ISSN No: 2348-4845
International Journal & Magazine of Engineering, Technology, Management and Research
A Peer Reviewed Open Access International Journal

The New Hybrid Energy Based Modular Multilevel Inverter for Grid Interface Applications

Ragiboguda Sreevidya
M.Tech,
Department of PEED,
HITAM Engineering College.

N.Ravi
Assistant Professor,
Department of EEE,
HITAM Engineering College.

ABSTRACT:

A modular cascaded H-bridge multilevel photovoltaic (PV) inverter is proposed for single- or three-phase grid-connected applications. The PV systems efficiency and flexibility can be improved by using the modular cascaded H bridge inverter. To extract maximum power from the PV system a MPPT control is applied to both single- and three-phase multilevel inverters, which allows separate control for each dc-link voltage. PV mismatches may introduce unbalanced supplied power, leading to unbalanced grid current For three-phase grid-connected applications. To compensate this problem a modulation control is used. By using nine H-bridge modules (three modules per phase) An simulated three-phase seven-level cascaded H-bridge inverter has been built. Here we are using the fuzzy logic controller compared to other controller, because of its high accuracy performance. Each H-bridge module is connected to a 185-W solar panel. Simulation results are shown using MATLAB/SIMULINK.

Index Terms:

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

I. INTRODUCTION:

Solar-electric-energy demand has grown consistently by 20%–25% per annum over the past 20 years [1], and the growth is mostly in grid-connected applications. Because of the decreasing resources like fossil fuels and conventional energy resources and pollution problems. Therefore market demands for PV systems are gets increasing. [2]–[7]. 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 favor this topology in medium and large grid-connected PV systems. configurations of the PV system of Five inverter:

1) central inverters families;
2) string inverters;
3) multistring inverters;
4) ac-module inverters; and
5) cascaded inverters 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 with their associated converters are still connected in series to create a high dc voltage, which is provided to a simplified dc/ac inverter.

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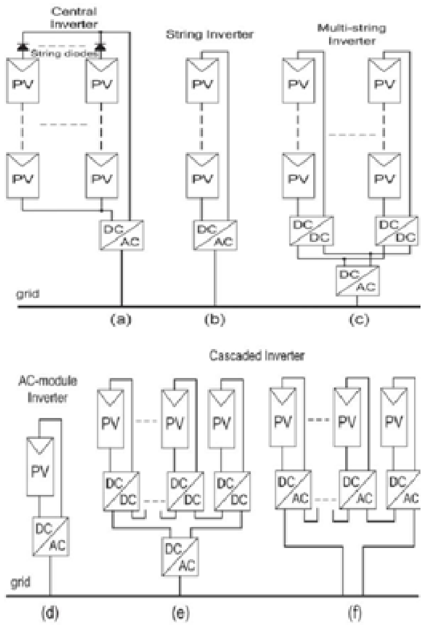

Fig. 1. Configurations of PV systems. (a) Central inverter. (b) String inverter.(c) Multi string inverter. (d) AC-module inverter. (e) Cascaded dc/dc converter. (f) Cascaded dc/ac inverter.

This approach combines aspects of string inverters and ac-module inverters and offers the benefits of individual module maximum point (MPP)tracking (MPPT), however it's less costly and more efficient than ac-module inverters. However, there are 2 power conversion stages in this configuration. Another cascaded inverter is shown in Fig. 1(f), where every PV panel is connected to its own dc/ac inverter, and those inverters are then placed serial to achieve a high-voltage level. This cascaded inverter} would

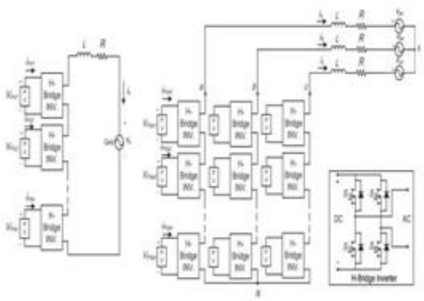

Fig. 2. Topology of the modular cascaded H-bridge multilevel inverter for grid-connected PV systems.

A cascaded structure inverter with n input sources can offer 2n + 1 levels to synthesize the ac output wave form. This (2n + 1)-level voltage wave form allows the reduction of harmonics within the synthesized current, reducing the dimensions of the required output filters. structure inverters even have other advantages such as reduced voltage stresses on the semiconductor switches and having higher efficiency when compared to alternative converter topologies.

III. PANEL MISMATCHES:

Due to the unequal received irradiance, different temperatures, and aging of the PV panels, the MPP of each PV module may be different. PV mismatch is an important issue in the PV system. The efficiency of the overall system will get decreased if the PV controlling is not done separately. Every H-bridge has its own 185-W PV panel connected as an isolated dc source.

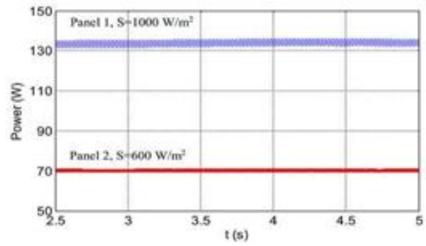

Fig. 3. Power extracted from two PV panels

The PV panel is modeled in keeping with the specification of the commercial PV panel from a robust energy CHSM-5612M. take into account an in operation condition that every panel includes a different irradiation from the sun; panel one has irradiance S =1000 W/m2, and panel two has S = 600 W/m2. If only panel one is tracked and its MPPT controller determines the typical voltage of the 2 panels, the power extracted from panel one would be 133 W, and the power from panel two would be seventy 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.

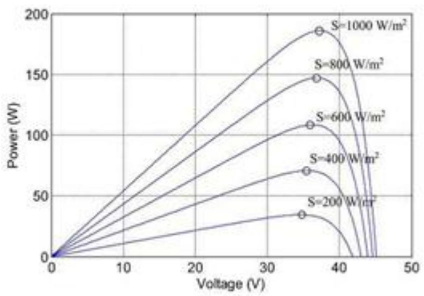

Fig. 4. *P–V* characteristic under the different irradiance

The maximum output power values will be 185 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. For example, to unbalance the current per phase more than 10% is not allowed for some utilities, where the percentage imbalance is calculated by taking the maximum deviation from the average current and dividing it by the average current To solve the PV mismatch issue, a control scheme with individual MPPT control and modulation compensation is proposed

IV. CONTROL SCHEME

A. Distributed MPPT Control:

To increase the efficiency and to eliminate the mismatching effect this control scheme is proposed. The separate dc links in the cascaded H-bridge multilevel inverter make independent voltage control possible. To realize individual MPPT control in each PV module, the control scheme proposed in [19] is updated for this application. The distributed MPPT control of the three-phase cascaded H-bridge inverter is shown in Fig. 5.

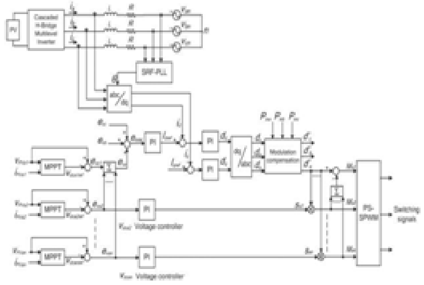

Fig. 5. Control scheme for three-phase modular cascaded H-bridge multilevel PV inverter.

In each H-bridge module, an MPPT controller is added to generate the dc-link voltage reference. 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 Idref. The reactive current reference Iqref can be set to zero, or if reactive power compensation is required, Iqref can also be given by a reactive current calculator [20], [21]. The synchronous reference frame phase-locked loop (PLL) has been used to find the phase angle of the grid voltage [22]. As the classic control scheme in three-phase systems, the grid currents in abc coordinates are converted to dq coordinates and regulated through fuzzy controllers to generate the modulation index in the dq coordinates, which is then converted back to three phases.

The distributed MPPT control scheme for the single-phase system is nearly the same. The total voltage controller gives the magnitude of the active current reference, and a PLL provides the frequency and phase angle of the active current reference. The current loop then gives the modulation index. To make each PV module operate at its own MPP, take phase a as an example; the voltages v d c a2 to v d c a n are controlled individually through n − 1 loops. Each voltage controller gives the modulation index proportion of one H-bridge module in phase a.

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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 fuzzy 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 devices of each H-bridge. It can be seen that there is one H-bridge module out of *N* modules whose modulation index is obtained by subtraction.

For single-phase systems, $N = n$, and for three-phase systems, $N = 3n$, 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 $N - 1$ voltage loops, and one modulation index has to be obtained by subtraction. Many MPPT methods have been developed and implemented [23], [24]. 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.

B. Modulation Compensation:

As mentioned earlier, a PV mismatch may cause more problems to a three-phase modular cascaded H-bridge multilevel PV inverter. 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 can be imposed upon the phase legs in order to affect the current flowing into each phase [25], [26]. If the updated inverter output phase voltage is proportional to the unbalanced power, the current will be balanced. 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 how to update the modulation index of each phase without increasing the

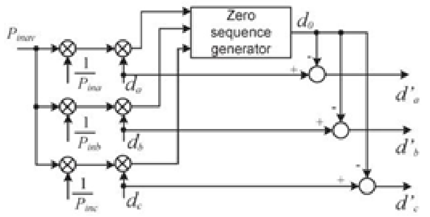

Fig. 6. Modulation compensation scheme.

Complexity of the control system. First, the unbalanced power is weighted by ratio *r j*, which is calculated as

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

where *Pinj* is the input power of phase *j* ($j = a, b, c$), and *Pinav* is the average input power. Then, the injected zero sequence modulation index can be generated as

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

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

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

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 = 0.8 P = 1 P = 1 (4)

By injecting a zero sequence modulation index at $t = 1$ s, the balanced modulation index will be updated, as shown in Fig. 7.

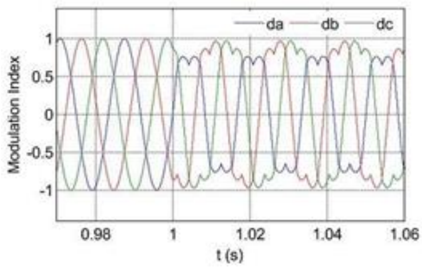

Fig. 7. Modulation indices before and after modulation compensation.

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It can be seen that, with the compensation, the updated modulation index is unbalanced proportional to the power, which means that the output voltage ($v\ j\ N$) of the three-phase inverter is unbalanced, but this produces the desired balanced grid current.

V. SIMULATION RESULTS:

A three-phase seven-level cascaded H-bridge inverter is simulated and tested. Each H-bridge has its own 185-W PV panel (Astronergy CHSM-5612M) connected as an independent source. The inverter is connected to the grid through a transformer, and the phase voltage of the secondary side is 60 Vrms. The system parameters are shown in Table II.

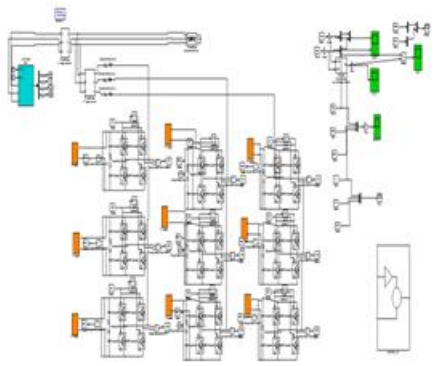

Fig.8. simulation model for proposed method

TABLE II: 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

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 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. 8. At the beginning, all PV panels are operated at an MPP voltage of 36.4 V. As the irradiance changes, the first and second dc

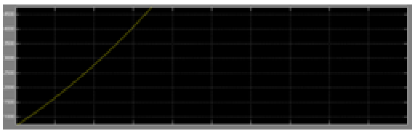

Fig. 9. DC-link voltages.

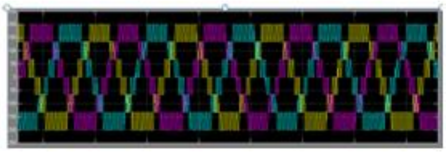

Fig. 10. Three-phase inverter output voltage waveforms with modulation compensation.

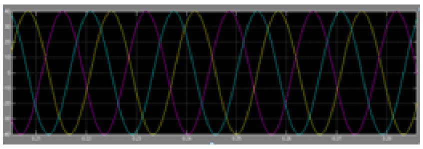

Fig. 11. Three-phase grid current waveforms with modulation compensation.

VI. CONCLUSION:

A modular cascaded H-bridge multilevel photovoltaic (PV) inverter is proposed for single-or three-phase grid-connected applications. Here by using MPPT and modular cascaded H bridge inverter we extracted the maximum power and overall efficiency is increased respectively For the three-phase grid-connected PV system. and the three-phase grid current is balanced even with the unbalanced supplied solar power. PV mismatches may induce the unbalances in the power supply resulting in unbalanced injected grid current.

A modulation compensation scheme, is suggested to balance the grid currents which will not increase the complexity and power loss of the system. Here we are using the fuzzy controller compared to other controllers. With the proposed control scheme, each PV module can be operated at its own MPP to maximize the solar energy extraction.

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International Journal & Magazine of Engineering, Technology, Management and Research
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Author Details:

Ragiboguda Sreevidya, Received B.Tech degree from Narsimha Reddy engineering college, Maisammaguda, Medchal mandal, Ranga Reddy, Telangana in 2014. And currently pursuing M.Tech in Power electronics & electrical drives at Hyderabad institute of technology and management, Gowdavelly, Medchal mandal, R.R.district, Telangana. Her area of interest in Power Electronics field.

Mr.N.Ravi Obtained his B.Tech(EEE) degree from AGCET, JNTUH in 2008, M.Tech (Power Electronics) from ASRCET, JNTUK in 2013. He has been working as Asst.Prof. in dept. of EEE at HITAM Hyderabad since 2010. His area of interest includes power electronics & electrical circuits. He is having 8 years of teaching experience.