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Design Simulation of Multilevel Neutral Point Clamped Inverter System for Solar Photovoltaic Applications

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Abstract- This paper presents design and simulation of Neutral Point Clamped multi-level inverter system connected to a solar photovoltaic system. The design of multilevel inverter is based on neutral point clamped topology. The improved space vector pulse width modulation enables better performance and output of the system in both qualitative as well as quantitative factor. The system is connected to solar photovoltaic system and the output is realized in the form of voltage and current from the output of inverter. In the present research the system is analyzed for high power application of the solar photovoltaic system. Simulation is done on MATLAB Simulink platform. The output obtained have shown promising and efficient result after the application of proposed topology.

Keywords: Multi level inverter, solar photovoltaic system, MPPT, Neutral Point Clamped, THD.

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I. INTRODUCTION

Sustainable power source has been picking up significance in the logical field of examination. PV systems can be seen as a promising option in contrast to the worldwide interest of power [1]. Power created from PV systems are generally provided to a grid system through a transformer, which prompts an expansion in by and large size and cost, and diminishing in the proficiency of the system. So as to conquer this issue, the utilization of transformer-less inverter have been considered. The decision of geography utilized relies upon boundaries like Total Harmonic Distortion (THD), diminished basic mode voltage, spillage current misfortune and voltage stress. Multilevel inverters [9] have been attracting interest the ongoing past because of their great harmonic dismissal limit, and capacity to deal with high voltages [2]. The proposed system utilizes diode-clamped inverter innovation that gives decreased dv/dt weights on exchanging, capacity to control receptive power stream and expanded effectiveness of yield because of more noteworthy decrease of regular mode voltages [3]. The wellspring of the inverter is gotten from a PV system whose vitality proficiency is upgraded by tracking the maximum power point. PV exhibits are commonly known to be non-direct in nature and convey maximum power at a specific working point. This point is followed by utilizing a Perturb and Observe (P and O) Maximum Power Point Tracker (MPPT) strategy [4]. Space Vector Modulation has been picking up prominence because of its exhibition at low modulation proportion as contrasted with the standard Pulse Width Modulation (PWM) procedures [5], and effortlessness in equipment and programming usage. A Space Vector Voltage Control (SVVC) is examined so as to utilize hexagonal hysteresis territories. This is an adjustment of the disentangled space vector PWM procedure [6].

II. PV ARRAY AND MPPT ALGORITHM

The PV Array includes any number of PV modules, additionally called as sun powered cells. These cells include p-n intersection semiconductors that create DC current on introduction to light. The measure of sunlight based irradiance gotten will decide the yield power of the grid [7]. The strategy selected in the proposed system is the Annoy and Observe (P&O) strategy. In the P&O technique, the ‘dP/Dv’ estimation of the system is constantly followed. This worth when more noteworthy than zero (positive) is supposed to be on the left side, and keeping in mind that it is not exactly zero (negative), it is accepted to arranged towards the right. At the point when the worth is certain, that is more noteworthy than zero, it is realized that irritation is causing the array’s working point development towards the MPP. The P&O calculation will give the annoyance access a similar heading when the worth is sure, and when the worth of ‘dP/dV’ is negative; the working point development is away from MPP. Subsequently, the P&O calculation will turn around the annoyance heading. [8]. The principle preferred position of P&O calculation is its simple implementation

,[10] low interest for counts and its adaptability in the application part. [11 and 12].PV arrays can be work with the assistance of arrangement and equal mix of sun based cells, which can be essentially spoken to by the electrical comparable circuit model, for example, one given in the following figure(1),

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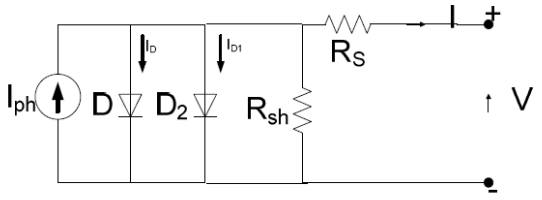

Fig. 1 Electrical Equivalent circuit of a PV cell

Accordingly PV board yield is subject to sun powered insolation and temperature. A two diode model has been given in MATLAB in 'SIMSCAPE' library and results or normal for sun powered cell have been acquired by reproduction under various light and temperature. The conduct of sun based module can likewise check by the trial arrangement given in fig.2.

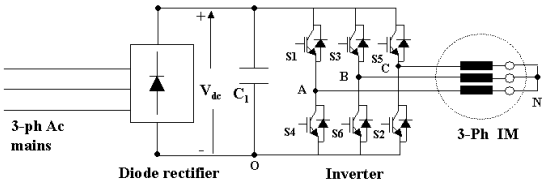

Fig. 2 Connection Diagram of Multi Level Inverter with Induction Motor Drive

III. HYSTERESIS SPACE VECTOR MODULATION

Space Vector Modulation Pulse Width Modulation (SVPWM) is in effect progressively received as the favored modulation record for inverters by virtue of its higher voltage sizes, productivity and lower changing misfortunes when contrasted with other modulation procedures.

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Execution of SVM passes by the accompanying calculation:

(a)Location of segment in which the vector lies in the d-q space;

(b)Determination of exchanging vectors nearby the triangulated position,

(c) Duty cycle estimation of exchanging vectors; Switching design count and application.

Fig.3 shows the portrayal of the exchanging states in the d-q vector space. The vector space is isolated into three unmistakable territories spoke to by the three distinct hues in it. The qualification in territories is with the end goal that the deepest hexagon comprises of the 3 zero vectors, the center part comprises of 12 little vectors and the external partition contains 6 medium and 6 huge vectors, making 27 vectors taking all things together, each speaking to an exchanging state.

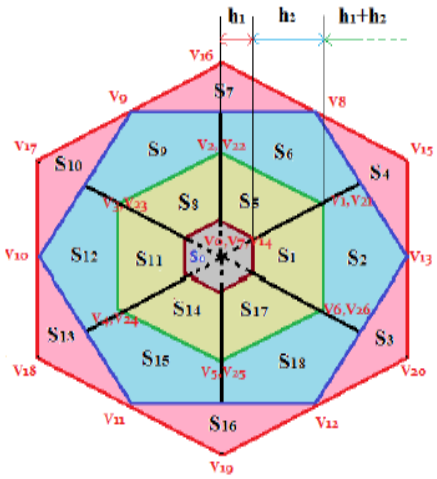

Fig.3 Hexagonal Couture Containing all possible switching state combination

The displaying of PV panel has been finished by utilizing two diode model and one test system has been utilized for the investigation of and IV (Current versus Voltage) and PV (Power versus Voltage) trademark under different ecological condition. An analysis has been directed with the assistance of sunlight based test system planned and created .The characteristics of solar photovoltaic system largely depends on temperature and irradiations.

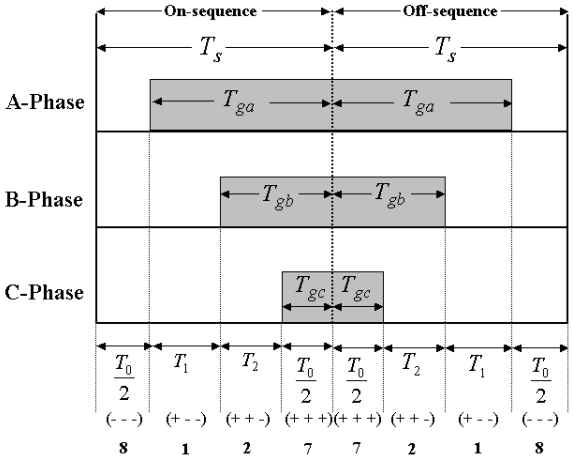

Fig. 4 Gating pulses for the A, B and C phases

By the assistance of sun based test system distinctive attribute of sun powered cell can get like IV trademark and PV trademark for various insolation's, for various working temperature. The determination of sunlight based cell utilized in sun oriented test system is given in table I

Table-1 (Specifications of PV System)

Standard test Condition insolation 1000W/m^2 at 25°C

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V_{OC}	600mV
I_{SC}	400Ma
Solar Cell area	$16cm^2$

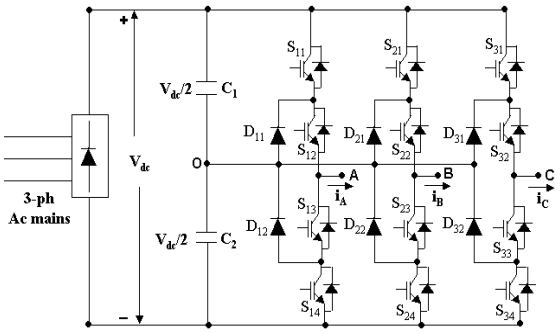

Fig.5 Circuit Diagram of NPC-MLI

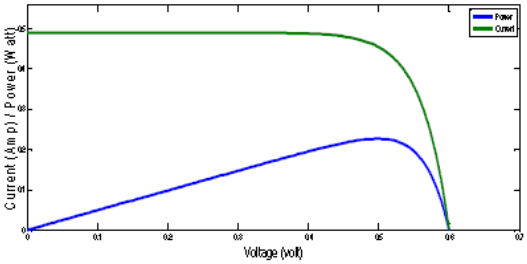

Fig. 6 IV and PV characteristics

Fig. 7 shows the characteristics of Solar Cell with Different Insolation at 25°C

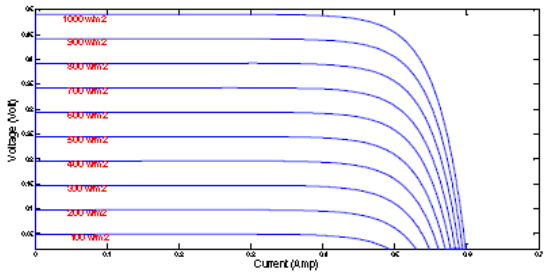

Fig 7 I-V characteristics of a solar cell

Fig 8 shows PV characteristics of a solar cell with different insolation at 25°C

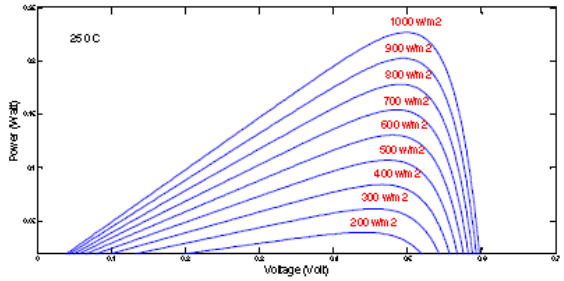

Fig 8 P-V Characteristics of a solar cell

Fig 9 shows IV characteristics of Solar cell with $1000W/m^2$ at temperature equals to 0°C, 30°C and 60°C

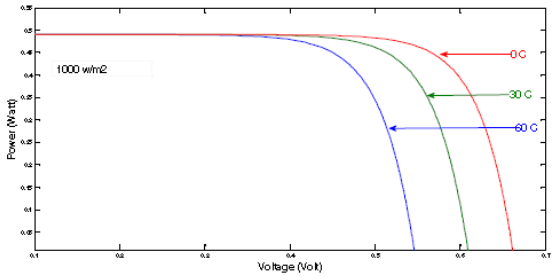

Fig- 9 IV characteristics of a solar cell at different temperature

Fig 10 shows PV characteristics of solar cell with $1000W/m^2$ at temperature equals to 0°C, 30°C and 60°C and constant solar insolation i:e $1000W/m^2$

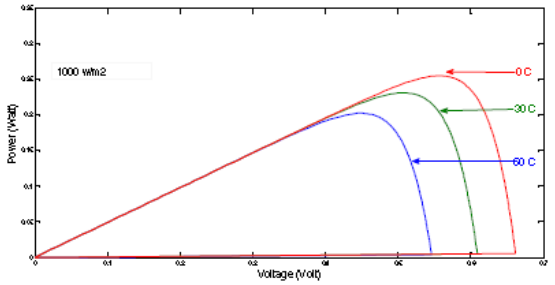

Fig 10 P-V characteristics of Solar cell at different temperature

The voltage of the cell decreases as the temperature increments proportionally and. cut off will be diminishing logarithmically. As from the IV Characteristic, sunlight based cell can be demonstrated as Current source in light of the fact that around 70-80% of its trademark is like that of current wellspring of DC type. Thus for the AC load the yield of the cell (or panel) ought to be transformed that should be possible by either traditional two level inverter or by multilevel inverter. Here in this paper DC to AC conversion is done by Nutral point clamped multilevel inverter.The relationship

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between (v_α, v_β) and the instantaneous phase voltages (v_{AN}, v_{BN}, v_{CN}) is given by the conventional ABC-αβ transformation namely:

$$\begin{bmatrix} v_\alpha \\ v_\beta \end{bmatrix} = \begin{bmatrix} \frac{3}{2} & 0 & 0 \\ 0 & \frac{\sqrt{3}}{2} & -\frac{\sqrt{3}}{2} \end{bmatrix} \begin{bmatrix} v_a \\ v_b \\ v_c \end{bmatrix} \quad (1.1)$$

Each pole in a two-level inverter can independently assume two values namely 0 and V_{dc} as mentioned earlier. Therefore, the total number of states a two-level inverter can assume is 8 (i.e. 2^3). These states are graphically illustrated in Fig.1.6a through Fig.1.6h. In these diagrams, the symbols '+' and '-' respectively indicate that the top switch and the bottom switch in a given phase leg are turned on. In any given phase leg, the top switch and the bottom switch are turned on complimentarily. The following example illustrates the method of determination of the space vector location for a given state. When the inverter assumes a state of '2' (+ + -)

$$v_{AO} = V_{dc} \quad ; \quad v_{BO} = V_{dc} \quad ; \quad v_{CO} = 0 \quad (1.2)$$

Hence the space vector for this state is given by from eqn.1.1,

$$\mathbf{V_s} = (V_{dc}) + (V_{dc}).\exp[j(2\pi/3)] + (0).\exp[j(4\pi/3)] = V_{dc}\left(\frac{1}{2} + j\frac{\sqrt{3}}{2}\right) = V_{dc}\angle 60^0 \quad (1.3)$$

The following example illustrates the method of determination of the space vector location for a given state. When the inverter assumes a state of '2' (+ + -)

$$v_{AO} = V_{dc} \quad ; \quad v_{BO} = V_{dc} \quad ; \quad v_{CO} = 0 \quad (1.4)$$

Hence the space vector for this state is given by from eqn.1.1,

$$\mathbf{V_s} = (V_{dc}) + (V_{dc}).\exp[j(2\pi/3)] + (0).\exp[j(4\pi/3)] = V_{dc}\left(\frac{1}{2} + j\frac{\sqrt{3}}{2}\right) = V_{dc}\angle 60^0 \quad (1.5)$$

The space vector locations for the rest of the states may similarly be evaluated.

IV. SIMULATION AND RESULTS

The improved space vector pulse width modulation enables better performance and output of the system in both qualitative as well as quantitative factor. The system is connected to solar photovoltaic system and the output is realized in the form of voltage and current from the output of inverter. In the present research the system is analyzed for high power application of the solar photovoltaic system. Simulation is done on MATLAB Simulink platform. The output obtained have shown promising and efficient result after the application of proposed topology.. The exchanging beats are determined comparing to the decided exchanging states. The IGBTs in the inverters are activated utilizing these heartbeats and the shut circle proceeds to work for resulting patterns of activity as long as the source is provided to the inverter.

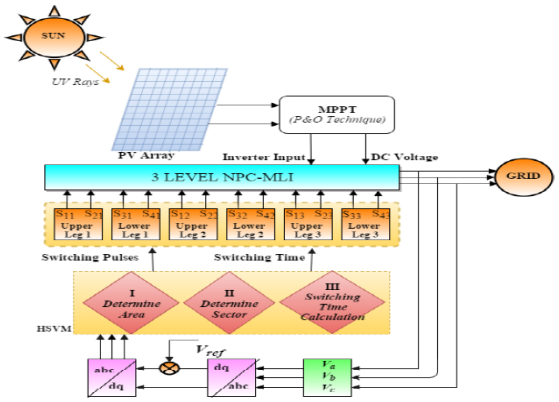

Fig 11 controlled strategy for proposed system

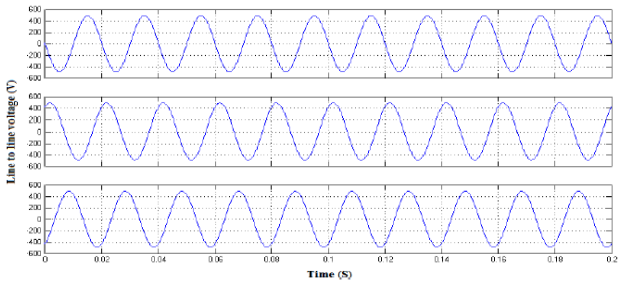

Fig 12 NPC-MLI output voltage with grid connected system

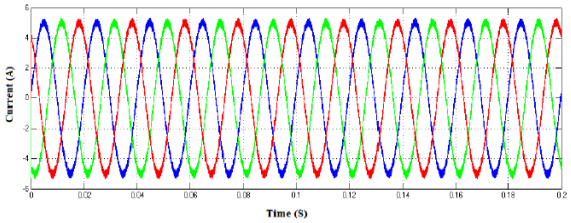

Fig 13 NPC-MLI output current with grid connected system

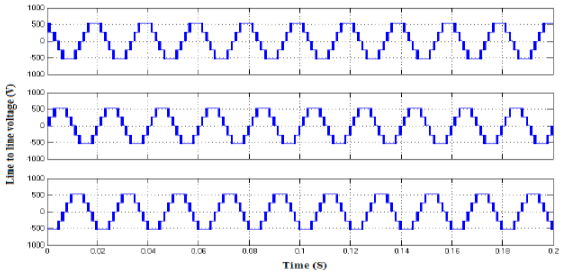

Fig 14 3-Level NPC-MLI Output Voltage

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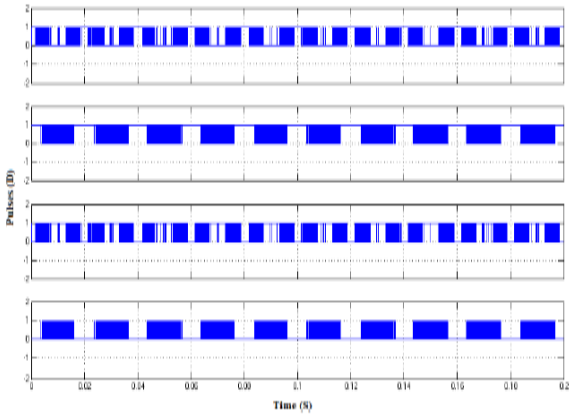

Fig 15 Switching pulses for leg A of NPC-MLI

Figures 12 and 13 show the output voltage and current of the NPC-MLI connected to the grid. Output The voltage of the three-phase MLI is shown in Figure 8. The switching pulse of NPC-MLI's leg A pin is at Figure 15.

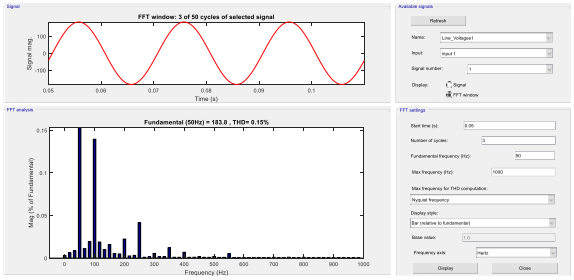

Fig 16 THD for output Voltage of NPC-MLI

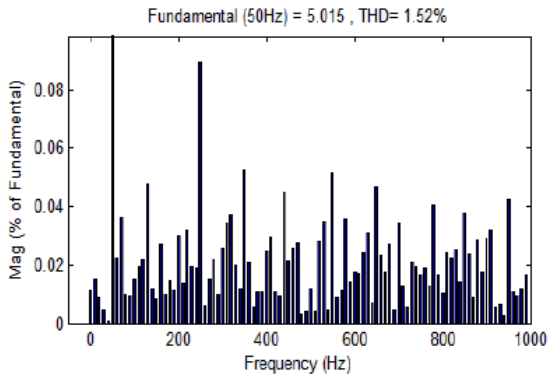

Fig 17 THD for output current of NPC-MLI

The Total Harmonic Distortion factor was evaluated for yield voltage and current for the NPC-MLI, which was seen as 0.15 % in the event of voltage and 1.52% if there should be an occurrence of current at an essential recurrence of 50Hz, as appeared in fig.16 and 17.

V. CONCLUSION

Renewable energy is a promising energy source among the existing energy resources, solar photovoltaic power generation. The reason why it is most popular is that it has obvious advantages over other methods type of renewable energy. PV system has modeled in Matlab and got the result. Photovoltaic panels have been connected to Neutral point clamped multi-level inverter. As the number of levels increases the number of switches has also increased. It has reduced harmonics, reduce switching losses, reduced total harmonic distortion (THD), reduced size and cost. The system was simulated for high power applications of photovoltaic system.

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