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PERFORMANCE ENHANCEMENT OF MULTILEVEL INVERTER IN PV SYSTEM WITH NEW TOPOLOGY

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Abstract*- The purpose of this paper is to propose a cascaded H Bridge (CHB) inverter with reduced DC source for PV applications since each PV panel can act as a separate DC source for each cascade H bridge module. The main disadvantages of the cascade multilevel inverters is a need of an isolated dc voltage sources for each H-bridge, due to this reason size of the inverter and cost increases, by virtue of which reliability of the system reduces. This Disadvantage of inverter is the key motivation for the present work .In this paper Cascaded Multilevel inverter for photovoltaic generating system is presented with reduced dc source to show the benefits of cascade the PV system. The performance of the cascaded multilevel inverter with fundamental switching scheme for different levels is studied through simulation using PSCAD 4.2. A Mathematical model for Photo Voltaic system is developed and implemented with the multilevel inverter. The overall system performance is studied for different solar intensities and temperature. A prototype PV system with 5-level inverter is implemented in PSCAD 4.2.*

Index Terms*- Multilevel converter topologies, photovoltaic (PV) systems, renewable energy, pulse width-modulated (PWM) inverter.*

I. INTRODUCTION

In present scenario peoples are more and more concerned with the fossil fuel exhaustion and the environmental problems caused by the conventional power generation, renewable energy sources such as solar energy, wind power, hydro, and other renewable Energy sources are wildly used for energy generation[1].This trend will continue during the next years because the energy produced by renewable sources is expected to satisfy 30% and more than 50% of the total needs of power in 2020 and 2050, respectively.

Solar energy conversion system playing a vital importance in power generation due to its easy availability and eco-friendly nature and its demand has grown consistently by 20% to 30% per annum over the past 15 years, which is mainly due to the decreasing costs and prices of PV panel. This decline has been driven by the following: 1) an increasing efficiency of solar cells; 2) manufacturing-technology improvements; and 3) economies of scale. A PV inverter, which is an important element in the PV system, is used to convert dc power from the solar modules into ac power [2]. The cascaded multi-level inverter has been widely used in high voltage fields. It has many inherent benefits likes: (1) its modular structure, (2) it can be easily implemented through the series connection of identical H-bridges, (3) generate near sinusoidal voltages with only fundamental frequency switching and finally and (4) no electromagnetic interference or common-mode voltages. This flexibility has resulted CHBMLI topology in various applications like medium-voltage industrial drives, electric vehicles and the grid connection of photovoltaic-cell generation systems. It has the advantages of good output waveform, low switching stress. Its structure is suitable for modularization. It is a kind of suitable choice of replacing the existing PWM inverter. The multi-level has entered a new stage of development; there have been a variety of topologies which can be summed up in three kinds that divided into the following ways: diode-clamped structure (DMS), and Capacitor-clamped structure (CCS) and H-bridge cascade structure [3]. Compare with other two structures, the Cascaded multi-level inverter structure (CMIS) needs the least components when the power level is the same that it is easy to implement redundant module with simple control, and can be mixed to achieve a combined application of a variety of devices that it is most viable under high-voltage output.

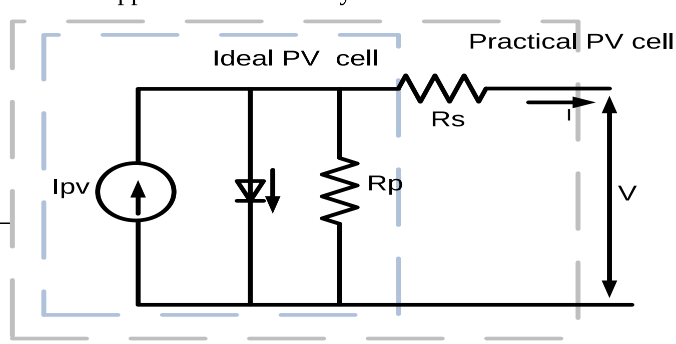

Figure 1.Equivalent Circuit of a PV Device including the Resistances.

The equivalent circuit of PV cell is shown in figure 1. The PV cell is represented by a parallel current source with diode. R_s and R_p represent series and parallel resistance respectively. The output current and voltage cell are represented by I and V [4].

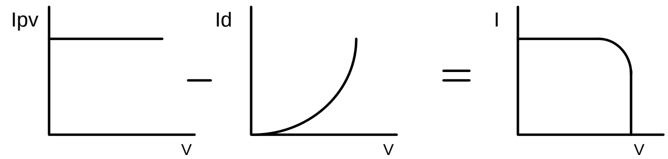

Figure 2.Characteristic I–V curve of the PV cell.

The I-V characteristics of PV cell are shown in Figure 2. The net cell current *I* is composed of the light-generated current I_{pv} and the diode current I_d.

$$I = I_{pv} - I_d \qquad (1)$$

Where:

$I_d = I_0 \exp(qv/akT)$
I_0= leakage current of the diode
q= electron charge
k= Boltzmann constant
T= Temperature of pn junction
a= diode ideality constant.

The basic equation (1) of the PV cell does not represent the *I– V* characteristic of a practical PV array. Practical arrays are composed of several connected PV cells and the observation of the characteristics at the terminals of the PV array requires the inclusion of additional parameters to the basic equation [4].

$$I = Ipv - \left[\exp(V + \frac{RsI}{Vta}) - 1 \right] - \frac{V + RsI}{Rp} \qquad (2)$$

Where: V_t= NskT/q is the thermal voltage of the array with Ns cells connected in series. Cells connected in parallel increase the current and cells connected in series provide greater output voltages. The I-V characteristics of a practical PV cell with maximum power point (MPP), short circuit current (I_{sc}) and open circuit voltage (V_{oc}) is shown in Figure 3. The MPP represents the point at which maximum power is obtained [5].

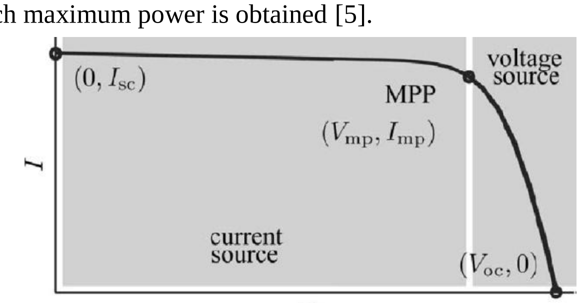

Figure 3.Characteristic I–V curve of the PV cell with MPPT .

V_{mp} and I_{mp} are voltage and current at MPP respectively. The output from PV cell is not the same throughout the day; it varies with varying temperature and insulation (amount of radiation). Hence with varying temperature and insulation maximum power should be tracked so as to achieve the efficient operation of PV system.

According to the MIL-HDBK-217F standard, the System reliability is indirectly proportional to the number of its components, it means that less the components more the reliability. On comparing with m-level DMS, CCS, and P2MS, which use m-1 capacitors on the dc bus, the CMIS uses only (m-1)/2 capacitors for same m-level [6] due to this reason, many researchers are addressing their efforts in proposing new inverter topologies or in improving the existing ones, aiming at modifying the quality of the energy available at the inverter terminals. Among them, pulse-width modulated (PWM) multilevel inverters (MLIs) are gaining both popularity and applications, becoming an effective alternative to current inverter topologies (CIs).

There are three basic multi-level inverter topologies (MLIs): neutral-point-clamped and flying-capacitor MLIs, requiring only one dc source, and cascaded H-bridge MLI (CHB-MLI), requiring separate dc sources. This characteristic, which is a drawback when a single dc source is available, becomes a very attractive feature in the case of PV systems, because solar cells can be assembled in a number of separate sources. In this way, they satisfy the requirements of the CHB-

MLI, obtaining additional advantages such as a possible elimination of the dc/dc booster (needed in order to adapt voltage levels), a significant reduction of the power drops caused by sun darkening (usually, it influences only a fraction of the overall PV field) [7], and therefore, a potential increase of efficiency and reliability.

Many authors has proposed new modulation technique and many other ways to increase the efficiency and reduced the THD of output current. In this paper we are also try to implement such a system by which THD can be reduced and we can get the smooth output waveform so that the user can get the good quality of alternating current.

A significant problem in multilevel inverter design is the complexity of their control and of their pulse width modulation method .Many author's proposed different solutions. In the case of converters for PV sources [8], another important issue is the achievement of the maximum power point tracking (MPPT) different algorithms has been proposed for maximum power point tracking.

II. MLI FOR PV APPLICATIONS

In the Fig. 4 we can see the cascade multilevel inverter consisting of *k* dc sources and *k* cascaded H-bridges arranged in a single-phase multilevel inverter topology. Each dc source consists of PV cell arrays which can be connected in series and/or in parallel, thus we can obtain the desired output voltage and current. H-bridges basically consist of four metal–oxide–semiconductor field-effect transistors (MOSFETs) which are embedding with anti-parallel diode and a driver circuit for the proper switching operation [9].

Three-phase systems can be realized by delta or wye connection of three single-phase systems. The number n of H-bridges depends on the number *p*=2n+ 1 of desired levels, which have to be chosen by taking into, account both the available PV fields and design considerations:

The higher the number of levels, the better the sinusoidal voltage and the current waveforms we can get. However, the number of levels increases the complexity level and the cost of the system while reducing its switching frequency in comparison with two-level and three level inverter outputs. From the energy point of view, it can be noticed that, Even if the amount of switching losses increases proportion all to the number of devices in series, the transistor [MOSFET or insulated-gate bipolar transistor (IGBT)] conduction resistance decreases when using devices with lower maximum applicable voltage. Hence, by this ways we can make the total losses lower using a multilevel inverter rather than using a two-level converter. We know that the MOSFET is low voltage and high switching frequency devices .The instantaneous total output voltage of the *n*-level cascade inverter is $VAN = \sum_{i=1}^{n} Vouti,$ the i-stage output voltage.

Each H Bridge can be driven by with a suitable duty cycle or a PWM pattern, thus the result will be staircase without or with embedded PWM. In the considered single-phase 230-V system, the cells are arranged into four distinct arrays, thus resulting in a nine-level converter, which can be considered a reasonable trade off among complexity, performance and cost.

III. EFFECT OF CHANGE IN IRRADIATION/TEMPERATURE

Up to the previous section, it is assumed that PV cell produces constant rated voltage because nominal irradiation (1000W/m2) and temperature (25 degree C) are considered. In this section, by changing irradiation and temperature simulation of all above cases is repeated [10]. Table I shows the effect of change in irradiation with constant temperature. Table II shows the effect of change in temperature keeping irradiation at nominal value.

It is identified from the results that output voltage of the PV fed inverters is decreasing with decrease in irradiation and increase in temperature. But in symmetrical and asymmetrical

MLIs, decrease in voltage is lesser than two level inverter. When irradiation is reduced to 800W/m^2 the output voltage is reduced by 1.25V and 1.2V in square wave and asymmetrical MLI respectively [11]. But in symmetrical MLI it is just 1.02V. Similarly, though there is no much change in THD, fundamental component starts decreasing with decrease in irradiation.

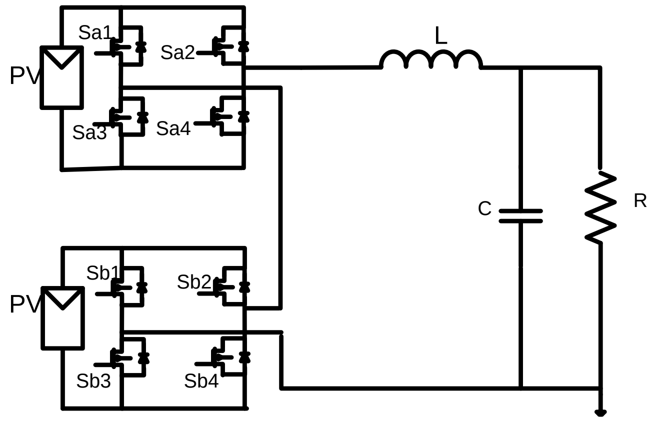

Figure 4.Two H bridge inverter in cascade to generate the 5 level output.

TABLE I. EFFECT OF CHANGE IN IRRADIATION In THREE LEVEL, Five LEVEL

		Three level inverter	Five level inverter
Output Voltage	Irr=1000W/m^2 T=25 degree	319.45	323.23
	Irr= 800W/m^2 T=25 degree	315.07	319.58
	Irr=400W/m^2 T=25 degree	311.95	315.79
THD (%)	Irr=1000W/m^2 T=25 degree	6.03	0.84
	Irr=800W/m^2 T=25 degree	5.89	0.82
	Irr=600W/m^2 T=25 degree	5.26	0.81

But the effect of temperature change is found more significant.
The analysis is done for 23C, 29C and 33C at the nominal irradiation. The decrease in temperature from nominal value increases the output voltage in the symmetrical MLI by 0.8V; in asymmetrical by 0.72V and in two level inverter by 0.7V. Similar to effect of change in irradiation on THD, here also not much change is shown. But it is identified that fundamental component of output voltage also changes with temperature like output voltage [12].

TABLE II. EFFECT OF CHANGE IN TEMPERATURE IN TWO LEVEL, Five LEVEL

	Three level inverters	**Five level inverter**

Output Voltage (V)	Irr=1000W/m^2 T=23 degree	316.43	318.03
	Irr=1000W/m^2 T=29 degree	309.18	310.93
	Irr=1000W/m^2 T=33 degree	304.72	305.08
THD (%)	Irr=1000W/m^2 T=25 degree	6.06	0.68
	Irr=1000W/m^2 T=30 degree	7.05	1.05
	Irr=1000W/m^2 T=35 degree	8.03	1.62

IV. SIMULATION STUDY

In this paper simulation study results of PV fed single phase CHB MLI is presented for five levels. The performance of five levels is analysed and presented here. Further, the effect of change in PV input parameters is studied in detail through simulation results.

A. Simulation of PV Module

The modelling of PV cell is done based on the PSCAD 4.2 model of PV is developed with irradiation and temperature as two input parameters. The photovoltaic current I_{pv} and diode current I_d are modelled using equations (1) and (2).Series resistance R_s and parallel resistance R_p are calculated by considering MPP as operating point.

B. Simulation of PV Fed CHB Inverter

Five-level inverter simulating in PSCAD 4.2 is presented here, and a detailed performance analysis is done in terms of harmonic contents, voltage stress across the switches and number of switches needed.

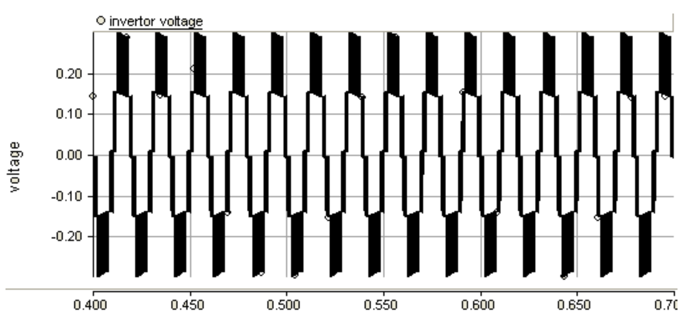

Figure 5 Five level .inverter output voltage for cascade multilevel inverter.

The inverter output voltage waveform which is five levels is shown in the fig.5 .the output voltage is 300 volt and which is generated by making Two H Bridge inverter in cascade operation. As explain above the advantage of cascade multilevel inverter the output voltage level increase and the output THD decrease.

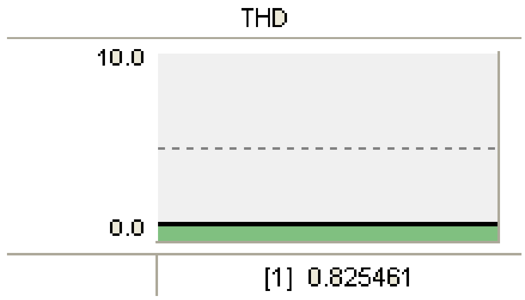

Figure 6.THD of output current.

Fig.6. shows the THD of cascade multilevel inverter and the comparison of this THD result is compare with two level inverter output, as shown in table I and table II. And by which we can conclude that the as we go on increase the THD level there is decrease in THD and output waveform is more smooth.

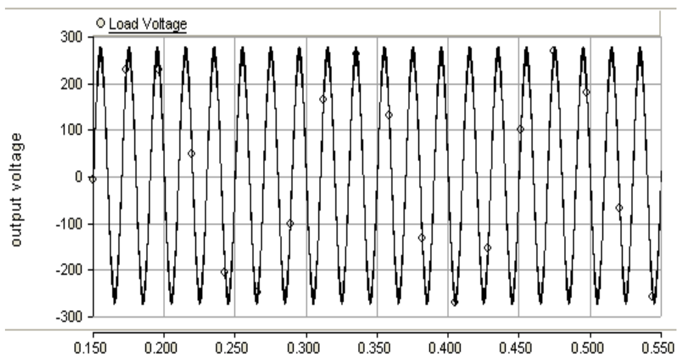

Figure 7.output voltage waveform of cascade multilevel inverter.

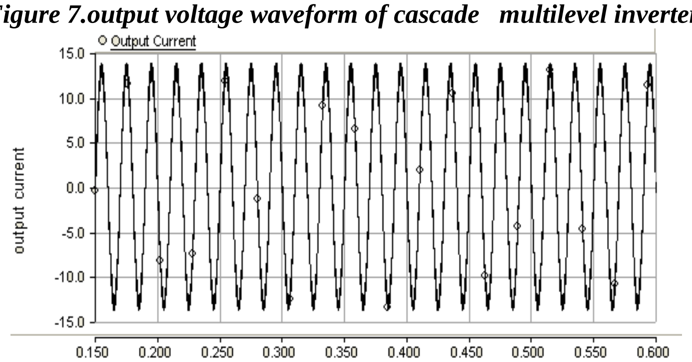

Figure 8.output current waveform of cascade multilevel inverter.

Fig.7and fig8. Shows the output voltage and current waveform for the cascade multilevel inverter, by the results we can see that current and voltage both are the sinusoidal in nature which is required.

V. CONCLUSION

In this paper PV system fed with multi-level inverter is proposed. This paper contributes a performance enhancement of PV system fed cascade multilevel inverter. We can also see that the THD is also reducing in this and wave form is near to sinusoidal. When irradiation reduces, output voltage also proportionately decreases whereas it increases with decrease in temperature. PV system fed multilevel inverter has low stress, high conversion efficiency and uses least number of devices to produce higher voltage level and also eliminates the need of filter at output side.

Analysing and observing modelling and simulation results we conclude that PV system fed cascade level inverter is best alternative of DC source fed multilevel inverter.

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