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PV Based Cascaded SVPWM Multilevel Converter Fed Induction Drive

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Abstract: The multilevel converter is a seven-level active neutral-point-clamped (ANPC)-based and is a cascaded connection of a three-level ANPC converter and an H-bridge per phase. Depending on the switching states of converter the voltage level is maintained. The converter is operated under space vector pulse width modulation (SVPWM) to reduce the total harmonic distortion.

Keywords: active neural point clamped, multilevel inverter, PV panel, space vector pulse width modulation (SVPWM).

I. INTRODUCTION

The multi level inverter was introduced as a solution for the reduction of harmonics in the output waveform without increasing the switching frequency or decreasing the power output. The proposed multilevel converter is a cascaded connection of a three level ANPC converter and an H bridge per phase fed by photovoltaic panel.

The increase in the number of levels complicates the voltage balancing of capacitor and neutral point voltages [2],[3]. The multilevel SHE-PWM used in the seven level converter to eliminate lower order harmonics and can be used only for the low power applications [1].The hybrid cascaded converter with H-bridge cells have been proposed to eliminate the need for individual dc sources for every converter stage and extend the number of levels [5],[9]. A topology based on the cascaded interconnection of a two-level inverter with individual H-bridge cells for each phase is used with selective harmonic elimination PWM(SHE-PWM) offers the potential for improved waveform quality compared to other existing modulation techniques but their total harmonic distortion (THD) is more. The modulation techniques mostly used are the sinusoidal pulse width modulation, selective harmonic elimination and space vector technique.

The multilevel SHE-PWM used in the seven level converter to eliminate lower order harmonics and can be used only for the low power applications. Hence in the proposed system, the space vector technique is used to reduce harmonic contents in the output load current and voltage waveforms. SVPWM also improves the total harmonic distortion (THD).

Also the active switches provide redundancies in the zero-voltage level switching states that can be selected through the appropriate modulation process. Hence they are used in wide industrial applications [4] such as motor drives, advanced static compensators, HVdc transmission , and grid-connected photovoltaic systems.

With increase in population, the demand of energy increases. Alternative energy generation techniques are also increasing. Renewable energy technologies are clean sources of energy that have a much lower environmental impact than conventional energy technologies.

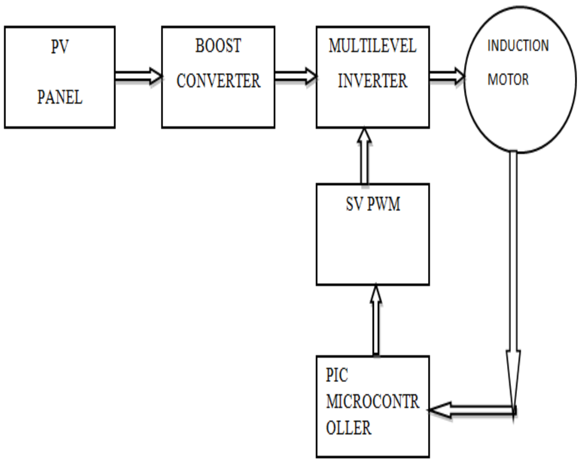

Fig 1 Block diagram of proposed system

The proposed switching strategy generates a voltage vector with very low harmonic distortion and reduced switching frequency. This new control method is an attractive alternative to the classic multilevel pulse width modulation techniques [6]-[16] considering the following aspects, mainly, minimization of voltage and current total harmonic distortion (THD), extension of range of linear operation; and least number of commutations. To solve the problem of computational complexity in multilevel inverters due to the large number of space vectors and redundant switching states, a simple and general space vector PWM algorithm is proposed. Based on this

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algorithm, the location of the reference voltage vector can be easily determined and the calculation of dwell times becomes very simple. To verify the algorithms, a seven-level cascaded H-bridge inverter drive system was constructed and simulation results are presentedThe block diagram of the proposed circuit is shown in fig.1, which shows the inverter feeding the IM controlled by space vector PWM.

MPPT technique is followed for maximum energy tracking from the sun. The boost converter improves the voltage gain of the energy obtained from the panel. The DC input is converted into AC output using the proposed multilevel converter which is controlled using SVPWM technique to feed an induction motor drive.

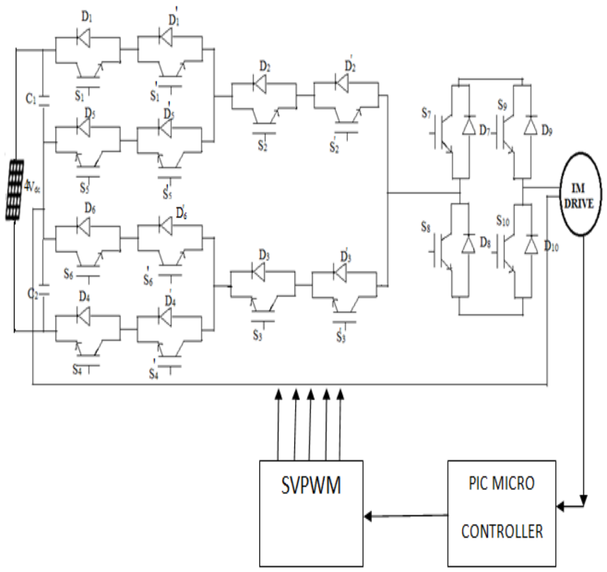

Fig.2 multilevel inverter

Fig. 2. shows an input dc link voltage of . The flying capacitors and DC link capacitors are designed with values of micro farads. The multilevel converter based on the cascaded interconnection of a 3L-ANPC converter and individual H-bridges for each phase. the output of the inverter is given as an input to the asynchronous machine. The value of the inverter current and voltages are measured. The performance of the motor such as speed, torque and the rotor currents are noted. Also the inverter is controlled using the space vector technique.

The operational principles of the sevenlevel multiltilevel inverter is explained in section II.

II. OPERATING PRINCIPLE

For real power conversions from ac to dc and then dc to ac, the cascaded inverters need separate dc sources. The structure of separate dc sources is well suited for various renewable energy sources such as fuel cell, photovoltaic, and biomass.

Connecting dc sources between two converters in aback to back fashion is not possible because a short circuit can be introduced when two back to back converters are not switching synchronously.

TABLE I
SWITCHING STATES OF MULTILEVEL CONVERTER

	S_1	S_2	S_3	S_4	S_5	S_6	S_7	S_8	S_9	S_{10}	V_o
V_1	1	1	0	0	0	1	0	1	1	0	$3V_{dC}$
V_2							1	0	1	0	$2V_{dC}$
V_3							0	1	0	1	$2V_{dC}$
V_4							1	0	0	1	V_{dC}
V_5	0	1	1	1	1	0	0	1	1	0	V_{dC}
V_6							1	0	1	0	0
V_7							0	1	0	1	0
V_8							1	0	0	1	$-V_{dC}$
V_9	1	0	1	0	0	1	0	1	1	0	V_{dC}
V_{10}							1	0	1	0	0
V_{11}							0	1	0	1	0
V_{12}							1	0	0	1	$-V_{dC}$
V_{13}	0	1	0	1	1	0	0	1	1	0	V_{dC}
V_{14}							1	0	1	0	0
V_{15}							0	1	0	1	0
V_{16}							1	0	0	1	$-V_{dC}$
V_{17}	0	0	1	1	0	1	0	1	1	0	V_{dC}
V_{18}							1	0	1	0	0
V_{19}							0	1	0	1	0
V_{20}							1	0	0	1	$-V_{dC}$
V_{21}	0	0	1	1	1	0	0	1	1	0	$-V_{dC}$
V_{22}							1	0	1	0	$-2V_{dC}$
V_{23}							0	1	0	1	$-2V_{dC}$
V_{24}							1	0	0	1	$-3V_{dC}$

The switching states generates voltage levels of 3 V_{dC} , $2V_{dC}$ $V_{dC,0,-}$ $V_{dC,}$ - $2V_{dC}$ and 3 V_{dC}. the switching states are genereated by the 3L- ANPC converter and the H bridge.

III. SVPWM

The spaced vector PWM is an alternative to multilevel PWM as it minimizes the total harmonic distortions in both current and voltage waveforms with least number of commutations. To solve the complexity simple generalized spacevector algorithms are used.

A. *Principle of spacevector*

To implement space vector modulation a reference signal V_{ref} is sampled with a frequency f_s ($T_s = 1/f_s$). The reference signal may be generated from three separate phase references using the $\alpha\beta\gamma$ transform. The reference vector is then synthesized using a combination of the two

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adjacent active switching vectors and one or both of the zero vectors. Various strategies of selecting the order of the vectors and which zero vector(s) to use exist. Strategy selection will affect the harmonic content and the switching losses.

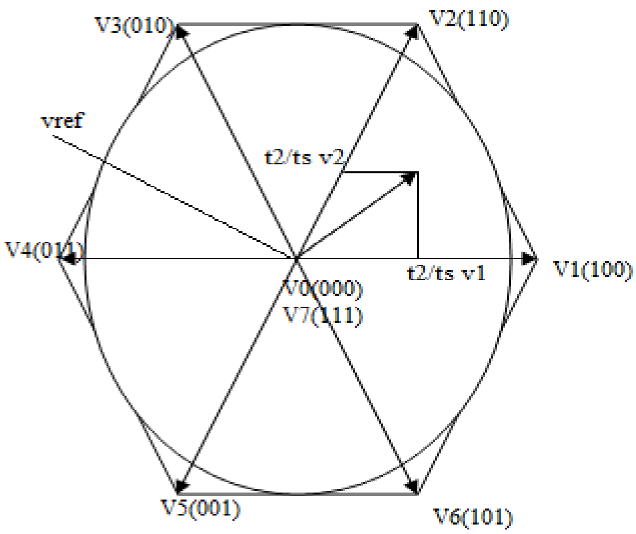

Fig. 4 switching vectors

For a three phase inverter as the switches must be controlled so that at no time are both switches in the same leg turned on or else the DC supply would be shorted.

TABLE II
SWITCHING STATES OF THREE PHASE INVERTER

VECTOR	SWITHING STATE	
V0	000	Zero vector
V1	100	Active vector
V2	110	Active vector
V3	010	Active vector
V4	011	Active vector
V5	001	Active vector
V6	101	Active vector
V7	111	Zero vector

This requirement may be met by the complementary operation of the switches within a leg. This leads to eight possible switching vectors for the inverter, V_0 through V_7 with six active switching vectors and two zero vectors.

All possible switching vectors for a three-leg inverter using space vector modulation is shown in the above table. An example V_{ref} is shown in the first sector. V_{ref_MAX} is the maximum amplitude of V_{ref} before non-linear overmodulation is reached.

B. SVPWM for seven level inverter

Space vector algorithm can be used for all the 3, 5 and seven level vectors.

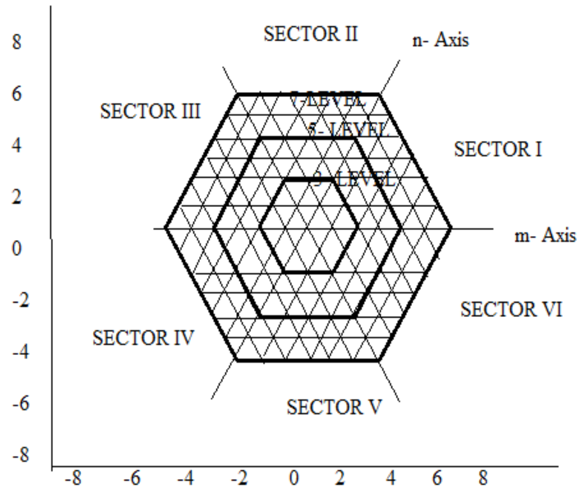

Fig.5 space vector for 7- level converter

All possible switching vectors for the 7 level converter is shown in fig.5. the multilevel inverter needs separate dc source for each bridge. For which the corresponding spacevectors are used and the seven level convertor consists of 216 triangles and vertex of each triangle representing the space vectors. The hexagon vectors can be grouped into six major triangular sectors (I to VI). Only the first sector co-ordinates are used because the vectors located in other sector can be transformed ito first sector by clockwise rotating by an angle of $k*(\pi/3)$, where k=1,2,3,4,5 for sectors 2 to 5. All sectors are identical and their reference axis V_{ref} . for a M+1 inverter the reference axis is divided into m and n axis of V_{rrn} and V_{rn} respectively.

$$V_{rm}= 2*M*V_{ref}/ 3V_{dc} \sin (\pi/3- \theta) \quad (1)$$
$$V_{rm}=2*M*V_{ref} / 3V_{dc} \sin(\theta) \quad (2)$$

Where θ is the rotating reference vector.
The proposed algorithm considers over-modulation case also. It is easy to judge whether SVPWM is in over modulation region or not, simply by checking the following inequality:
if (Vrm + Vrn) > M, it becomes over-modulation.

IV. PV PANEL AND PO ALGORITHM

A Solar panel is a set of solar photovoltaic modules electrically connected and mounted on a supporting structure. A photovoltaic module is a packaged, connected assembly of solar cells. A Solar Cell is a device that converts light into electric current using the photoelectric-effect. The photovoltaic panel is connected with six boost converters. The boost converter helps to improve the voltage gain of the energy observed by the pv panel.

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The output from the panel is unregulated and so boost converters are used to regulate the dc output. The switches used involves switching losses thereby decreasing the efficiency. The control voltage V_c is compared with the desired voltage. The boost converter helps in improving the voltage gain of the output obtained from the panel.

The maximum power can be tracked from the sun. for this purpose various maximum power point tracking methods are used. In recent years large numbers of technicques have been used for maximum power tracking (MPPT) from the sun. Here the perturb and observe (P&O) algorithm of simple feedback and measured parameters have been used. It operates by perturbing (i.e. incrementing or decrementing) the solar array voltage and comparing the PV power output with that of the previous turbation cycle. the proposed system uses the perturb and observe (P&O) methods for maximum tracking. Thus the peak power tracker continuously seeks the maximum power condition.

In this manner the maximum power tracked is fed to the induction motor using the proposed multilevel inverter. The boost converter connected with the MPPT system helps to improve the voltage gain obtained from the panel. The DC input is converted into AC output using the proposed multilevel converter which is controlled using SVPWM technique to feed an induction motor drive.

V. INDUCTION DRIVE

The ac power inverted by the multilevel inverter is fed to an induction drive. An induction or asynchronous motor is an AC electric motor in which the electric current in the rotor needed to produce torque is induced by electromagnetic induction from the magnetic field of the stator winding. An induction motor therefore does not require mechanical commutation, separate-excitation or self-excitation for all or part of the energy transferred from stator to rotor, as in universal, DC and large synchronous motors. An induction motor's rotor can be either wound type or squirrel-cage type.

In induction, the AC power supplied to the motor's stator creates a magnetic field that rotates in time with the AC oscillations. The rotating magnetic flux induces currents in the windings of the rotor; in a manner similar to currents induced in a transformer's secondary windings. The currents in the rotor windings in turn create magnetic fields in the rotor that react against the stator field. Due to Lenz's Law, the direction of the magnetic field created will be such as to oppose the change in current through the rotor windings. The cause of induced current in the rotor windings is the rotating stator magnetic field, so to oppose the change in rotor-winding currents the rotor will start to rotate in the direction of the rotating stator magnetic field. The rotor accelerates until the magnitude of induced rotor current and torque balances the applied load. Since rotation at synchronous speed would result in no induced rotor current, an induction motor always operates slower than synchronous speed. Under load, the speed drops and the slip increases enough to create sufficient torque to turn the load. An induction motor can be used as an induction generator, or it can be unrolled to form a linear induction motor which can directly generate linear motion.

VI. SIMULATION RESULTS

The MATLAB is used for simulating the multilevel converter under SVPWM. Simulink (Simulation and Link) is an extension of MATLAB by Math works Inc. It works with MATLAB to offer modeling, simulating, and analyzing of dynamical systems under a graphical user interface (GUI) environment. The DC source is provided by the photovoltaic panel has an output of 150V. The flying capacitors and DC link capacitors are designed with values1000 and 3300 micro farads respectively. The multilevel converter based on the cascaded interconnection of a 3L-ANPC converter and individual H-bridges for each phase and the output of the inverter is around 200V and is given as an input to the asynchronous machine. The value of the inverter current and voltages are measured. The performance of the motor such as speed, torque and the rotor currents are noted.

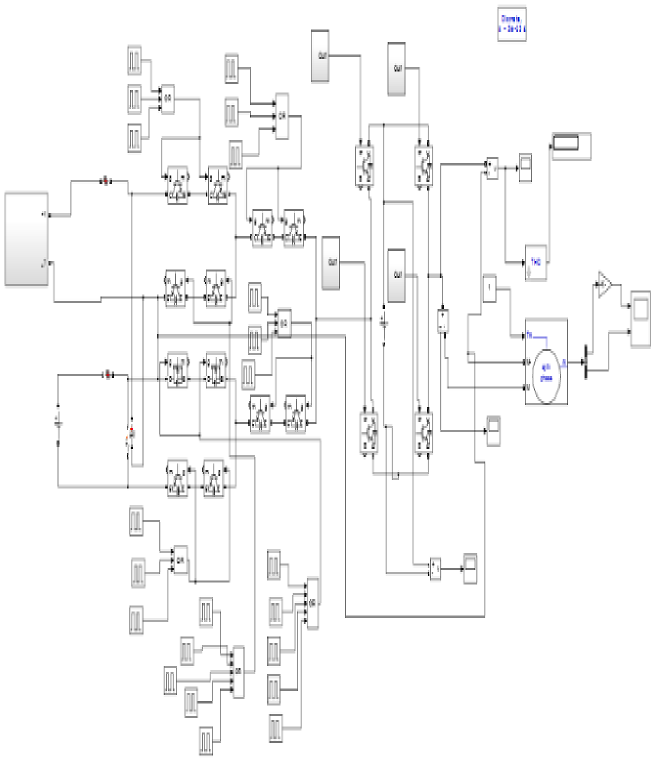

Fig. 5 simulation diagram

The fig.5 represents the simulated circuit of the proposed converter with a Dc input from PV panel, feeding an induction drive.

The output voltage and current waveform of the multilevel inverter feeding IM drive is shown in fig.6 and fig.7 respectively. The speed and torque characteristics of the induction drive connected is shown in fig.8.

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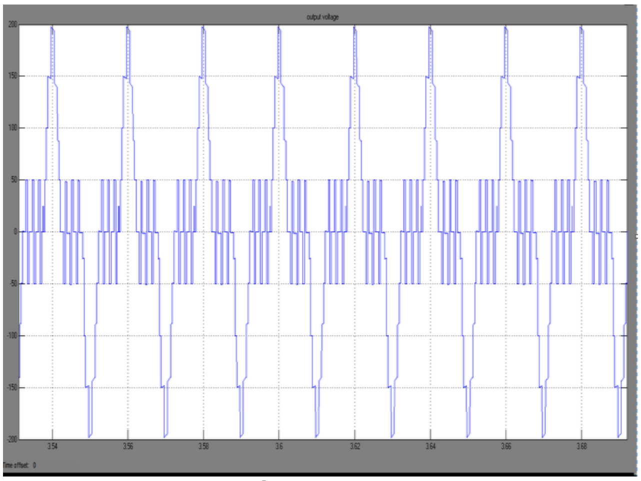

Fig. 6 output voltage

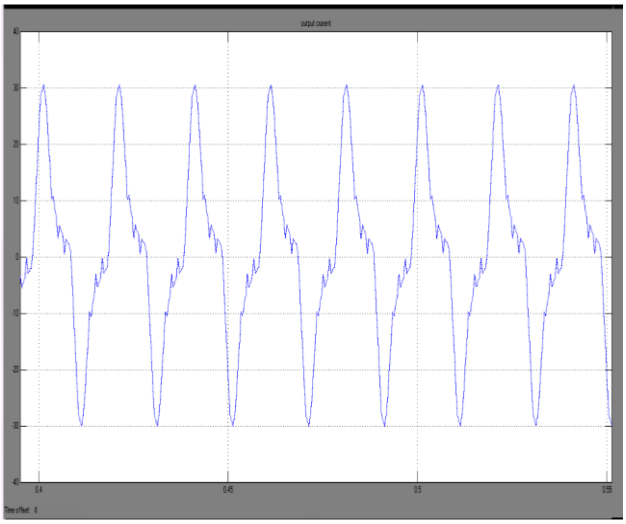

Fig.7 output current

The harmonic spectrum is shown in fig.9. The simulation results shows improvement in THD value.

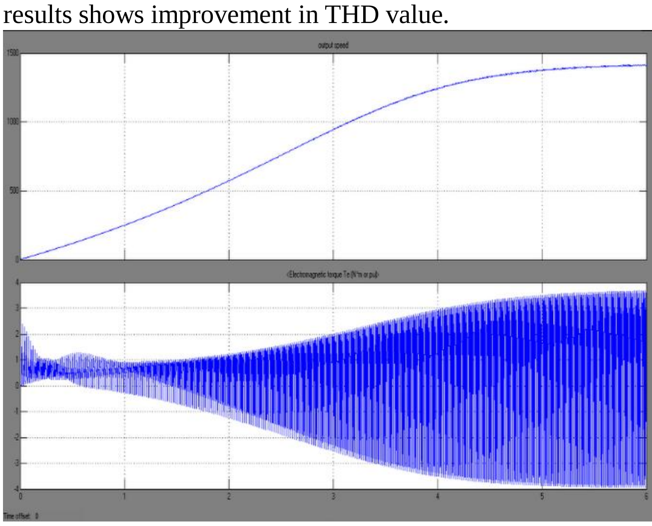

Fig. 8 speed and torque characteristics

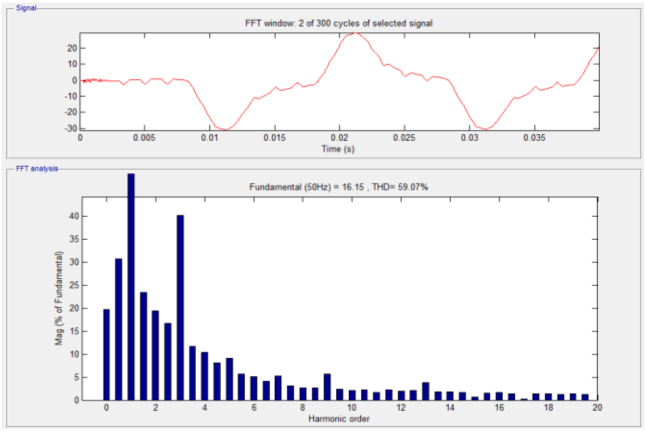

Fig.9 harmonic spectrum

V. CONCLUSION

Thus the space vector technique method has been studied. This method has the advantage of improving the total harmonic distortion over other PWM methods. Also this technique features easy implementation and more importantly, minimum harmonic content in the inverter output voltage and current of the Induction Motor Load.

The simulation of the multilevel converter circuits is completed. The seven level inverter uses the cascaded interconnection of a 3L-ANPC converter and individual H-bridges for each phase with SVPWM is proposed. The simulation with multilevel converter with induction motor has been done and the output is verified.

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