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Asynchronous Motor Based Modular Cascaded H-Bridge Multi Level Pv Inverter For Industrial Applications

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Abstract-This paper presents a seven-level photovoltaic (PV) inverter topology for three phase induction motor with a sinusoidal pulse width modulation (SPWM) control scheme and MPPT. Thus reducing the complexity of the system, these MPPT algorithmic methods which are based on the use of Incremental Conductance (IC) algorithms have been proposed with the PV panel to determine an optimum operating current for the maximum output power. Multilevel inverter as compared to single phase inverter has advantages like minimum harmonic distortion and can operate on several voltage level inverters. A key component in this paper is the DC to AC seven level multilevel inverter. The inverters are categorized according to the configuration of the PV system, the configuration of the conversion stages within the inverter and whether they use transformers. 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. This paper proposed a three phase seven level inverter with voltage control method using semiconductor power devices for three phase induction motor in order to achieve a smooth, continuous and low total harmonics distortion (THD) waveforms. The simulation results are performed by using Matlab/Simulink software.

Index Terms—cascaded multilevel inverter, distributed maximum power point (MPP) tracking (MPPT), modular, modulation Compensation.

I. INTRODUCTION

Power inverter is an important part of many DC to AC conversion equipment's such as uninterrupted power supply (UPS), induction motor drive and automatic voltage regulator (AVR) systems. In these systems, it is the major requirement for the power inverter to be capable of producing and maintaining a stable and clean sinusoidal output voltage waveform regardless of the type of load connected to it. The main key to successfully maintain this ability is to have a feedback controller [1-3].

Photovoltaic (PV) source is one of the significant players in the world's energy portfolio, and it will make one of the biggest contributions to electricity generation among all the renewable energy candidates by 2040, because it is clean, emission-free, and renewable electrical generation source with the high reliability. The output voltage of PV arrays is relatively low [4]. In order to satisfy the high bus voltage requirements for the full-bridge, half-bridge, or multilevel grid inverter. A solar inverter can be fed into a commercial electrical grid or used by an off-grid electrical network. The special functions of solar inverters are adapted for use with photovoltaic arrays, maximum power point tracking (MPPT) and anti-islanding protection.

The modular cascaded H-bridge multilevel inverter, which requires 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 [5]. 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 [6]. A modular cascaded H-bridge multilevel inverter topology for single- or three-phase grid-connected PV systems is 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 [7-9].

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.

Improved Incremental Conductance method of Maximum Power Point Tracking control for photovoltaic power systems in [10]. He explained about the Incremental Conductance method. Maximum photovoltaic power tracking an algorithm for rapidly changing atmospheric conditions explained in [11]. Evaluation of maximum power point tracking methods for grid connected photovoltaic systems discussed in [12]. In the maximum power point tracking method so many methods are available but he used the suitable tracker.

The proposed three phase seven level inverter is very suitable to PV module with induction motor load, because of compare to common three phase multi-level inverter have high switching, but it could also unfortunately increase switching losses, acoustic noise, and level of interference to other equipment. Improving its output waveform reduces its harmonic content and, hence, also the size of the filter used and the level of electromagnetic interference (EMI) generated by the inverter’s switching operation [13-15].

II. SYSTEM DESCRIPTION

Modular cascaded H-bridge multilevel inverters for single and three-phase grid-connected PV systems are shown in Fig.1. 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 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 Astronergy 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. Without individual MPPT control, the total power harvested from the PV system is 203 W.

However, 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/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.

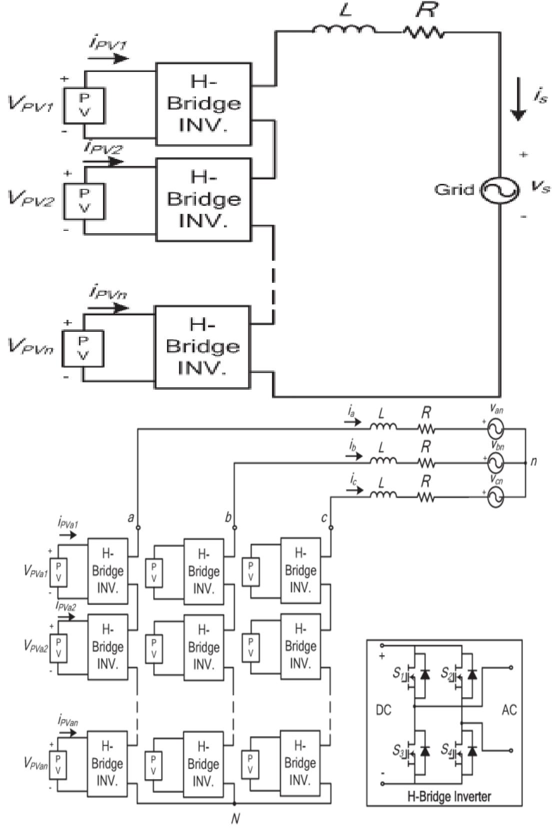


Fig. 1. Topology of the modular cascaded H-bridge multilevel inverter for grid-connected PV systems.

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.

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 is updated for this application.

The distributed MPPT control of the three-phase cascaded H-bridge inverter is shown in Fig.2. 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. 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 d_q coordinates and regulated through proportional–integral (PI) controllers to generate the modulation index in the d_q 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 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.

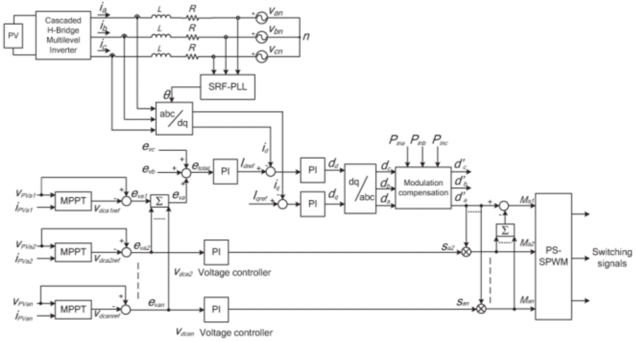


Fig.2. Control scheme for three-phase modular cascaded H-bridge multilevel PV inverter.

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

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. 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. 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. 3, 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 complexity of the control system. First, the unbalanced power is weighted by ratio rj, which is calculated as

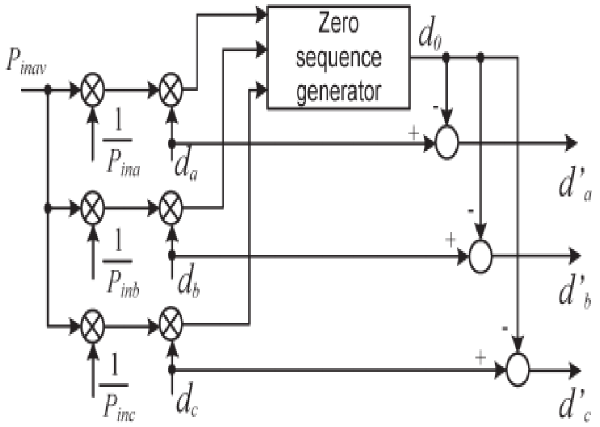


Fig. 3. Modulation compensation scheme.

$$r_j = \frac{P_{\text{inav}}}{P_{\text{inj}}} \tag{1}$$

Where $P_{\text{inj}}$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

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

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

The modulation index of each phase is updated by

$$d'_j = d_j - d_0. \tag{3}$$

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

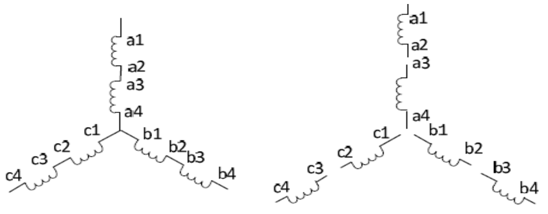
$$P_{\text{ina}} = 0.8 \qquad P_{\text{inb}} = 1 \qquad P_{\text{inc}} = 1 \tag{4}$$

V. INDUCTION MOTOR

In a conventional four pole induction motor, there are two sets of identical voltage profile windings will be present in the total phase winding. These two windings are connected in series as shown in fig. 4(a). For the proposed inverter these two identical voltage profile winding coils are disconnected, and the available four terminals are taken out, like shown in the fig.4 (b). Since these two windings are separated equally, stator resistance, Stator leakage inductance and the magnetizing inductance of each identical voltage profile windings are equal to the half of the normal induction motor shown in fig.4 (a).The voltage equitation for the stator winding is given by common dc link.

$$V_{a1} - V_{a2} = \left(\frac{r_s}{2}\right) * i_{as} + \left(\frac{L_{ss}}{2}\right) * i_{as} - \left(\frac{1}{2}\right) * \left(\frac{L_m}{2}\right) * i_{bs} - \left(\frac{1}{2}\right) * \left(\frac{L_m}{2}\right) * i_{cs} \tag{5}$$

$$V_{a3} - V_{a4} = \left(\frac{r_s}{2}\right) * i_{as} + \left(\frac{L_{ss}}{2}\right) * i_{as} - \left(\frac{1}{2}\right) * \left(\frac{L_m}{2}\right) * i_{bs} - \left(\frac{1}{2}\right) * \left(\frac{L_m}{2}\right) * i_{cs} \tag{6}$$



(a) (b)

Fig. 4 Induction Motor Stator Winding (A) General Arrangement (B) Arrangement for the Proposed Inverter.

The effective voltage across the stator winding is the sum of the voltages across the two individual windings.

$$V_{as} = \left(V_{a1} - V_{a2}\right) + \left(V_{a3} - V_{a4}\right) \tag{7}$$

The motor phase voltage can be achieved by substituting equations (5) and (6) in (7)

$$V_{as} = r_s * i_{as} + L_{ss} * i_{as} - \left(\frac{1}{2}\right) * L_m * i_{bs} - \left(\frac{1}{2}\right) * L_m * i_{cs} \tag{8}$$

Similarly voltage equitation for the remaining phases are

$$V_{bs} = r_s * i_{bs} + L_{ss} * i_{bs} - \left(\frac{1}{2}\right) * L_m * i_{as} - \left(\frac{1}{2}\right) * L_m * i_{cs} \tag{9}$$

$$V_{cs} = r_s * i_{cs} + L_{ss} * i_{cs} - \left(\frac{1}{2}\right) * L_m * i_{as} - \left(\frac{1}{2}\right) * L_m * i_{bs} \tag{10}$$

Voltage equations in dq0 frame can be solved from the basic equations of induction motor

$$V_{qs} = r_s * i_{qs} + \omega * \lambda_{ds} + \rho * \lambda_{qs}$$

$$V_{ds} = r_s * i_{ds} - \omega * \lambda_{qs} + \rho * \lambda_{ds}$$

$$V_{0s} = r_s * i_{0s} + \rho * \lambda_{0s}$$

$$V_{qr} = r_r * i_{qr} + (\omega - \omega_r) * \lambda_{dr} + \rho * \lambda_{qr}$$

$$V_{dr} = r_r * i_{dr} - (\omega - \omega_r) * \lambda_{qr} + \rho * \lambda_{dr}$$

$$V_{0r} = r_r * i_{0r} + \rho * \lambda_{0r}$$

Flux linkages are as follows

$$\lambda_{qs} = L_{ss} * i_{qs} + L_M * i_{qr}$$

$$\lambda_{ds} = L_{ss} * i_{ds} + L_M * i_{dr}$$

$$\lambda_{0s} = L_{1s} * i_{0s}$$

$$\lambda_{qr} = L_{rr} * i_{qr} + L_M * i_{qs}$$

$$\lambda_{dr} = L_{rr} * i_{dr} + L_M * i_{ds}$$

$$\lambda_{0r} = L_{1r} * i_{0r}$$

The expression for the electromagnetic torque in terms of dq0 axis currents is

$$T_e = \left(\frac{3}{2}\right) * \left(\frac{P}{2}\right) * L_M * \left(i_{qs} * i_{dr} + i_{ds} * i_{qr}\right) \tag{11}$$

Rotor speed in terms of Torque is

$$\frac{d}{dt}\omega_e = \left(\frac{P}{2 * J}\right) * (T_e - T_L) \tag{12}$$

VI. MATLAB/SIMULATION RESULTS

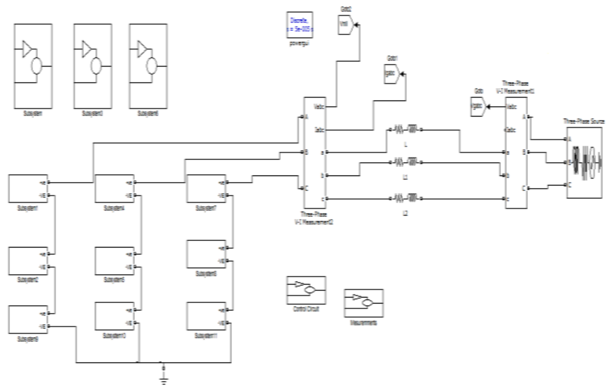
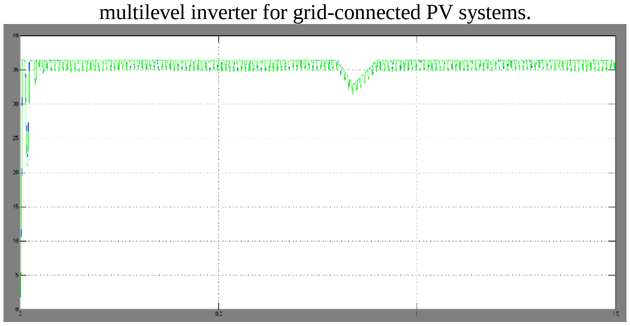
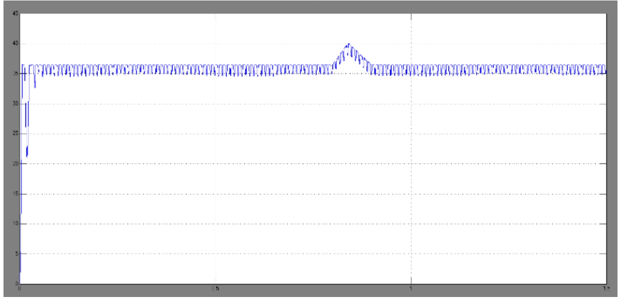


Fig.5.Matlab/Simulation model of the modular cascaded H-bridge multilevel inverter for grid-connected PV systems.



(a)



(b)

Fig. 6. 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.

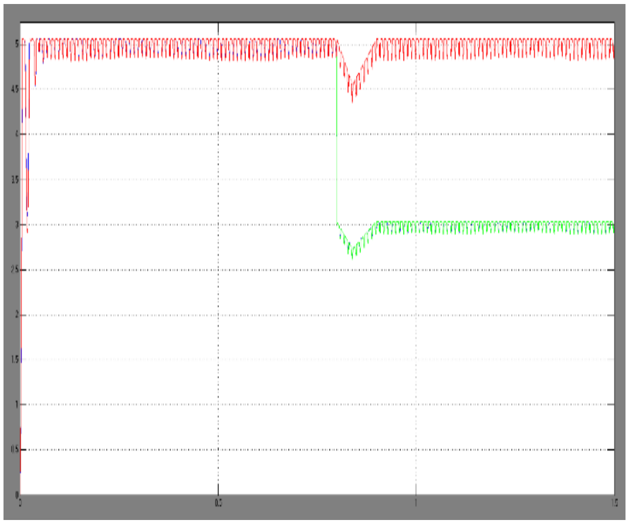


Fig.7. PV currents of phase a with distributed MPPT (T = 25 ◦C).

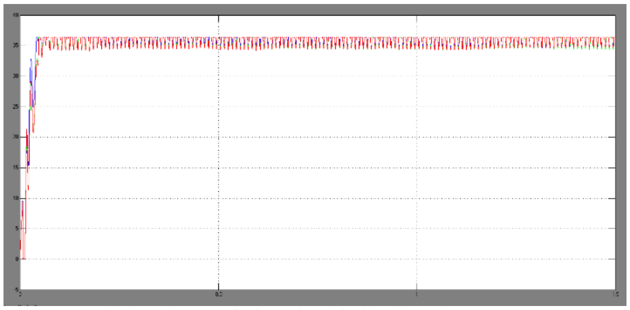


Fig.8. DC-link voltages of phase b with distributed MPPT (T = 25 ◦C).

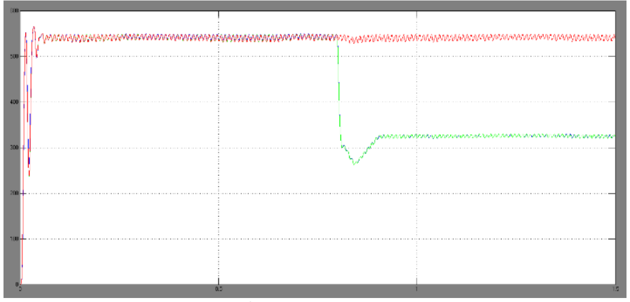


Fig.9. Power extracted from PV panels with distributed MPPT.

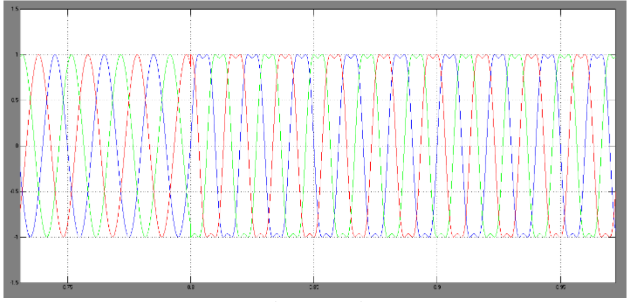


Fig.10. Modulation indices before and after modulation compensation.

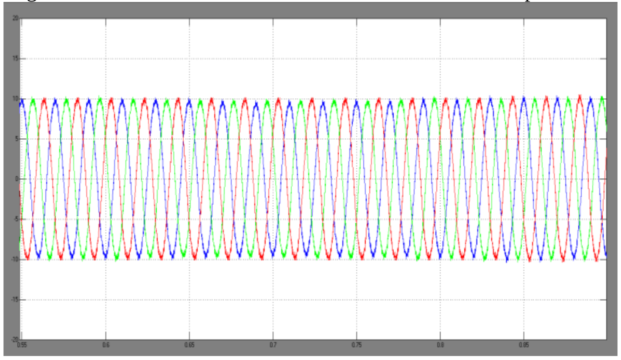


Fig. 11. Three-phase grid current waveforms with modulation compensation.

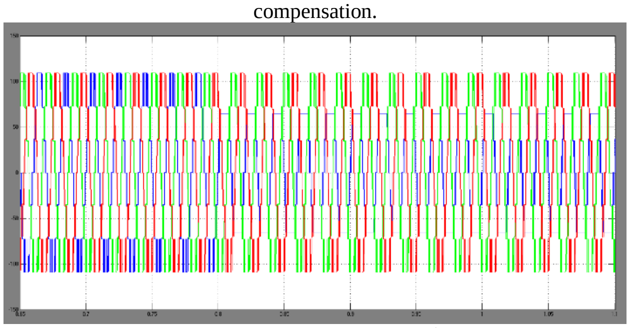


Fig. 12. Three-phase inverter output voltage waveforms with modulation compensation.

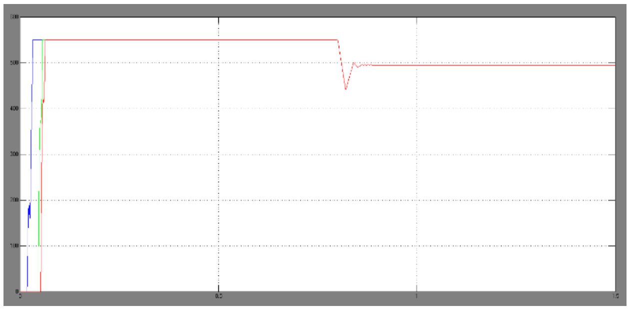


Fig.13. Power injected to the grid with modulation compensation.

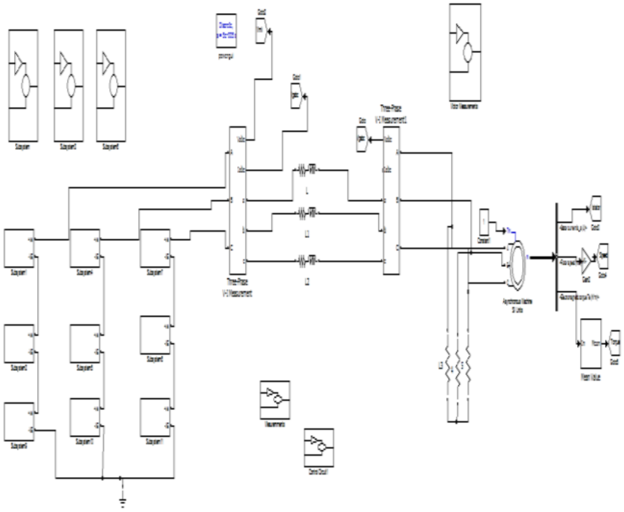


Fig.14. MATLAB/Simulation model of modular cascaded distributed system asynchronous motor for industrial applications

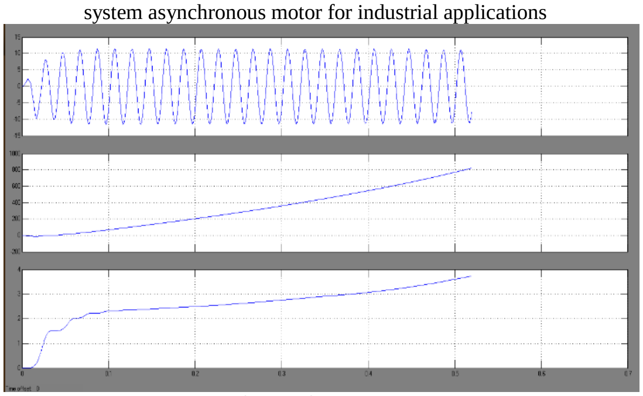


Fig.15.Simulation waveforms of Stator current, speed and torque.

VII. CONCLUSION

The multilevel inverter topology will help to improve the utilization 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. This paper discussed the possibilities of MMC being used as an interface between the three phase induction motor and PV panels, and proposed an improved multilevel inverter based on the sinusoidal PWM. This method can produce seven level output in MMC Simulation results were carried out under the conditions of load and the effectiveness of the method was proved well. Multilevel inverters offer improved output waveforms and lower THD. In this topology less THD in the seven-level inverter compared with that in the five-level inverters is connected PV inverters. This inverter provided to induction motor with smooth output and better voltage.

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 singlephase 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 transformer less 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, pp. 2703–2712, Jul. 2008.

[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] 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.

[14] 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.

[15] B. Xiao, L. Hang, and L. M. Tolbert, “Control of three-phase cascadedvoltage source inverter for grid-connected photovoltaic systems,” in Proc. IEEE APEC Expo., Mar. 2013, pp. 291–296.