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Distributed MPPT Connected with Cascade H-Bridge Multilevel PV Inverter for Grid Friendly Applications by Fuzzy

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Abstract

This paper exhibits a secluded fell H-bridge multilevel photovoltaic (PV) inverter for single or three stage lattice associated applications. The measured fell multilevel topology enhances the effectiveness and adaptability of PV frameworks. To acknowledge better usage of PV modules and expand the sun based vitality extraction, a dispersed greatest forced point control plan connected to both single-and three-stage multilevel inverters, which permits autonomous control of every dc-join voltage. For three-stage network associated applications, PV criss crosses may present unequal supplied power, prompting lopsided framework current. To fathom this issue, a control plan with balance remuneration is proposed. Here fuzzy logic is used for controlling and compared with other controller the simpered systems tool has proved that the combined system will at the same time inject maximum power.A trial three stage seven level fell H-bridge inverter has been assembled using nine H-span modules (three modules for every stage). Every H-span module is associated with a 185-W sunlight based board. Reproduction and exploratory results are introduced to confirm the plausibility of the proposed approach.

Keywords: Cascaded multilevel inverter, distributed maximum power point (MPP) tracking (MPPT), modular, modulation compensation, photovoltaic (PV).

I. INTRODUCTION

Because of the deficiency of fossil powers and ecological issues on by traditional force era, renewable vitality, especially sun oriented vitality, has turned out to be exceptionally mainstream. Sun oriented electric-vitality request has become reliably by 20%–25% for every annum in the course of recent years, and the development is for the most part in matrix associated applications. Inverter has identified with various designs of the PV framework: 1) focal inverters 2) string inverters 3) multi string inverters 4) air conditioning module inverters and 5) fell inverters. The setups of PV frameworks are in Fig. 1. Fell inverters comprise of a few converters associated in arrangement; consequently, the high power and/or high voltage.

There are two sorts of fell inverters. Fig. 1(e) demonstrates a fell dc/dc converter association of PV modules. Each PV module has its own particular dc/dc converter, and the modules with their related converters are still associated in arrangement to make a high dc voltage, which is given to a rearranged dc/air conditioning inverter. This methodology consolidates parts of string inverters and air conditioning module inverters and offers the upsides of individual module most extreme force point (MPP) following (MPPT). Another fell inverter is appear in Fig. 1(f), where each PV board is associated with its own dc/air conditioning inverter, and those inverters are then set in arrangement to achieve a high-voltage level. The advantages are "one converter for every board, better usage PV module, capacity of blending distinctive sources. Likewise, this dc/air conditioning fell inverter expels the requirement for the per-string dc transport and the focal dc/air conditioning inverter, which further enhances the general effectiveness.

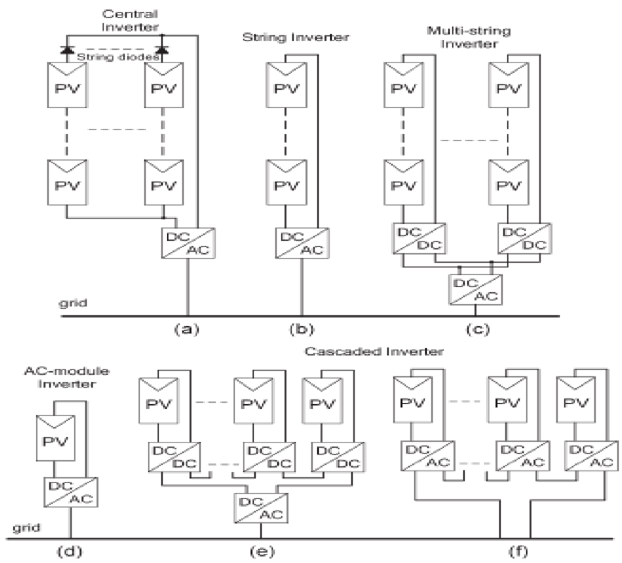

Fig. 1: Configurations of PV systems (a) Central inverter (b) String inverter(c) Multistring inverter(d) AC-module inverter(e) Cascaded dc/dc converter(f) Cascaded dc/ac inverter.

The measured fell H-span multilevel inverter, which requires a disconnected dc hotspot for every H-scaffold, is one dc/fell inverter topology. The different dc joins in the multilevel inverter make autonomous voltage control conceivable. In the interim, the measured quality and minimal effort of multilevel converters would position them as a prime contender for the up and coming era of productive, strong, and solid network associated sun oriented force hardware.

A particular fell H-bridge multilevel inverter topology for single-or three-stage lattice associated PV frameworks has displayed in this paper. To adjust the three-stage framework current, balance pay has added to the control framework.

A three-stage secluded fell multilevel inverter proto sort has fabricated. Every H-extension is associated with a 185-Wsolar board. The measured outline will build the adaptability of the framework and lessen the expense.

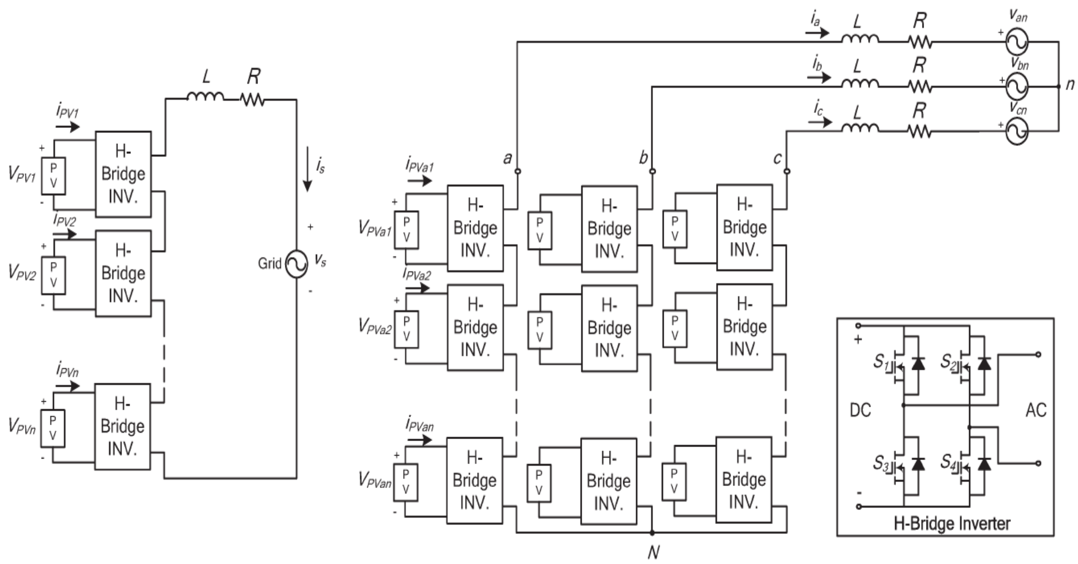

Fig. 2: Topology of the modular cascaded H-bridge multilevel inverter for grid-connected PV systems.

II. SYSTEM DESCRIPTION

Modular cascaded H-bridge multilevel inverters for single and three phase grid connected PV systems are shown in Fig. 2.Each phase consists of an H-bridge converters connected in series, and the dc link of each H-bridge can be fed by a PV panel or a short string of PV panels. The cascaded multilevel inverter is connected to the grid through *L* filters, which are used to reduce the switching harmonics in the current. By different combinations of the four switches in each bridge module, three output voltage levels can be generated: $-v_{dc}$, 0, or $+v_{dc}$. A cascaded multilevel inverter has an input sources will provide $2n + 1$ levels to synthesize the ac output waveform. This $(2n + 1)$ level voltage waveform enables the reduction of harmonics in the synthesized current, reducing the size of the needed output filters. Multilevel inverters also have other advantages such as reduced voltage stresses on the semiconductor switches and having higher efficiency when compared to other converter topologies.

III. PANEL MISMATCHES

PV confuses in the PV framework because of the unequal got irradiance, distinctive temperatures, and maturing of the PV boards, the MPP of each PV module might be distinctive. To demonstrate the need of individual MPPT control, a five-level two H-span single stage inverter is re-enacted in MATLAB/SIMULINK by utilizing fluffy rationale controller. Every H-span has its own 185W PV board associated as a separated dc source.

Consider a working condition that every board has an alternate illumination from the sun; board 1 has irradiance S = 1000 W/m2, and board 2 has S = 600 W/m2. In the event that exclusive board 1 is followed and its MPPT controller decides the normal voltage of the two boards, the force separated from board 1 would be 133 W, and the force from board 2 would be 70 W, as can be found in Fig. 3.

Fig. 4 demonstrates the MPPs of the PV boards under the diverse irradiance. The most extreme yield power qualities will be 185 and 108.5 W when the S qualities are 1000 and 600 W/m2.

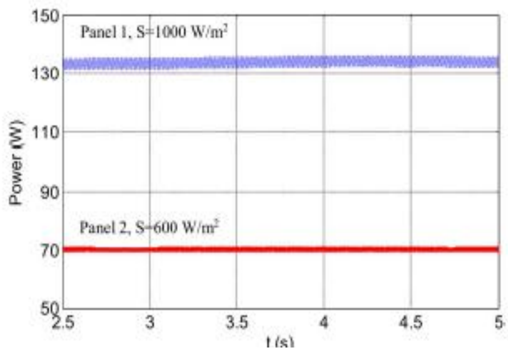

Fig.3. Power extracted from two PV panels.

In a three-phase grid-connected PV system, a PV mismatch may cause more problems. Aside from decreasing the overall efficiency, this could even introduce unbalanced power supplied to the three-phase grid-connected system.

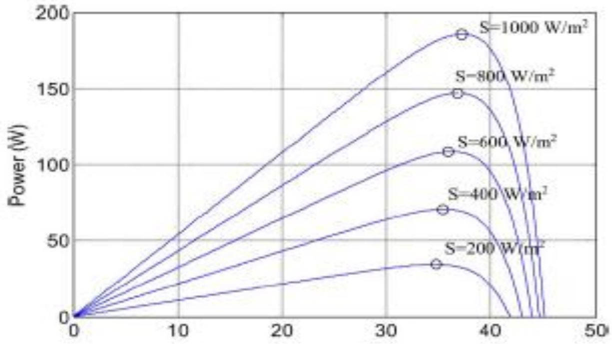

Fig.4. P–V characteristic under the different irradiance.

To solve the PV mismatch issue, a control scheme with individual MPPT control and modulation compensation is proposed. The details of the control scheme will be discussed in the next section.

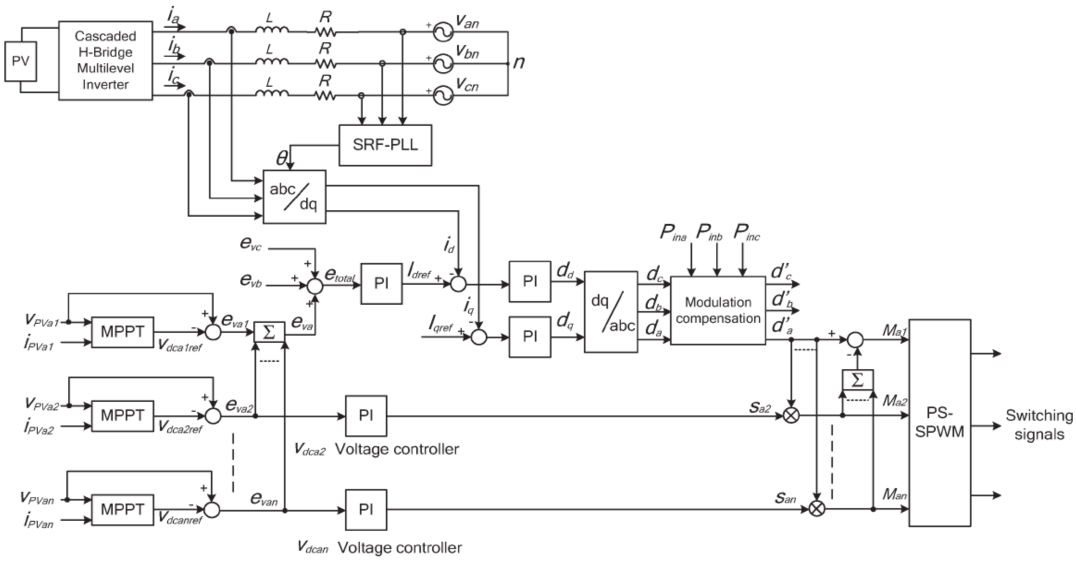

Fig.5. Control scheme for three-phase modular cascaded H-bridge multilevel PV inverter.

IV. CONTROL SCHEME

A. Distributed MPPT Control

In order to eliminate the adverse effect of the PV modules mismatches and increase the efficiency to operate at different voltages and to improve the utilization of PV module.

The separate dc links in the cascaded H-bridge multilevel inverter make independent voltage control possible. The distributed MPPT control of the three-phase cascaded H-bridge inverter is shown in Fig. 5. In each H-bridge module, an MPPT controller is added to generate the dc-link voltage reference. The reactive current reference I_{qref} can be set to zero, or if reactive power compensation is required, I_{qref} can also be given by a reactive current calculator.

As the classic control scheme in three-phase systems, the grid currents in abc coordinates are converted to dq coordinates and regulated through proportional–integral (PI) controllers to generate the modulation index in the dq coordinates, which is then converted back to three phases.

B. Modulation Compensation

With the individual MPPT control in each H-bridge module, the input solar power of each phase would be different, which introduces unbalanced current to the grid. To solve the issue, a zero sequence voltage be imposed upon the phase legs in order to affect the current flowing into each phase.

Thus, the modulation compensation block, as shown in Fig. 6, is added to the control system of three-phase modular cascaded multilevel PV inverters. First, the unbalanced powers weighted by ratio *rj*, which is calculated as

$$r_j = \frac{P_{inav}}{P_{inj}} \quad (1)$$

Where *P*in*j* is the input power of phase *j* (*j = a, b, c*), and *P*inav is the average input power. Then, the injected zero sequence modulation index can be generated as

$$d_o = \frac{1}{2}[\min(r_a.d_a, r_b.d_b, r_c.d_c) + \max(r_a.d_a, r_b.d_b, r_c.d_c) \quad (2)$$

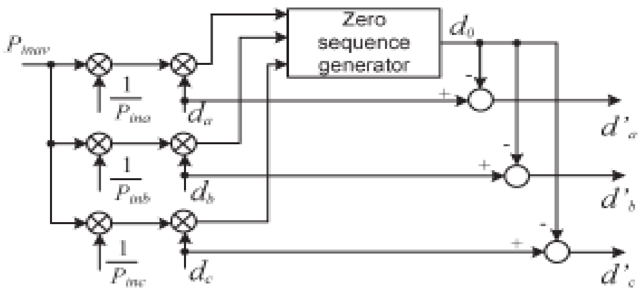

Fig.6. Modulation compensation scheme.

where *dj* is the modulation index of phase *j* (*j = a, b, c*) and is determined by the current loop controller. The modulation index of each phase is updated by

$$d'_j = d_j - d_0 \quad (3)$$

Only simple calculations are needed in the scheme, which will not increase the complexity of the control system. To show the modulation compensation scheme more clearly. Assume that the input power of each phase is unequal.

$$P_{ina} = 0.8 \quad P_{inb} = 1 \quad P_{inc} = 1 \quad (4)$$

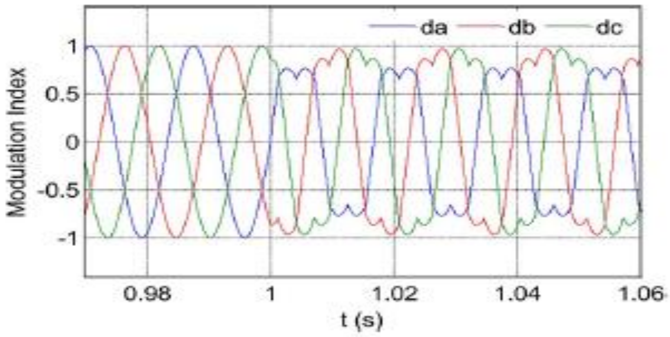

Fig.7. Modulation indices before and after modulation compensation.

TABLE I: SYSTEM PARAMETERS

Parameters	Value
DC-link capacitor	3600 µF
Connection inductor L	2.5 mH
Grid resistor R	0.1 ohm
Grid rated phase voltage	60 Vrms
Switching frequency	1.5 kHz

By injecting a zero sequence modulation index at t = 1s, the balanced modulation index will be updated, as shown in Fig.7. It can be seen that, with the compensation, the updated modulation index is unbalanced proportional to the power, which means that the output voltage (*vjN*) of the three-phase inverter is unbalanced, but this produces the desired balanced grid current.

V. FUZZY LOGIC CONTROLLER

In FLC, basic control action is determined by a set of linguistic rules. These rules are determined by the system. Since the numerical variables are converted into linguistic variables, mathematical modeling of the system is not required in FC.

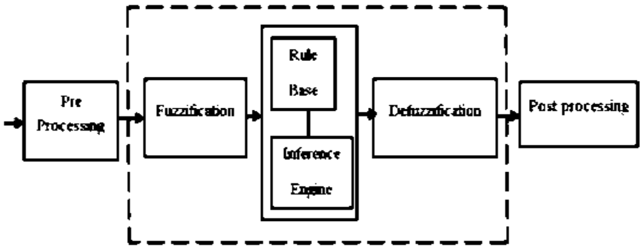

Fig.8. Fuzzy logic controller

The FC comprises of three parts characterized as i. seven fuzzy sets for each input and output. ii. Triangular membership functions for simplicity. iii. Fuzzification using continuous universe of discourse. iv. Implication using Mamdani's, 'min' operator. v. Defuzzification using the height method.

TABLE I: Fuzzy Rules

Change in error	Error						
	NB	NM	NS	Z	PS	PM	PB
NB	PB	PB	PB	PM	PM	PS	Z
NM	PB	PB	PM	PM	PS	Z	Z
NS	PB	PM	PS	PS	Z	NM	NB
Z	PB	PM	PS	Z	NS	NM	NB
PS	PM	PS	Z	NS	NM	NB	NB
PM	PS	Z	NS	NM	NM	NB	NB
PB	Z	NS	NM	NM	NB	NB	NB

Fuzzification: In this system the input scaling factor has been designed such that input values are between -1 and +1. The input error for the FLC is given as

$$E(k) = \frac{P_{ph(k)} - P_{ph(k-1)}}{V_{ph(k)} - V_{ph(k-1)}} \qquad (5)$$

$$CE(k) = E(k) - E(k-1) \qquad (6)$$

Inference Method: Several composition methods such as Max–Min and Max-Dot have been proposed in the literature. In this paper Min method is used. The output membership function of each rule is given by the minimum operator and maximum operator. Table 1 shows rule base of the FLC.

Defuzzification: As a plant usually requires a non-fuzzy value of control, a defuzzification stage is needed. To compute the output of the FLC, height method is used and the FLC output modifies the control output. Further, the output of FLC controls the switch in the inverter.

The set of FC rules are derived from

$$u=-[\alpha E + (1-\alpha)*C] \qquad (7)$$

Where α is self-adjustable factor which can regulate the whole operation. E is the error of the system, C is the change in error and u is the control variable.

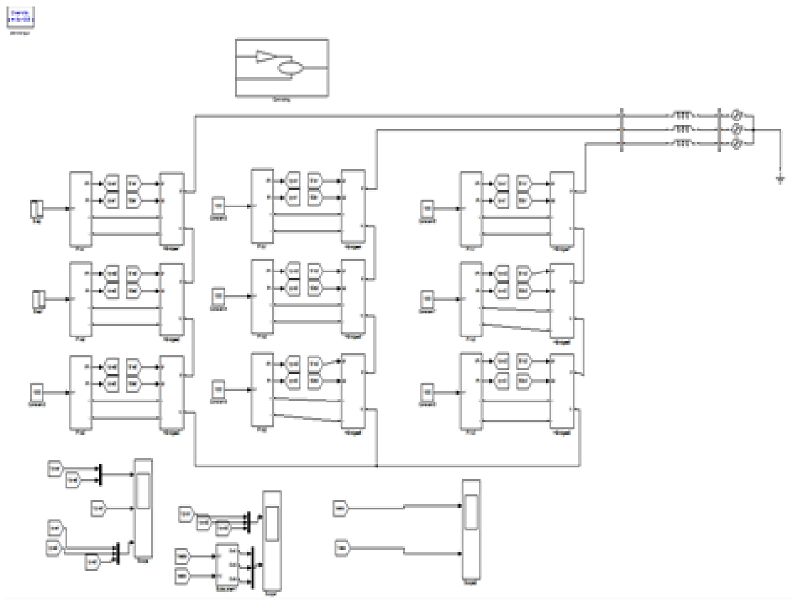

Fig.10: Simulated diagram by using fuzzy controller.

VI. SIMULATION RESULTS

A modular cascaded multilevel inverter prototype has built by using fuzzy logic controller. The MOSFET IRFSL4127 as selected as inverter switches operating at 1.5 kHz. The control signals to the H-bridge inverters are sent by a space ds1103 controller.

A three-phase seven-level cascaded H-bridge inverter as simulated by fuzzy. Each H-bridge has its own 185W PV panel (A stronger CHSM-5612M) connected as an independent source. The inverter as connected to the grid through a transformer, and the phase voltage of the secondary side is 60 V_{rms}.

First, all PV panels are operated under the same irradiance S = 1000 W/m2 and temperature T = 25 ◦C. At t = 0.8 s, the solar irradiance on the first and second panels of phase *a* decreases to 600 W/m2, and that for the other panels stays the same. The dc-link voltages of phase *a* are shown in Fig.11. The PV current waveforms of phase *a* are shown in Fig. 12. After t = 0.8 s, the currents of the first and second PV panels are much smaller due to the low irradiance, and the lower ripple of the dc-link voltage in Fig.11(a).

The dc-link voltages of phase *b* are shown in Fig.13. All phase-*b* panels track the MPP voltage of 36.4 V, which shows that they are not influenced by other phases. With the distributed MPPT control, the dc-link voltage of each H-bridge can be controlled independently. In other words, the connected PV panel of each H-bridge can be operate at its own. Thus, more solar energy can be extract, and the efficiency of the overall PV system be increased.

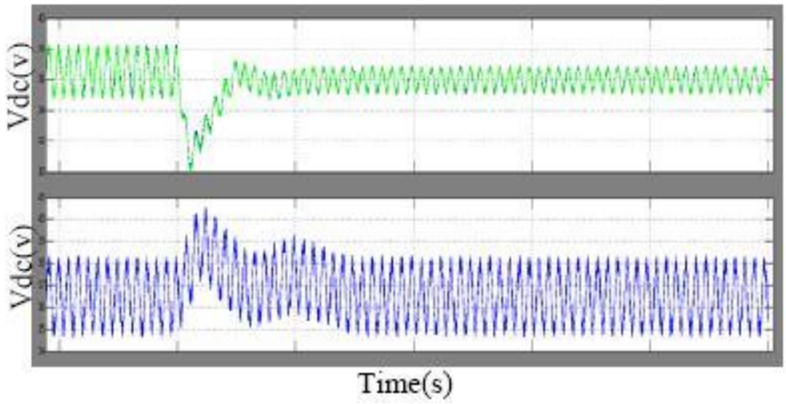

Fig.11. DC-link voltages of phase *a* with distributed MPPT (*T* = 25 ◦C). (a) DC-link voltage of modules 1 and 2.(b) DC-link voltage of module 3.

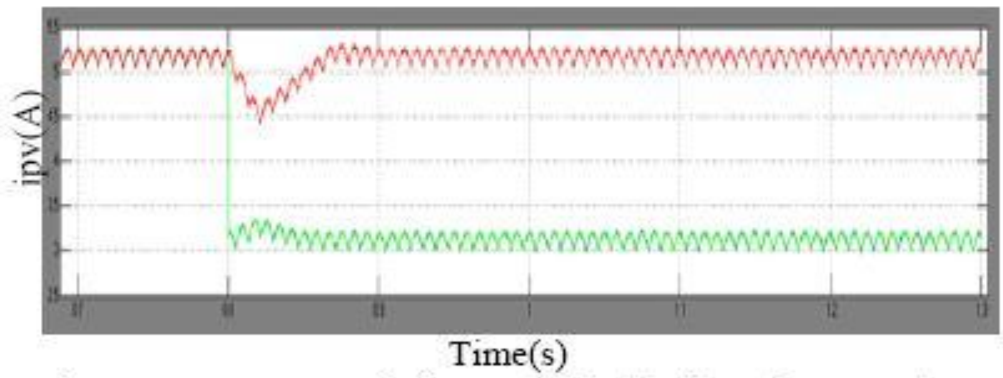

Fig.12. PV currents of phase *a* with distributed MPPT (*T* = 25 ◦C).

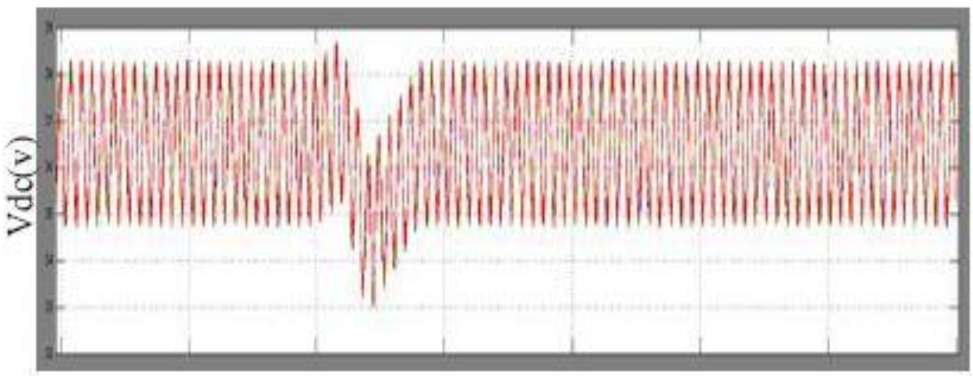

Fig.13. DC-link voltages of phase *b* with distributed MPPT (*T* = 25 ◦C).

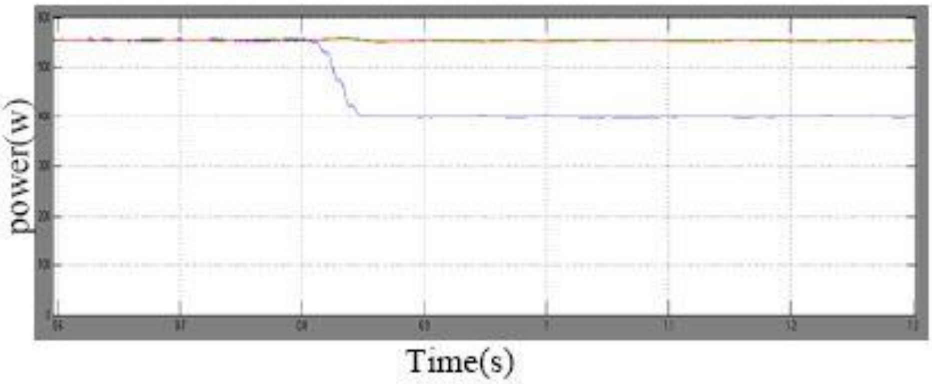

Fig.14. Power extracted from PV panels with distributed MPPT.

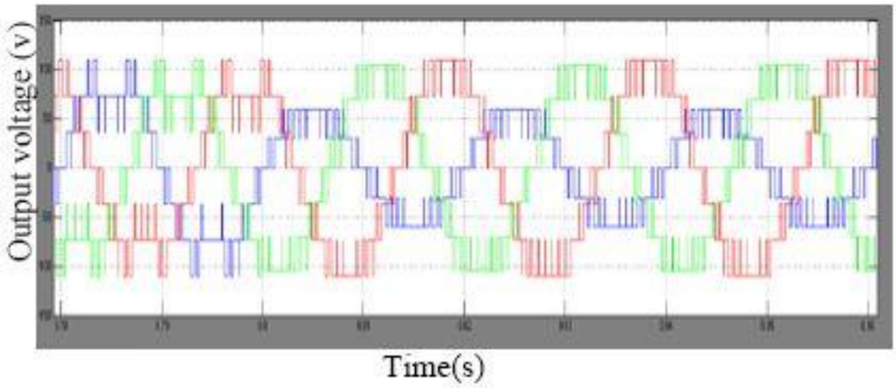

Fig.15. Three-phase inverter output voltage waveforms with modulation compensation.

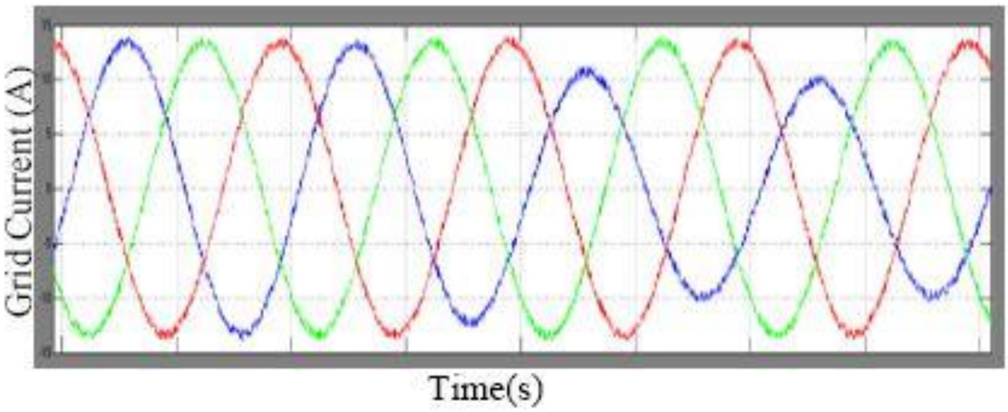

Fig.16. Three phase grid current waveforms with modulation compensation.

VII. CONCLUSION

A modular cascaded H-bridge multilevel inverter for grid-connected PV applications has presented by using fuzzy logic controller. The multilevel inverter topology will help to improve the utilization of connected PV modules if the voltages of the separated links has controlled independently. Thus, a distributed MPPT control scheme for both single and three phase PV systems has applied to increase the overall efficiency of PV systems in MATLAB simulink. The MATLAB/Simpower Systems simulation shows sensible performances of this controller. Here fuzzy controllers has used compared to alternative controllers because of its accurate performance.For the three-phase grid-connected PV system; PV mismatches may introduce unbalanced supplied power, resulting in unbalanced injected grid current. A modulation compensation scheme, which will not increase the complexity of the control system or cause extra power loss, as added to balance the grid current. A modular three-phase seven-level cascaded H-bridge inverter has built in the laboratory and tested with PV panels under different partial shading conditions. With the proposed control scheme, each PV module be operated at its own MPP to maximize the solar energy extraction, and the three-phase grid current is balanced even with the unbalanced supplied solar power.

REFERENCES

[1] J. M. Carrasco *et al.*, "Power-electronic systems for the grid integration of renewable energy sources: A survey," *IEEE Trans. Ind. Electron.*, vol. 53, no. 4, pp. 1002–1016, Jun. 2006.

[2] S. B. Kjaer, J. K. Pedersen, and F. Blaabjerg, "A review of single-phase

[3] grid connected inverters for photovoltaic modules," *IEEE Trans. Ind. Appl.*, vol. 41, no. 5, pp. 1292–1306, Sep./Oct. 2005.

[4] M. Meinhardt and G. Cramer, "Past, present and future of grid connected photovoltaic- and hybrid power-systems," in *Proc. IEEE PES Summer Meet.*, 2000, vol. 2, pp. 1283–1288.

[5] M. Calais, J. Myrzik, T. Spooner, and V. G. Agelidis, "Inverter for single phase grid connected photovoltaic systems—An overview," in *Proc. IEEEPESC*, 2002, vol. 2, pp. 1995–2000.

[6] J.M. A.Myrzik and M. Calais, "String and module integrated inverters for single-phase grid connected photovoltaic systems—A review," in *Proc. IEEE Bologna Power Tech Conf.*, 2003, vol. 2, pp. 1–8.

[7] F. Schimpf and L. Norum, "Grid connected converters for photovoltaic, state of the art, ideas for improvement of transformer less inverters," in *Proc. NORPIE*, Espoo, Finland, Jun. 2008, pp. 1–6.

[8] B. Liu, S. Duan, and T. Cai, "Photovoltaic DC-building-module-based BIPV system—Concept and design considerations," *IEEE Trans. Power Electron.*, vol. 26, no. 5, pp. 1418–1429, May 2011.

[9] L. M. Tolbert and F. Z. Peng, "Multilevel converters as a utility interface for renewable energy systems," in *Proc. IEEE Power Eng. Soc. SummerMeet.*, Seattle, WA, USA, Jul. 2000, pp. 1271–1274.

[10] H. Ertl, J. Kolar, and F. Zach, "A novel multicell DC–AC converter for applications in renewable energy systems," *IEEE Trans. Ind. Electron.*, vol. 49, no. 5, pp. 1048–1057, Oct. 2002.

[11] S. Daher, J. Schmid, and F. L. M. Antunes, "Multilevel inverter topologies for stand-alone PV systems," *IEEE Trans. Ind. Electron.*, vol. 55, no. 7, pp. 2703–2712, Jul. 2008.

[12] G. R. Walker and P. C. Sernia, "Cascaded DC–DC converter connection of photovoltaic modules," *IEEE Trans. Power Electron.*, vol. 19, no. 4, pp. 1130–1139, Jul. 2004.

[13] E. Roman, R. Alonso, P. Ibanez, S. Elorduizapatarietxe, and D. Goitia, "Intelligent PV module for grid-connected PV systems," *IEEE Trans. Ind.Electron.*, vol. 53, no. 4, pp. 1066–1073, Jun. 2006.

[14] F. Filho, Y. Cao, and L. M. Tolbert, "11-level cascaded H-bridge gridtied inverter interface with solar panels," in *Proc. IEEE APEC Expo.*, Feb. 2010, pp. 968–972.

[15] C. D. Townsend, T. J. Summers, and R. E. Betz, "Control and modulation scheme for a cascaded H-bridge multi-level converter in large scale photovoltaic systems," in *Proc. IEEE ECCE*, Sep. 2012, pp. 3707–3714.

[16] B. Xiao, L. Hang, and L. M. Tolbert, "Control of three-phase cascaded voltage source inverter for grid-connected photovoltaic systems," in *Proc. IEEE APEC Expo.*, Mar. 2013, pp. 291–296.

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