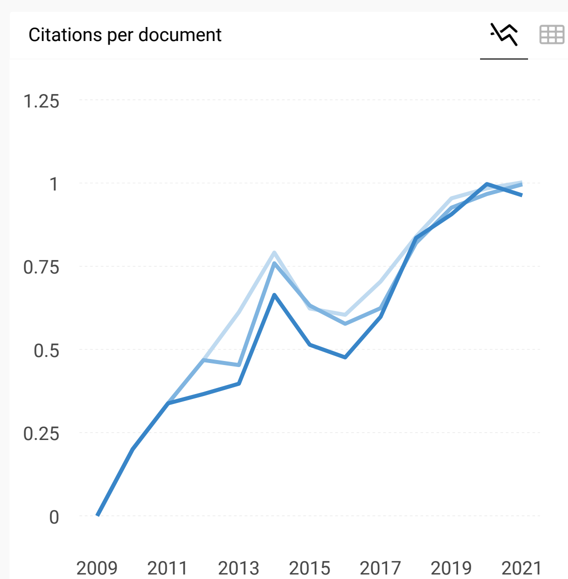

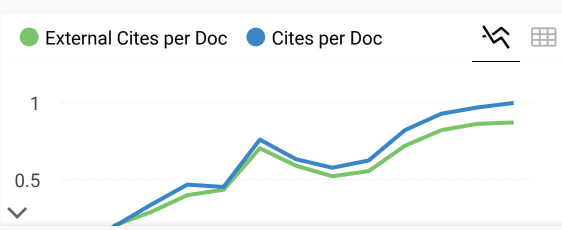

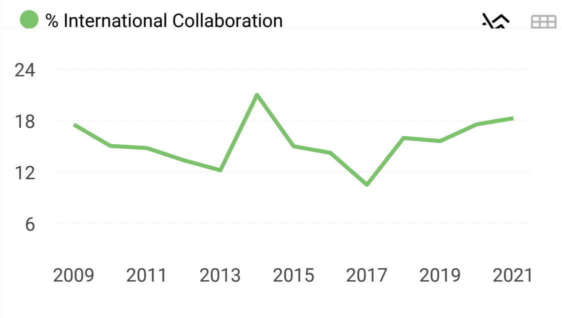

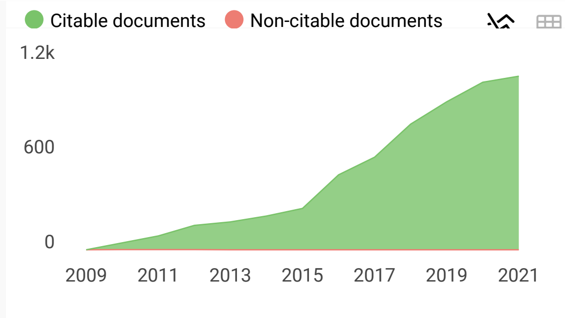

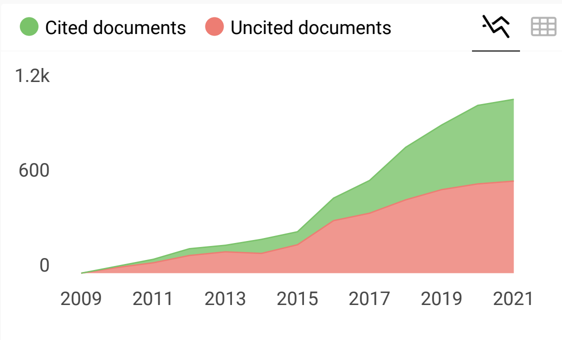

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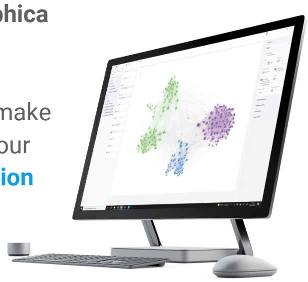

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Melanie Ortiz 2 years ago

Dear M.Sivasankara,
Thank you for contacting us.
Unfortunately, we cannot help you with your request.
Best Regards, SCImago Team

P

Ponum Almas 2 years ago

hello ,
is this impact factor journal ? what is the publication fee for an aticle ? is there any discout for developing countries ?

reply

SCImago Team

Melanie Ortiz 2 years ago

journal's website or contact directly with the editorial staff.
Best Regards, SCImago Team

D

daus 2 years ago

this is ecsi journal, not scie

reply

SCImago Team

Melanie Ortiz 2 years ago

Dear Daus, thanks for your participation! Best Regards, SCImago Team

K

kartik 2 years ago

Hi,
Can i know what is the current Quartile ranking for this journal for the year 2020? tq

reply

SCImago Team

Melanie Ortiz 2 years ago

Dear Kartik,
Thank you for contacting us. You can consult that information just above. The SJR for 2019 was released on 11 June 2020.
Best Regards, SCImago Team

R

Raghad Hameed Ahmed 2 years ago

good greeting
What is the time required to obtain a research acceptance letter.

reply

SCImago Team

Melanie Ortiz 2 years ago

Dear Raghad,
thank you for contacting us.

deepthi 2 years ago

Hi,

Is it okey to cite an unpublished work can in the manuscript?

reply

SCImago Team

Melanie Ortiz 2 years ago

Dear Deepthi, thank you very much for your comment. Unfortunately, we cannot help you with your request, we suggest you contact the journal's editorial staff so they could inform you more deeply. Best Regards, SCImago Team

M.K. 3 years ago

Dear Melanie
I have submitted a paper for this journal about 6 months ago, and I did not receive the decision yet.The problem is the website of this journal does show any contact details except the email of the Executive Editor, who did not respond to my emails since May 2020. Do you know any other contact details for this journal please?

Best regards
M.K.

reply

SCImago Team

Melanie Ortiz 2 years ago

Dear M.K.,

Thank you for contacting us. Unfortunately, it seems that there is no other email contact shown in their website.

Best Regards, SCImago Team

Dr. Vijaya Shetty S 3 years ago

K

K. Bhatti 3 years ago

It's 300USD per article.

Melanie Ortiz 3 years ago

SCImago Team

Dear Dr. Vijaya,
thank you for contacting us.
Unfortunately, we cannot help you with your request, we suggest you visit the journal's homepage or contact the journal's editorial staff , so they could inform you more deeply.
Best Regards, SCImago Team

W

Waleed 3 years ago

Why there is no response to our emails? Someone should tell them that other OA journals respond very fast. It is really a negative point about their performance.Pay attention to your costumers.

reply

N

Nibras Khalid 3 years ago

Hello,
I submitted a manuscript for publication more than a week ago, but I haven't received a confirmation email of delivery. Is there a way to know if all the required documents have been received??

reply

Melanie Ortiz 3 years ago

SCImago Team

Dear Nibras,
thank you for contacting us.
Unfortunately, we cannot help you with your request, we suggest you contact the journal's editorial staff , so they could inform you more deeply.
Best Regards, SCImago Team

P

Phyu Phyu Thin 3 years ago

Dear Sir,

reply

sukanto wiryono 3 years ago

Dear Melanie Ortiz

Please inform me, is this JESTEC indexed by Q2 Scopus?

Thanks you

SCImago Team

Melanie Ortiz 3 years ago

Dear Sukanto, thank you very much for your comment, unfortunately we cannot help you with your request. We suggest you to consult the Scopus database directly. Keep in mind that the SJR is a static image (the update is made one time per year) of a database (Scopus) which is changing every day. The SJR's Quartile for 2018 is available just above.
Best Regards, SCImago Team

SCImago Team

Melanie Ortiz 3 years ago

Dear Phyu,
thank you for contacting us.
We are sorry to tell you that SCImago Journal & Country Rank is not a journal. SJR is a portal with scientometric indicators of journals indexed in Elsevier/Scopus.
Unfortunately, we cannot help you with your request, we suggest you to visit the journal's homepage (See submission/author guidelines) or contact the journal's editorial staff , so they could inform you more deeply.
Best Regards, SCImago Team

B G Shivaleelavathi 3 years ago

Sir/Madam,
i want to submit review paper. what is procedure.

reply

SCImago Team

Melanie Ortiz 3 years ago

Dear Shivaleelavathi,

F

Frans 3 years ago

I want to know, what is journal not a notification after submitting?
Thank you

reply

K

kareem 3 years ago

Dear Scopus people
I want to if this journal consdiered as an ISI journal and what is its impact factor.
Thanks

reply

SCImago Team

Melanie Ortiz 3 years ago

Dear Kareem, SCImago Journal and Country Rank uses Scopus data, our impact indicator is the SJR. Check our web to locate the journal. We suggest you to consult the Journal Citation Report for other indicators (like Impact Factor) with a Web of Science data source. Best Regards, SCImago Team

N

Nacer 3 years ago

Dear Abdulkareem

Please informe me if the publication is free or not?

Best regards

reply

A

abdulkareem 3 years ago

no, it is not free, USD300/aper

N

Nacer 3 years ago

Dear all

SCImago Team

Melanie Ortiz 3 years ago

Dear Nacer, SCImago Journal and Country Rank uses Scopus data, our impact indicator is the SJR. Check our web to locate the journal. We suggest you to consult the Journal Citation Report for other indicators (like Impact Factor) with a Web of Science data source. Best Regards, SCImago Team

S

supreetha B.S 3 years ago

I have published my research work in JESTEC. It is a quality journal with systematic review process.I received review comments from 5 reviewers and i answered all the comments and finally after 2 round review process my paper was accepted. Thanks to Dr.Abdulkareem Sh Mahdi Al-obaidi

reply

V

VIJAY B G 2 years ago

Hello madam, could you please tell me is their any processing charges that you have paid? also suggest some good Scopus indexed journal to publish my paper.
Thank you

Sudhakiran Gunda 2 years ago

Could you please tell me the duration for this entire process.
I would like to know the time taken for publication.

Thankyou

SCImago Team

Melanie Ortiz 3 years ago

Dear Supreetha, thanks for your participation! Best Regards, SCImago Team

K

Khaled 3 years ago

Hello there!
I have a little question about the publication process timeline, Can i know please how long will take between sending an article and (journal answer by acceptance/rejection) and finally the paper's online availability ????

Khaled 3 years ago

Thanks alot for your valuable response
Are there any publication fees or not ???????

Ali 3 years ago

Dear khaled
The timeline for publishing in this journal about 2-3 months for final acceptance and may be 9 months for online publication
with my regards

SCImago Team

Melanie Ortiz 3 years ago

Dear Ali, thanks for your participation! Best Regards, SCImago Team

SCImago Team

Melanie Ortiz 3 years ago

Dear Khaled,
thank you for contacting us.
Sorry to tell you that SCImago Journal & Country Rank is not a journal. SJR is a portal with scientometric indicators of journals indexed in Elsevier/Scopus.
Unfortunately, we cannot help you with your request, we suggest you to visit the journal's homepage or contact the journal's editorial staff , so they could inform you more deeply.
You can see the updated journal's information just above .
Best Regards, SCImago Team

ASWANT KUMAR SHARMA 3 years ago

I have published a paper with JESTEC in a proper time line. It is good if JESTEC provide DOI for article published with them

reply

Malathi Kunnudaiyan 2 years ago

Have paid any fees for the publication sir?

R

rati saluja 3 years ago

The journal that provides best services, never a single follow up query left unaswered. I had written several research papers in numerous journals, but I feel pride the way "Journal of Engineering Science and Technology" works, they reviwed eveery mm of my manuscript. Their editing team is soul of the body. Mr. Obaidi shares every detail regaring the review process as well as time duration, that made the process easy. Publishing in a reputed journal takes time, So eagerly waiting for the same.
Thanks a million to Dr. Abdulkareem Sh. Mahdi Al-Obaidi for sharing a wonderful platform to enhance one'knowledge and research.

Hats off

A happy author

reply

M

Melva Silitonga 4 years ago

This journal template has been used for the 2019 Kyoto APLSBE template that I have participated in, I am interested in the content of this journal and wish for publication in this journal

reply

W

Wajde Alyhya 4 years ago

Hi
I sent a manuscript for publication in this journal and I received two months later seven reviewers' comments. I answered all their comments, however, I have not received an acceptance or rejection letter till now. I sent more than one emails regarding the status of my manuscript without an answer. I do not know what to do after nearly more than 6 months of waiting.

reply

A

Abdulkareem Sh. Mahdi Al-Obaidi 3 years ago

Dear Wajde
We thank you for the comment.
As you mentioned your experience with JESTEC, i wonder why you did not mention that your paper is accepted and will be published soon.
It is good to give negative feedback for improvment, we thank you but it is also fair to tell positive feedback, right?

E

Emmanuel 4 years ago

@ Elena:I humbly suggest that the web link of all journals should be published alongside their name.This will eliminate the faking of journals in your data base.

reply

W

Wajde Alyhya 4 years ago

Dear All
Could you please tell me how long it takes to be accepted and published online.
Thanks

reply

D

Dr. mohammed alwazzan 4 years ago

3 to 4 month

Elena Corera 4 years ago SCImago Team

Dear Wadje, in the link below you will find the information corresponding to the author's instructions of this journal. Best regards, SCImago Team
http://jestec.taylors.edu.my/instructions.html

Leave a comment

Name

Email
(will not be published)

Submit

The users of Scimago Journal & Country Rank have the possibility to dialogue through comments linked to a specific journal. The purpose is to have a forum in which general doubts about the processes of publication in the journal, experiences and other issues derived from the publication of papers are resolved. For topics on particular articles, maintain the dialogue through the usual channels with your editor.