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Compatible cascaded HMO-bridge multilevel PV inverter with assigned MPPT for grid-connected applications

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Abstract

This paper presents a modular cascaded H-bridge multilevel photovoltaic (PV) inverter for single- or three-phase grid-connected applications. The modular cascaded multilevel topology helps to improve the efficiency and flexibility of PV systems. To realize better utilization of PV modules and maximize the solar energy extraction, 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.

Index Terms—Cascaded multilevel inverter, distributed maxi-mum power point (MPP) tracking (MPPT), modular, modulation compensation, photovoltaic (PV).

I. INTRODUCTION

DUE to the shortage of fossil fuels and environmental problems caused by conventional power generation, renewable energy, particularly solar energy, has become very popular. Solar-electric-energy demand has grown consistently by 20%–25% per annum over the past 20 years , and the growth is mostly in grid-connected applications. With the extraordinary market growth in grid-connected photovoltaic (PV) systems, there are increasing interests in grid-connected PV configurations. Five inverter families can be defined, which are related to different configurations of the PV system: 1) central inverters; 2) string inverters; 3) multistring inverters; 4) ac-module inverters; and 5) cascaded inverters.The configurations of PVsystems 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 [8]–[10].There are two types of cascaded inverters. Fig. 1(e) shows a cascaded dc/dc converter connection of PV modules [11], [12]. 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. This approach combines aspects of string inverters and ac-module inverters and offers the advantages of individual module maximum power point (MPP) tracking (MPPT), but it is less costly and more efficient than ac-module inverters. However, there are two power conversion stages in this configuration. 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 [13]–[16]. 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.

A modular cascaded H-bridge multilevel inverter topology for single- or three-phase grid-connected PV systems is pre-sented 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, modula-tion compensation is also added to the control system.

SYSTEM DESCRIPTION

Modular cascaded H-bridge multilevel inverters for single-and three-phase grid-connected PV systems are shown in Fig. 2.

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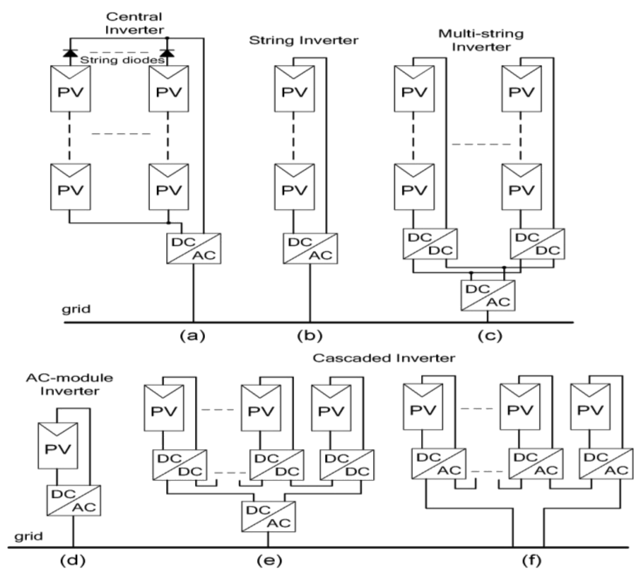

Each phase consists of n H-bridge converters connected in series, and the dc link of each H-bridge can be fed by a PV panel or a short string of PV panels. The cascaded multilevel inverter is connected to the grid through L filters, which are used to reduce the switching harmonics in the current.

By different combinations of the four switches in each H-bridge module, three output voltage levels can be generated: $-v_{dc}$, 0, or $+v_{dc}$. A cascaded multilevel inverter with n 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 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

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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 modeled 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/m^2, and panel 2 has S = 600 W/m^2. 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 be 185 and 108.5 W when the S values are 1000 and 600 W/m^2, 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.

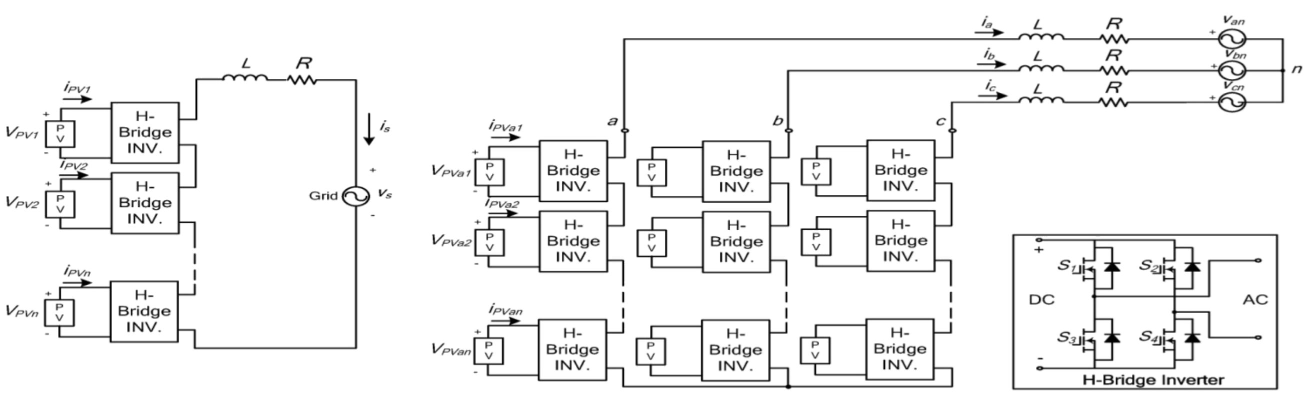

Fig. 2.Topology of the modular cascaded H-bridge multilevel inverter for grid-connected PV systems.

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IV. CONTROL SCHEME

A. Distributed MPPT Control

In order to eliminate the adverse effect of the mismatches and 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. 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. 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 I_{dref} . 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 [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 proportional–integral (PI) 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_{dca2} to v_{dcan} are con-trolled individually through $n - 1$ loops. Each voltage con-troller gives the modulation index proportion of one H-bridge module in phase a. After multiplied by the modulation in-dex 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

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difference is that all dc-link voltages are regulated through PI controllers, and *n* modulation index proportions are obtained for each phase.

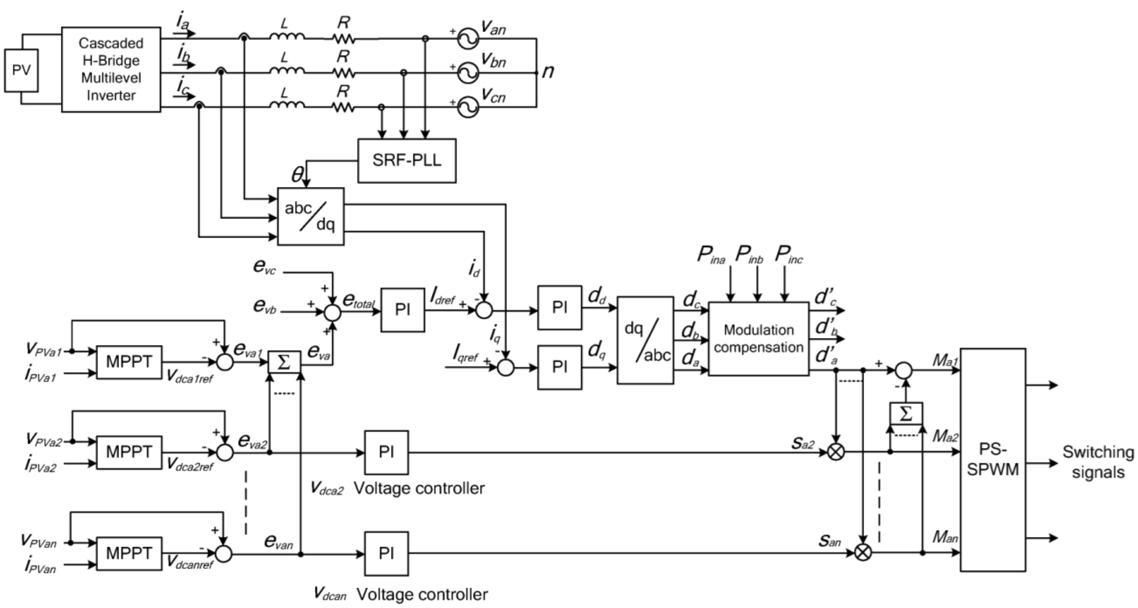

Fig. 5. Control scheme for three-phase modular cascaded H-bridge multilevel PV inverter.

A phase-shifted sinusoidal pulse width modulation switching scheme is then applied to control the switching devices of each H-bridge.

B. Modulation Compensation

As mentioned earlier, a PV mismatch may cause more problems to a three-phase modular cascaded H-bridge multi-level 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.

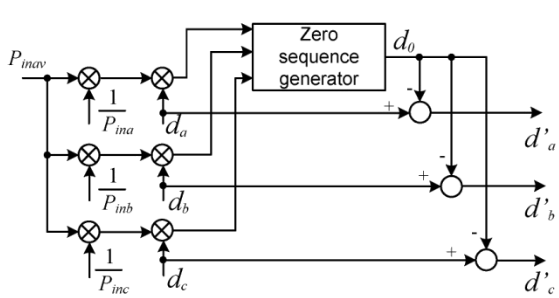

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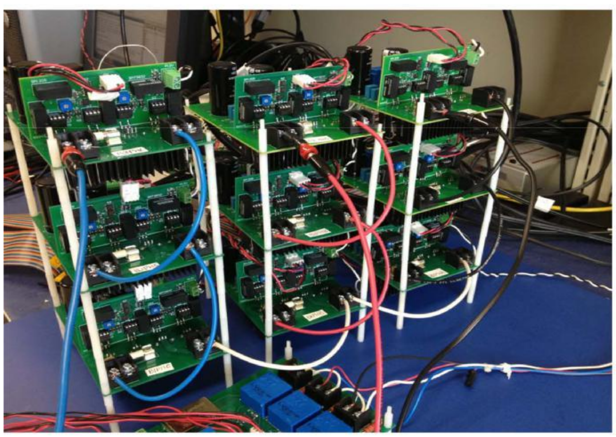
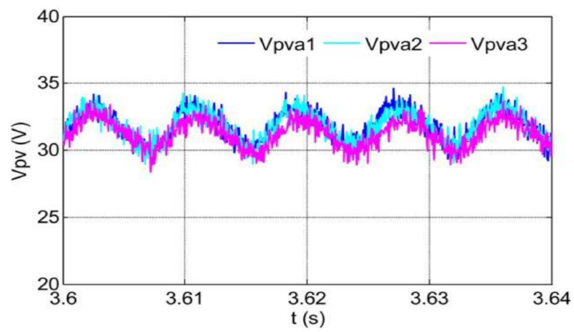
Fig. 6.Modulation compensation scheme


(a)


(b)



VI. CONCLUSION

In this paper, a modular cascaded H-bridge multilevel in-verter for grid-connected PV applications has been presented. The multilevel inverter topology will help to improve the uti-lization of connected PV modules if the voltages of the separate dc links are controlled independently. Thus, a distributed MPPT control scheme for both single- and three-phase PV systems has been applied to increase the overall efficiency of PV systems. 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, is added to balance the grid current.

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

[3] 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.

[4] 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.

[5] 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.

[6] 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.

[7] 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.

[8] 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.

[9] 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.

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