ISSN: 2350-0328

International Journal of Advanced Research in Science, Engineering and Technology

Vol. 6, Special Issue , August 2019

International Conference on Recent Advances in Science, Engineering, Technology and Management at Sree Vahini Institute of Science and Technology-Tiruvuru, Krishna Dist, A.P

PV fed Modified Cascaded Hybrid Multilevel Inverter using MPPT with grid applications

P Prasanth Kumar, K.V.S Manikanta, K Kamalakar , G. Tejaswi

UG Student, Sree Vahini Institute of Science & Technology, Tiruvuru, A.P., INDIA
UG Student, Sree Vahini Institute of Science & Technology, Tiruvuru, A.P., INDIA
UG Student, Sree Vahini Institute of Science & Technology, Tiruvuru, A.P., INDIA
[4]Asst. Professor, Sree Vahini Institute of Science & Technology, A.P., INDIA

ABSTRACT— This paper proposes a PV fed modified cascaded Hybrid multilevel inverter for single- or three-phase grid-connected applications. The modified cascaded multilevel topology helps to improve the efficiency and flexibility of PV systems. In general, the output of the PV array is unregulated DC supply due to change in weather conditions. The maximum power is tracked with respect to temperature and irradiance levels by using DC-DC converter, a distributed maximum power point tracking control scheme is applied to both single- and three-phase multilevel inverters, which allows independent control of each dc-link voltage. For three-phase grid-connected applications, PV mismatches may introduce unbalanced supplied power, leading to unbalanced grid current. To solve this issue, a control scheme with modulation compensation is also proposed. Using nine H-bridge modules (three modules per stage), a three-phase cascaded multilevel hybrid inverter was developed. Simulation results are presented to verify the feasibility of the proposed approach.

KEYWORDS: Maximum Power Point Tracking (MPPT), Photo-Voltaic (PV), Cascaded hybrid multilevel inverter

I. INTRODUCTION

Renewable energy, especially solar energy, has become very common due to the shortage of fossil fuels and environmental issues created by standard power generation. Over the previous 20 years, demand for solar-electric power has steadily risen by 20% –25% per annum, and growth is mostly in grid-connected apps. With the exceptional development of the market in grid-connected photovoltaic (PV) devices, interest in grid-connected PV settings is growing. It is possible to define five inverter families linked to distinct PV system settings: 1) main inverters; 2) string inverters; 3) multi-inverters; 4) ac-module inverters; and 5) cascaded inverters. The configurations of PV systems are shown in Fig. 1.Cascaded inverters consist of several converters connected in series; thus, the high power and/or high voltage from the combination of the multiple modules would favour this topology in medium and large grid-connected PV systems. There are two types of cascaded inverters. Fig. 1(e) shows a cascaded dc/dc converter connection of PV modules. Each PV module has its own dc / dc converter and the modules are still linked in series with their related converters to generate a elevated dc voltage that is supplied to a streamlined dc / ac inverter. This strategy incorporates string inverters and ac-module inverters and provides the benefits of individual module peak energy point (MPP) monitoring (MPPT), but it is less costly and more efficient than ac-module inverters. However, there are two power conversion stages in this configuration of another cascaded inverter is shown in Fig. 1(f), where each PV panel is connected to its own dc/ac inverter, and those inverters are then placed in series to reach a high-voltage level. This cascaded inverter would maintain the benefits of "one converter per panel," such as better utilization per PV module, capability of mixing different sources, and redundancy of the system. In addition, this dc/ac cascaded inverter removes the need for the per-string dc bus and the central dc/ac inverter which further improves the overall efficiency.

The modified cascaded Hybrid multilevel inverter, whichre quires an isolated dc source for each H-bridge, is one dc/ac cascaded inverter topology. The separate dc links in the multilevel inverter make independent voltage control possible. As a result, individual MPPT control in each PV module can be achieved, and the energy harvested from PV panels can be maximized. Meanwhile, the modularity and low cost of multilevel converters would position them as a prime candidate for the next generation of efficient, robust, and reliable grid connected solar power electronics. A modular cascaded H-bridge multilevel inverter topology for single- or three-phase grid-connected PV systems is

ISSN: 2350-0328
International Journal of Advanced Research in Science, Engineering and Technology
Vol. 6, Special Issue , August 2019
International Conference on Recent Advances in Science, Engineering, Technology and Management at Sree Vahini Institute of Science and Technology-Tiruvuru, Krishna Dist, A.P

presented in this paper. The panel mismatch issues are addressed to show the necessity of individual MPPT control, and a control scheme with distributed MPPT control is then proposed. The distributed MPPT control scheme can be applied to both single and three-phase systems. In addition, for the presented three-phase grid-connected PV system, if each PV module is operated at its own MPP, PV mismatches may introduce unbalanced power supplied to the three-phase multilevel inverter, leading to unbalanced injected grid current. To balance the three-phase grid current, modulation compensation is also added to the control system. Three-phase modular cascaded multilevel inverter prototype has been built. The modular design will increase the flexibility of the system and reduce the cost as well. Simulation results are provided to demonstrate the developed control scheme.

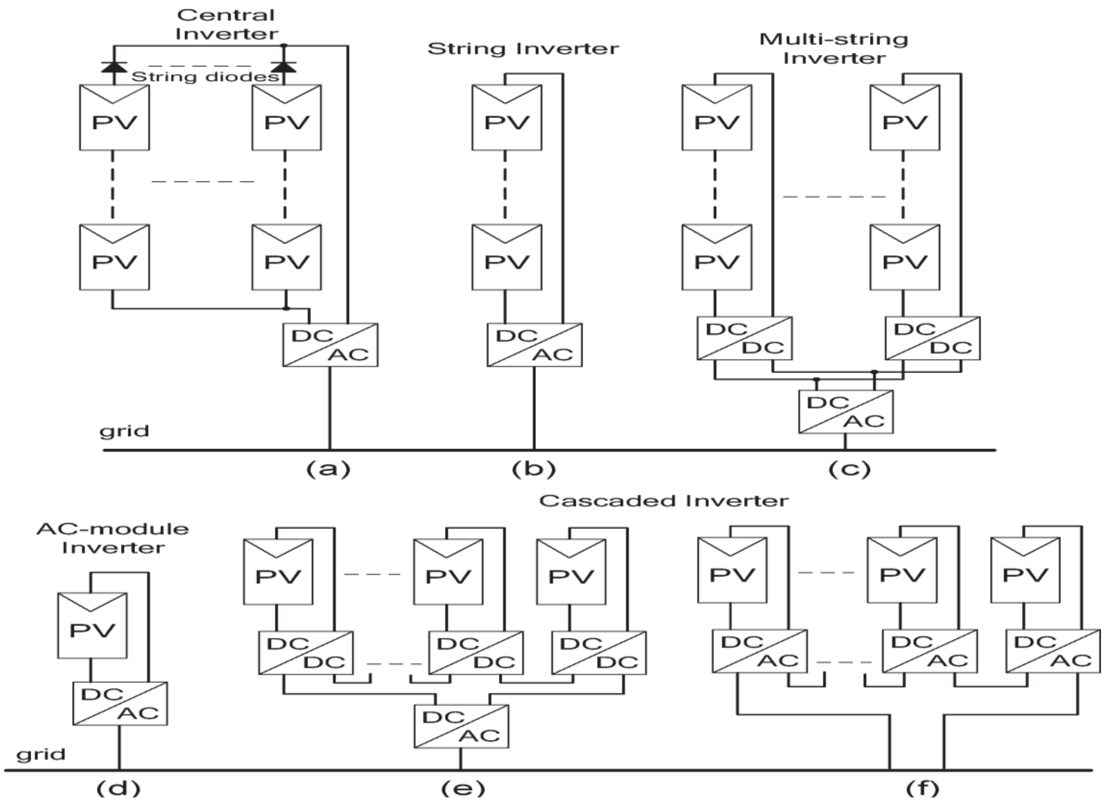


Fig. 1Configurations of PV systems. (a) Central inverter. (b) String inverter. (c) Multistring inverter. (d) AC-module inverter. (e) Cascaded dc/dc converter. (f)Cascaded dc/ac inverter.

II. SYSTEM DESCRIPTION

Modified cascaded H-bridge multilevel inverters for single and three-phase grid-connected PV systems are shown in Fig. 2. Each stage comprises of n series-connected H-bridge converters, and a PV panel or a brief string of PV panels can feed the dc connection of each H-bridge. The cascaded hybrid multilevel inverter is linked to the grid via L filters that are used to decrease the current's switching harmonics. Three output voltage levels can be generated by various combinations of the four switches in each H-bridge module:−vdc, 0, or + vdc. In order to synthesize the ac output waveform, a cascaded multilevel inverter with n input sources will provide 2n + 1 level. 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 mismatch is an important issue in the PV system. Due to the unequal received irradiance, different temperatures, and aging of the PV panels, the MPP of each PV module may be different. If each PV module is not controlled independently, the efficiency of the overall PV system will be decreased. To show the necessity of individual MPPT control, a five-level two-H-bridge single-phase inverter is simulated in MATLAB/SIMULINK. Each H-bridge has its own 185-W PV panel connected as an isolated dc source. The PV panel is modelled according to the specification of the commercial PV panel from Astrometry CHSM-5612M.Consider an operating condition that each panel has a different irradiation from the sun; panel 1 has irradiance S =1000 W/m2, and panel 2 has S = 600 W/m2. If only panel 1 is tracked and its MPPT controller determines the average voltage of the two panels, the power extracted from panel 1 would be 133 W, and the power from panel 2 would be 70 W, as can be seen in Fig. 3. Without individual MPPT control, the total power harvested from the PV system is 203 W. However, Fig. 4 shows the MPPs of the PV panels under the different irradiance. The maximum output power values will be185 and 108.5 W when the S values are 1000 and 600 W/m2, respectively, which means that the total power harvested from the PV system would be 293.5 W if individual MPPT can be achieved. This higher value is about 1.45 times of the one before. Thus, individual MPPT control in each PV module is required to increase the efficiency of the PV system.

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. If there are PV mismatches between phases, the input power of each phase would be different. Since the grid voltage is balanced, this difference in input power will cause unbalanced current to the grid, which is not allowed by grid standards. 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.

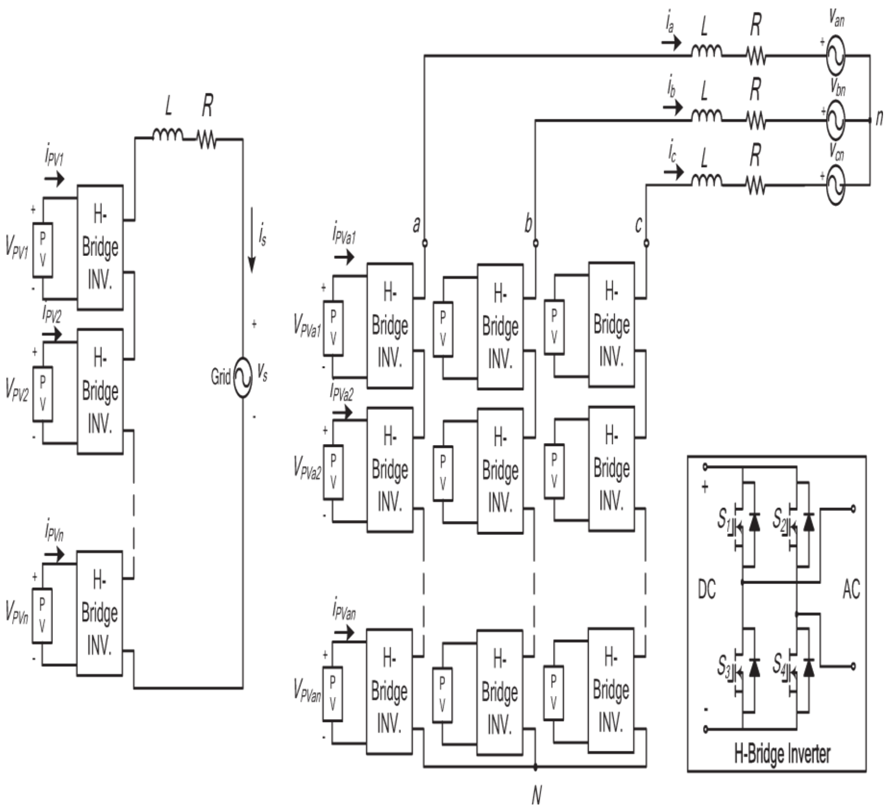


Fig. 2 Modified cascaded Hybrid multilevel inverter for grid-connected PV systems.

ISSN: 2350-0328
International Journal of Advanced Research in Science, Engineering and Technology
Vol. 6, Special Issue , August 2019
International Conference on Recent Advances in Science, Engineering, Technology and Management at Sree Vahini Institute of Science and Technology-Tiruvuru, Krishna Dist, A.P

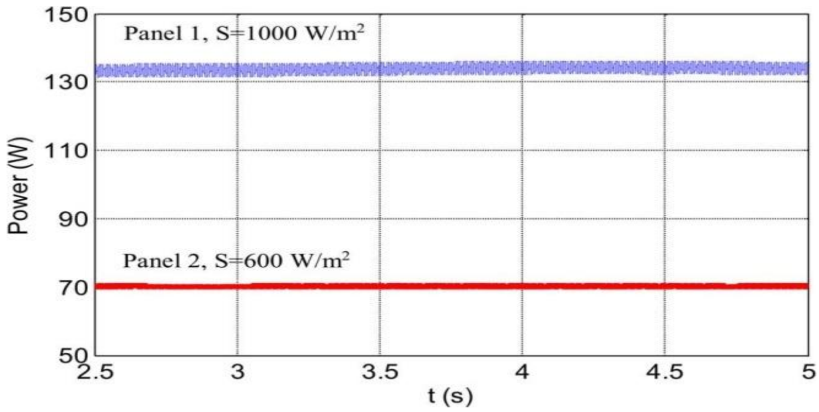


Fig. 3 Power extracted from two PV panels.

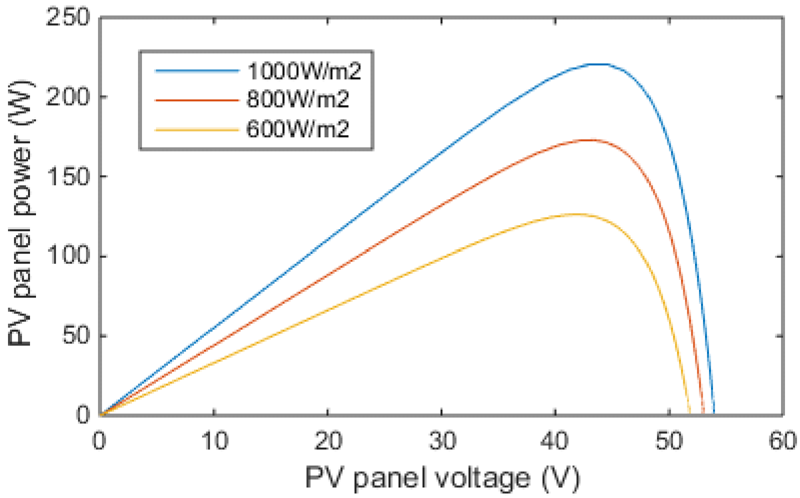


Fig. 4 *P –V* characteristic of different irradiance.

IV. CONTROL SCHEME

A. Distributed MPPT Control

In order to increase the efficiency of the PV system, the PV modules need to operate at different voltages to improve the utilization per PV module. The separate dc links in the cascaded H-bridge multilevel inverter make independent voltage control possible The control system suggested and is updated for this implementation to carry out individual MPPT controls in each PV module. The three-phase cascaded Hybrid Multilevel inverter's distributed MPPT control is shown in Fig. 5. To create the dc-link voltage reference, an MPPT controller is added to each H-bridge module. Each dc-link voltage is compared to the corresponding voltage reference, and the sum of all errors is controlled through a total voltage controller that determines the current reference Id_{ref}. The reactive current reference Iq_{ref} can be set to zero, or if reactive power compensation is required, Iq_{ref} can also be given by a reactive current calculator. The synchronous reference frame phase-locked loop (PLL) has been used to find the phase angle of the grid voltage. As the classic control scheme in three-phase systems, the grid currents in abc coordinates are converted to dq

ISSN: 2350-0328

International Journal of Advanced Research in Science, Engineering and Technology

Vol. 6, Special Issue , August 2019

International Conference on Recent Advances in Science, Engineering, Technology and Management at Sree Vahini Institute of Science and Technology-Tiruvuru, Krishna Dist, A.P

coordinates and regulated through proportional–integral (PI) controllers to generate the modulation index in the dq coordinates, which is then converted back to three phase.

For the single-phase system, the distributed MPPT control scheme is almost the same. The complete voltage controller offers the magnitude of the active present reference, and a PLL offers the active present reference frequency and phase angle. Then the current loop provides the index of modulation. To make each PV module operate at its own MPP, take phase a as an example; the voltages vdc_{a2} to vdc_{an} are controlled individually through n − 1 loops. Each voltage controller gives the modulation index To make each PV module operate at its own MPP, take phase a as an example; the voltages vdca2 to vdc_{an} are controlled individually through n − 1 loops. Each voltage controller gives the modulation index proportion of one H-bridge module in phase a. After multiplied by the modulation index of phase a, n − 1 modulation indices can be obtained. Also, the modulation index for the first H-bridge can be obtained by subtraction. The control schemes in phases b and c are almost the same. The only difference is that all dc-link voltages are regulated through PI controllers, and n modulation index proportions are obtained for each phase.

A phase-shifted sinusoidal pulse width modulation switching scheme is then applied to control the switching device so feach H-bridge. It can be seen that there is one H-bridge module out of N modules who semodulationindexisobtainedbysubtraction. Forsingle-phasesystems, N=n, andforthree-phasesystems, $N = 3n$, where n is the number of H-bridge modules per phase. The reason is that N voltage loops are necessary to manage different voltage levels on N H-bridges, and one is the total voltage loop, which gives the current reference. So, only N 1 modulation indices can be determined by the last N1 voltage loops, and one modulation index has to be obtained by subtraction. Many MPPT methods have been developed and the incremental conductance method has been used in this paper. It lends itself well to digital control, which can easily keep track of previous values of voltage and current and make all decisions.

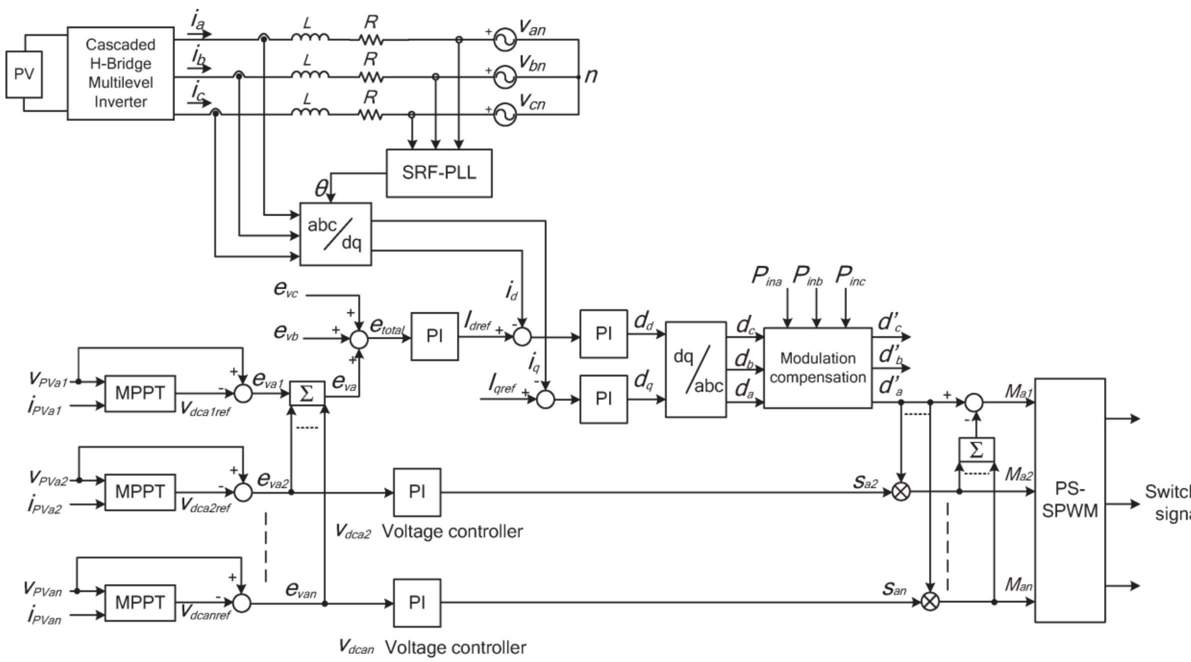


Fig. 5 Control scheme for three-phase modified cascaded Hybrid Multilevel PV inverter.

B Modulation Compensation: As stated above, a PV mismatch may cause more issues for a multi-level PV inverter with a three-phase modular cascaded H-bridge. Would the input solar power of each phase differ with the individual MPPT control in each H-bridge module, which introduces unbalanced current into the grid? To solve the problem, the phase legs may have a zero sequence voltage to affect the current flow. The current will be balanced if the updated phase voltage of the inverter output is proportional to the unbalanced energy. Thus, the modulation compensation block, as shown in Fig. 6, is added to the control system of three-phase modular cascaded multilevel PV inverters. The key is

ISSN: 2350-0328
International Journal of Advanced Research in Science, Engineering and Technology
Vol. 6, Special Issue , August 2019
International Conference on Recent Advances in Science, Engineering, Technology and Management at Sree Vahini Institute of Science and Technology-Tiruvuru, Krishna Dist, A.P

how to update the modulation index of each phase without increasing the complexity of the control system. First, the unbalanced power is weighted by ratio r_j, which is calculated as

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

where P_{inj} 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

$$d_0 = \frac{1}{2}[\min(r_a \cdot d_a, r_b \cdot d_b, r_c \cdot d_c) + \max(r_a \cdot d_a, r_b \cdot d_b, r_c \cdot d_c)] \quad (2)$$

Where d_j is the modulation index of phase j ($j=a,b,c$)and is determined by the current loop controller.

The modulation Windex of each phase is updated by

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

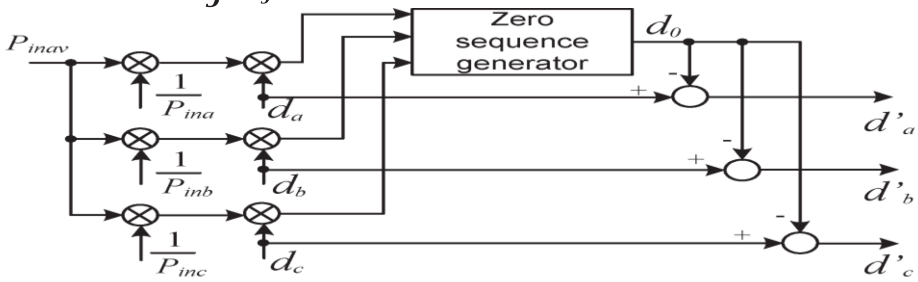


Fig. 6 Modulation compensation scheme.

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

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

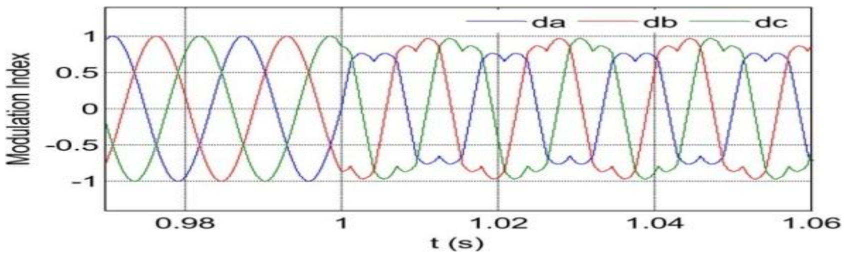


Fig.7 Modulation indices before and after modulation compensation.

TABLE I SYSTEM PARAMETERS

Parameter	Value
DC-Link capacitor	3600µF
Connection Inductor L	2.5mH
Grid resistor R	0.1 ohm
Grid Rated Phase Voltage	60 V_{rms}
Switching Frequency	1.5kHz

ISSN: 2350-0328

International Journal of Advanced Research in Science, Engineering and Technology

Vol. 6, Special Issue , August 2019

International Conference on Recent Advances in Science, Engineering, Technology and Management at Sree Vahini Institute of Science and Technology-Tiruvuru, Krishna Dist, A.P

By injecting a zero sequence modulation index at t = 1 s, 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 (v_{jN}) of the three-phase inverter is unbalanced, but this produces the desired balanced grid current.

V SIMULATION AND RESULTS

A. Simulation Results

To verify the proposed control scheme, the three-phase grid- connected PV inverter is simulated in two different conditions. First, all PV panels are operated under the same in radiance S = 1000 W/m^2 and temperature T = 25 $^\circ$C. At t = 0.8 s, the solar irradiance on the first and second panels of phase a decreases to 600W/m^2,and that for the other panels stays the same. The dc-link voltage so phase a are shown in Fig.8.At the beginning, all PV panels are operate data MPP voltage of 36.4V. As the irradiance changes, the first and second dc-link voltages decrease and track the new MPP voltage of 36V, while the third panel is still operated at 36.4V. The PV current wave form soft phase a are shown in Fig.9. After t=0.8s, the current so the first and second PV panels are much smaller due tothelowirradiance, andthelowerrippleofthedc-linkvoltage can be found in Fig.8(a).Fig. 9. PV currents of phase a with distributed MPPT (T = 25 $^\circ$C).

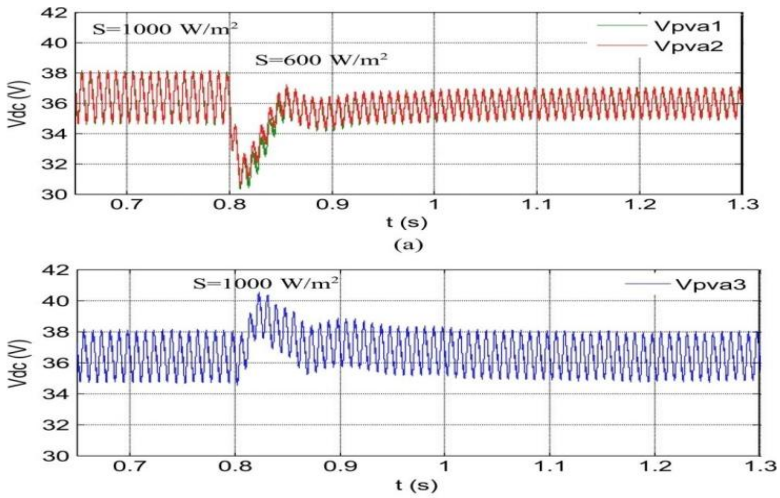


Fig. 8 DC-link voltages of phase *a* with distributed MPPT (*T* = 25 $^\circ$C)
(a) DC-link voltage of modules 1 and 2. (b) DC-link voltage of module3.

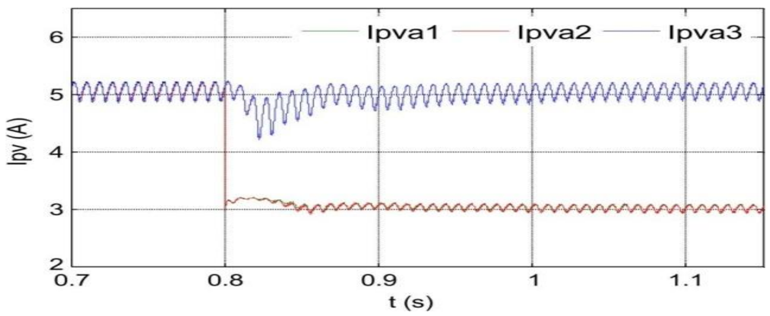


Fig. 9(a) DC-link voltage of modules 1 and 2. (b) DC-link voltage of module3.

The dc-link voltages of phase b are shown in Fig. 10. 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-

ISSN: 2350-0328
International Journal of Advanced Research in Science, Engineering and Technology
Vol. 6, Special Issue , August 2019
International Conference on Recent Advances in Science, Engineering, Technology and Management at Sree Vahini Institute of Science and Technology-Tiruvuru, Krishna Dist, A.P

bridge can be controlled independently. In other words, the connected PV panel of each Hybrid Can be operated at its own MPP voltage and will not be influenced by the panels connected to other H-bridges. Thus, more solar energy can be extracted, and the efficiency of the overall PV system will be increased. Fig. 11 shows the power extracted from each phase. At the beginning, all panels are operated under irradiance

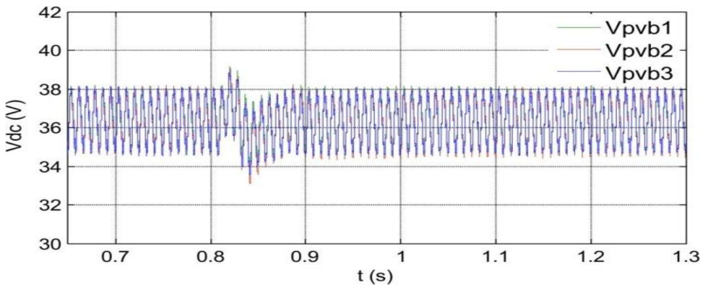


Fig. 10 DC-link voltages of phase *b* with distributed MPPT (*T* = 25 °C)

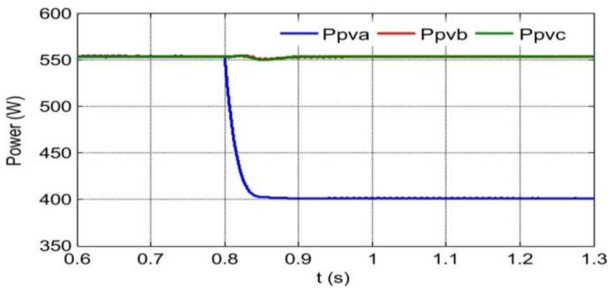


Fig. 11 Power extracted from PV panels with distributed MPPT.

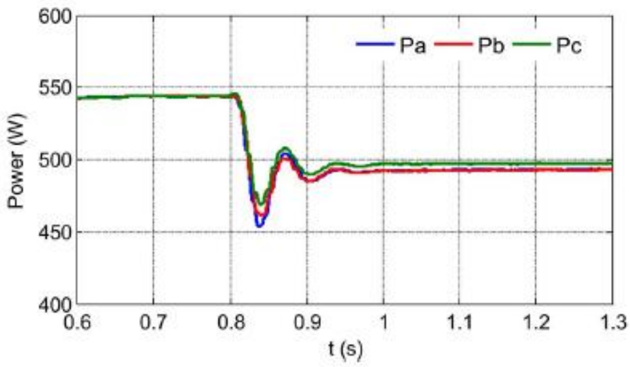


Fig. 12 Power injected to the grid with modulation compensation.

S = 1000 W/m^2, and every phase is generating a maximum power of 555 W. After t = 0.8 s, the power harvested from phase a decreases to 400 W, and those from the other two phases stay the same. Obviously, the power supplied to the three-phase grid-connected inverterisun balanced. However, by applying the modulation compensation scheme, the power injected to the grid is still balanced, as shown in Fig. 12. In addition, by comparing the total power extracted from the PV panels with the total power injected to the grid, it can be seen that there is no extra power loss caused by the modulation compensation scheme.

Fig.13shows the output voltages (v_{jN}) of the three-phase inverter. Due to the injected zero sequence component, they are unbalanced after t=0.8s, which help to balance the grid current shown in Fig.14.

ISSN: 2350-0328
International Journal of Advanced Research in Science, Engineering and Technology
Vol. 6, Special Issue , August 2019
International Conference on Recent Advances in Science, Engineering, Technology and Management at Sree Vahini Institute of Science and Technology-Tiruvuru, Krishna Dist, A.P

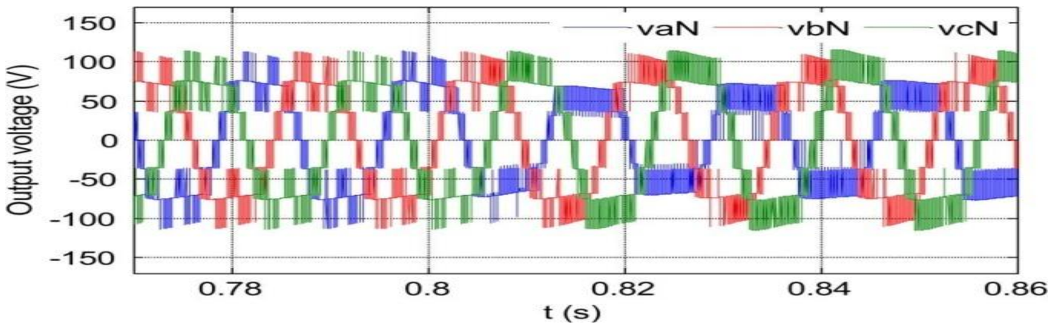
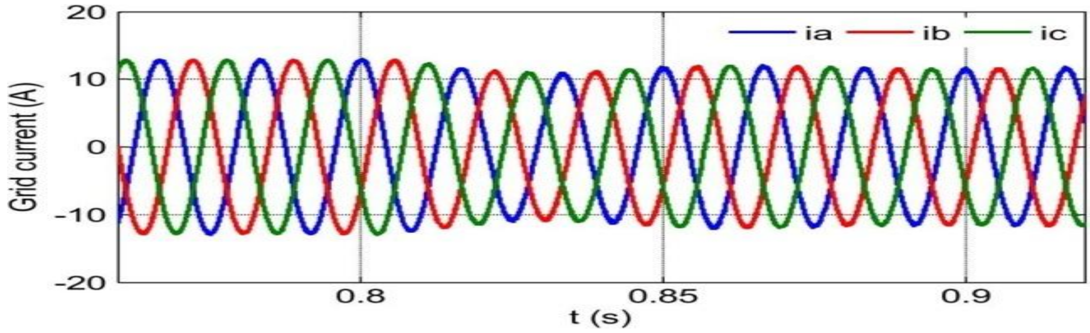


Fig**. 13 Three-phase inverter output voltage waveforms with modulation compensation**.

Fig. 14 Three-phase grid current waveforms with modulation compensation.



VI CONCLUSION

A modular cascaded H-bridge multilevel inverter was introduced in this article for grid-connected PV apps. The topology of the multilevel inverter will assist enhance the use of linked PV modules if the voltages of the distinct dc connections are separately regulated. In order to improve the general effectiveness of PV systems, a distributed MPPT control system was implemented for both single and three-phase PV systems. PV mismatches, a for the three-phase grid-connected PV system, may introduce unbalanced power supply, leading in unbalanced grid injection. To balance the grid current, a modulation compensation scheme is introduced that does not boost the complexity of the control system or cause additional energy loss. With the suggested control system, each PV module can be operated on its own MPP to maximize the extraction of solar energy, and even the unbalanced supplied solar power balances the three-phase grid current..

REFERENCES

[1] J.M.Carrasco*etal*.,"Power-electronicsystemsforthegridintegrationof renewableenergysources:Asurvey,"*IEEETrans.Ind.Electron*.,vol.53, no. 4, pp. 1002–1016, Jun.2006.

[2] B. Xiao, L. Hang, and L. M. Tolbert, "Control of three-phase cascaded voltagesourceinverterforgrid-connectedphotovoltaicsystems,"in*Proc. IEEE APEC Expo.*, Mar. 2013, pp.291–296.

[3] S. B. Kjaer, J. K. Pedersen, and F. Blaabjerg, "A review of single-phase grid connected inverters for photovoltaic modules," *IEEE Trans. Ind. Appl.*, vol. 41, no. 5, pp. 1292–1306, Sep./Oct.2005.

[4] J.M.A.MyrzikandM.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.

[5] 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.

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

[7] F. Schimpf and L. Norum, "Grid connected converters for photovoltaic, state of the art, ideas for improvement of transformerless

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, May2011.

[9] L. M. Tolbert and F. Z. Peng, "Multilevel converters as a utility interface for renewable energy systems," in *Proc. IEEE Power Eng. Soc. Summer Meet.*, 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] 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.

[12] 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.

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

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

AUTHOR'S BIOGRAPHY

G. Tejaswi was born in Machilipatnam in 1989 He was obtained the B.Tech Degree in Electrical and Electronics Engineering from DMSSVH College of Engineering in the Year 2010. He Completed M Tech in Lakireddy Balireddy college of Engineering. Currently, he has been working in Sree Vahini Institute of Science and Technology and also pursuing PH.D at Annamalai University, Chidambaram

P. Prasanth Kumar was Born 1999 in Tiruvuru. He Completed DIPLOMA in EEE at Sree Vahini Institute of Science and Technology in 2017. Currently, he Pursuing B.Tech in EEE at Sree Vahini Institute of Science and Technology, Tiruvuru.

K V S Manikanta was Born 1997 in Cheruvukommupalem. He Completed her DIPLOMA in EEE at **ABR** Engineering College of Science and Technology, Kanigiri in 2017. Currently he Pursuing B.Tech in EEE at Sree Vahini Institute of Science and Technology.

K. Kamalakar was Born 1999 in Anigandlapadu. Currently He Pursuing B Tech in EEE at Sree Vahini Institute of Science and Technology, Tiruvuru.