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Modeling and Simulation of 27- Level Hybrid H-Bridge Multilevel Inverter for PV System

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Abstract:
In this paper, modeling of photovoltaic array and hybrid H-bridge multilevel inverter is done using latest algorithm techniques in order to improve the performance of the PV system and decrease the complexity and total cost of the inverter. Here MPPT algorithm is used for extracting the maximum power from the solar PV module and transferring that power to the load by varying the duty cycle. Among MPPT algorithm techniques, incremental conductance method can perform maximum power point tracking under rapidly varying irradiation conditions with higher accuracy than the perturb and observe method .A hybrid H-bridge multilevel inverter is preferred over all other topologies as it requires less number of switches by which high number of voltage levels are obtained and also reduced THD. The modeling and simulation for the above systems is performed in MATLAB and the generated output voltage is analyzed.

Keywords: Photovoltaic array, Multi-level inverter, MPPT algorithm, Pulse width modulation, Simulink, MATLAB.

1. Introduction

Photovoltaic (PV) power generation has an important role to play due to the fact that it is a green source. The only emissions associated with PV power generation are those from the production of its components. After their installation they generate electricity from the solar irradiation without emitting greenhouse gases. In their lifetime, which is around 25years, PV panels produce more energy than that for their manufacturing. The efficiency of a PV plant is affected mainly by three factors: the efficiency of the PV panel (in commercial PV panels it is between (8-15%), the efficiency of the inverter (95-98 %) and the efficiency of the *maximum power point tracking* (MPPT) algorithm (which is over 98%). Improving the efficiency of the PV panel and the inverter is not easy as it depends on the technology available, it may require better components, which can increase drastically the cost of the installation. Instead, improving the tracking of the *maximum power point* (MPP) with new control algorithms is easier, not expensive and can be done even in plants which are already in use by updating their control algorithms, which would lead to an immediate increase in PV power generation and consequently a reduction in its price[1-15].

The multilevel inverter has gained much attention in recent years due to its advantages in high power possibility with low switching frequency and low harmonics. The general function of the multilevel inverter is to synthesize a desired high voltage from several levels of DC voltages. The dc sources can be batteries, fuel, cells, etc. In the hybrid topologies, the degrees of dc voltage sources are unequal or altered dynamically depending upon the need. These converters are very capable in the size and cost and improve the reliability since less number of semiconductors and capacitor are used in this topology [13-35]. The hybrid multilevel converters consist of altered multilevel topologies which are having uneven value sources of dc voltage magnitude and different modulation techniques. With appropriate mixture of switching devices and technique, the converter cost is reduced. The advancement in the pitch of power electronics and microelectronics made it probable to reduce the degree of harmonics with multilevel inverters, in which the number of levels of the inverters are increased fairly than increasing the size of the filters.

The performances of multilevel inverters enhance as the number of levels of the inverter increases.Therfore by interfacing both PV array and multisource inverter, the output AC sinusoidal voltage waveform with higher number of levels can be obtained and used for high power applications. This interfaced circuit is modeled and analyzed using SIMULINK in MATLAB.

2. Photo-Voltaic Array

Solar Array or Photo voltaic array is a system made up of a group of solar panels connected together. A photovoltaic array is therefore multiple solar panels electrically wired together to form a much larger PV installation (PV system) called an array, and in general the larger the total surface area of the array, the more solar electricity it will produce.

A complete photovoltaic system uses a photovoltaic array as the main source for the generation of the electrical power supply. The amount of solar power produced by a single photovoltaic panel or module is not enough for general use. Most manufactures produce standard PV panels with an output voltage of 12V or 24V. By connecting many single PV panels in series (for a higher voltage requirement) and in parallel (for a higher current requirement) the PV array will produce the desired power output.

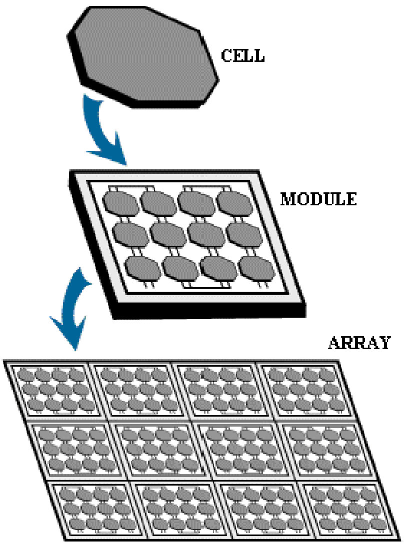

Figure 1

A Photovoltaic solar array

2.1 Electrical characteristics of PV Array

The electrical parameters on which PV array finds the relationship between output current and voltage are

- V_{OC} (open -circuit voltage)
- I_{SC} (Short-circuit current)
- P_{max} (Maximum power point)
- FF (Fill factor)
- %eff(percent efficiency)

V_{OC} (open-circuit voltage) is the maximum voltage that the array provides when the terminals are not connected to any load (an open circuit condition). This value is much higher than V_{max} which relates to the operation of the PV array which is fixed by the load. This value depends upon the number of PV panels connected together in series.I_{SC} (short-circuit current) is the maximum current provided by the PV array when the output connectors are shorted together (a short circuit condition). This value is much higher than I_{max} which relates to the normal operating circuit current.P_{max} maximum power point which relates to the point where the power supplied by the array that is connected to the load (batteries, inverters) is at its maximum value,

where $P_{max} = I_{max} \times V_{max}$.

The maximum power point of a photovoltaic array is measured in Watts (W) or peak Watts (W_p). FF (fill factor) is the relationship between the maximum power that the array can actually provide under normal operating conditions and the product of the open-circuit voltage times the short-circuit current, ($V_{OC} \times I_{SC}$) .This fill factor value gives an idea of the quality of the array and the closer the fill factor is to 1 (unity), the more power the array can provide. Typical values are between 0.7 and 0.8. The %eff (percent efficiency) is the efficiency of a photovoltaic array is the ratio between the maximum electrical power that the array can produce compared to the amount of solar irradiance hitting the array. The efficiency of a typical solar array is normally low at around 10-12%, depending on the type of cells (Monocrystalline, Polycrystalline, Amorphous or Thin film) being used. Photovoltaic I-V characteristics curves provide the information designers need to configure systems that can operate as close as possible to the maximum peak power point. The peak power point is measured as the PV module produces its maximum amount of power when exposed to solar radiation equivalent to 1000 watts per square meter, 1000 W/m^2 or $1kW/m^2$.

3. TYPES OF MULTILEVEL INVERTER

3.1 Cascaded H-bridge multilevel inverter

The general structure of the cascaded multilevel inverter for single phase is shown in figure 6. Each of the separate voltage source (V_{dc1}, V_{dc2}, V_{dc3}) connected in cascade with other sources via a special H-bridge circuit associated with it. Each of the circuit consists of four active switching elements that can make the output voltage source in positive or negative polarity; or it can be simply zero volts depending on the switching condition of the switches in the circuit. A conventional multilevel power inverter topology employs multiple/link voltage of equal magnitudes. It is fairly easy to generalize the number of distinct levels [20-40].

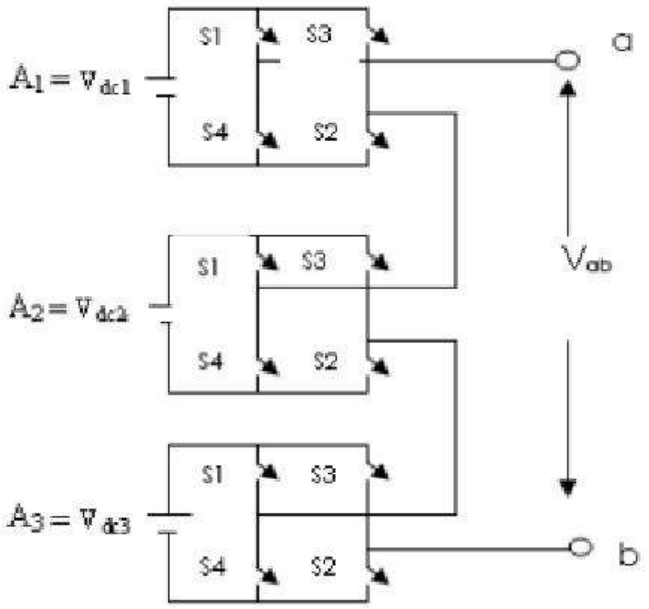

Figure 2 Topology for Cascaded H-Bridge Multilevel Inverter

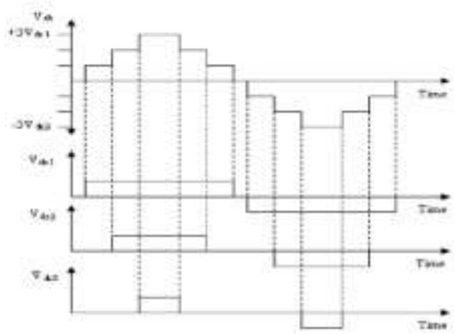

Figure 3: Typical Output Waveform for Cascaded H-Bridge Multilevel Inverter

3.2 Hybrid H-bridge Multi-level inverter

The general structure of the new hybrid multilevel inverter is in figure 10, each of the separate voltage source (V_1, V_2, V_3) connected in cascaded with other sources via a special H-bridge circuit associated with it. Each of the circuit consists of four active switching elements that can make the output voltage source in positive or negative polarity; or it can be simply zero volts depending on the switching condition of the switches in the circuit. The main advantages of hybrid multilevel inverter are high number of levels with reduced number of bridges and dc sources.

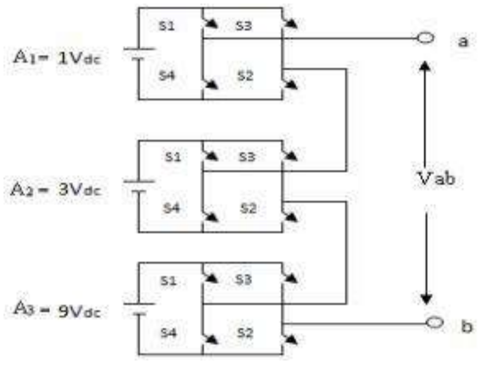

Figure 4: Hybrid H-Bridge Multilevel Inverter

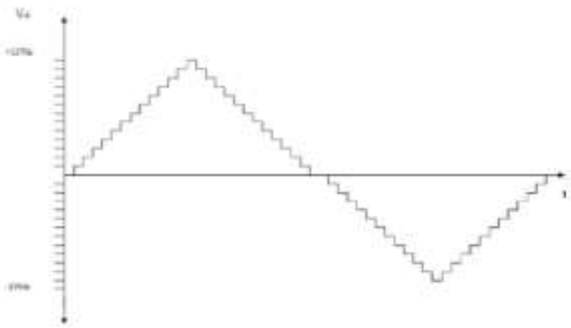

Figure 5: Typical output waveform for Hybrid H-Bridge Multilevel Inverter

4. Modeling and Simulation results

For each full bridge inverter the output voltage is given by

$$V_{Oi} = V_{dc} (S_{1i}-S_{2i})$$

and the input DC current is,

$$I_{dci} = I_a (S_{1i}-S_{2i})$$

i=1,2,3…(number of full bridge inverters employed). I_a is the output current of the new hybrid inverter. S_{1i} *and* S_{2i} is the upper switch of each full bridge inverter. A single phase output voltage of proposed inverter is given by

$$V_{on} = \sum_{i=1}^{n} V_{0i}$$

The topology of the proposed DC–AC H-bridge multilevel inverter is shown in Fig.4.The inverter uses a standard three -leg inverter and an H-bridge with its DC source in series with each phase leg. To see how the system operates, consider simplified single phase topology, shown in Fig.4. The output voltage $v1$ (3v) of this first leg of the top inverter is goes to ON state. For a negative half cycle this leg is connected in series with a full H-bridge, which, in turn, is supplied by a supply voltage. If the supply is kept charged to $Vdc/2$, then the output voltage of the H-bridge can take on the values +Vdc/2.When the output voltage $v = v1 + v2 + v3$ is required to be zero, one can either set

$v1 = +Vdc/2$ and $v2 = +Vdc/2$ and $v3 = -Vdc/2$ (or)

$v1 = -Vdc/2$ and $v2 = +Vdc/2$ and $v3 = +Vdc/2$

In general there are two modulation control schemes, it will be used for multilevel inverter they are fundamental switching frequency and high switching frequency Pulse Width Modulation. In this proposed paper, the simulation model based on the MATALB/SIMULINK and the model is developed under the high switching frequency SPWM. It has triangle carrier signal, one carrier signal for each level and it has one reference or modulation, signal for a single phase. Pulse width modulation technique as a good control strategy because it as an ability to control the fundamental voltage and the harmonic contents. The main aim of this technique is used to minimize the distortion in the output voltage and thereby increasing the efficiency.

PWM(a)=(-1)j+1Vm/3π[sin((2K-)π/m)sinδ].

The firing pulse generated to approach a better efficiency and thereby reducing the total harmonic distortion. In future this various switching technique can be used to generate firing pulse and this can overcome the distortion problems in the output side.

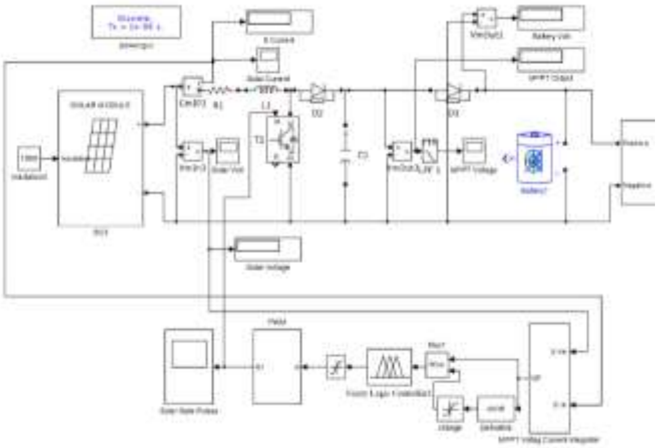

Figure 5: Simulink model for PV system using MPPT technique

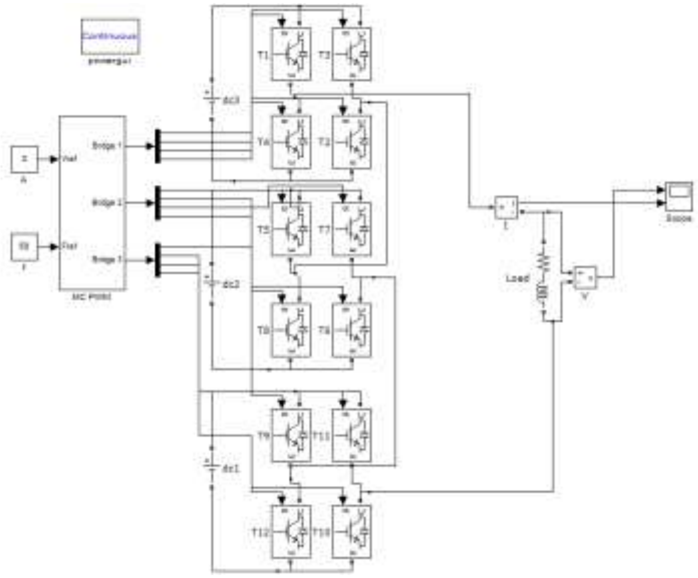

Figure 6: Simulink model for Hybrid H-Bridge Multilevel Inverter with 27 levels

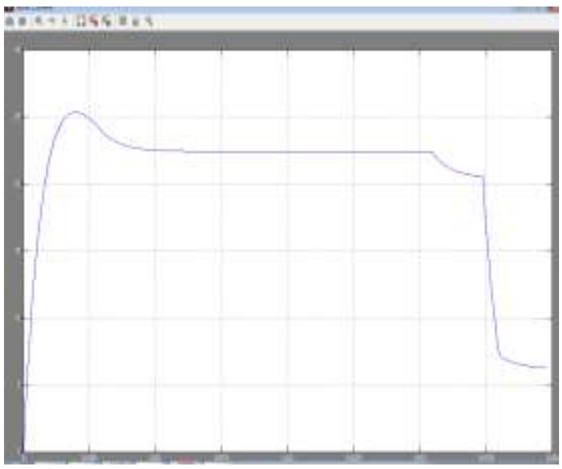

Figure 7: Output of Solar Current

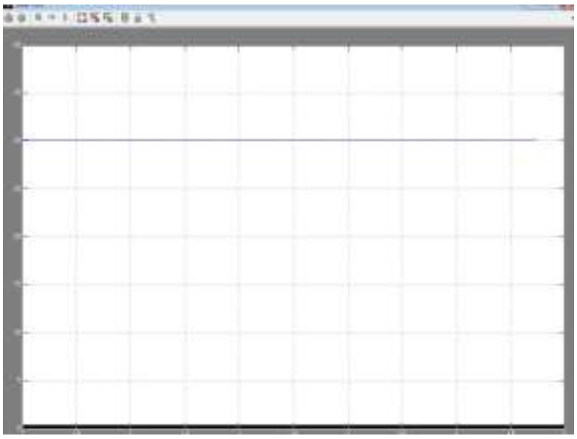

Figure 8: Output of Solar Voltage

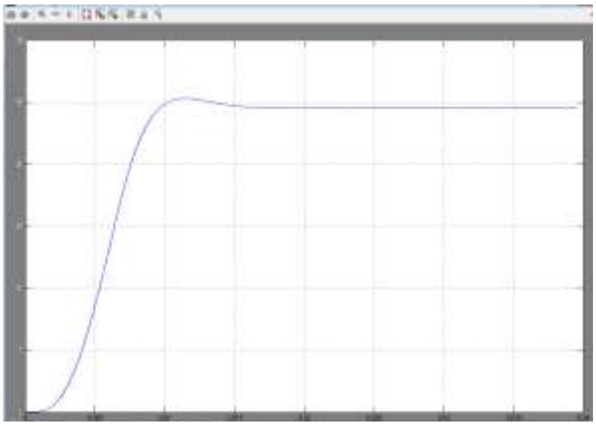

Figure 9: Output of MPPT Voltage

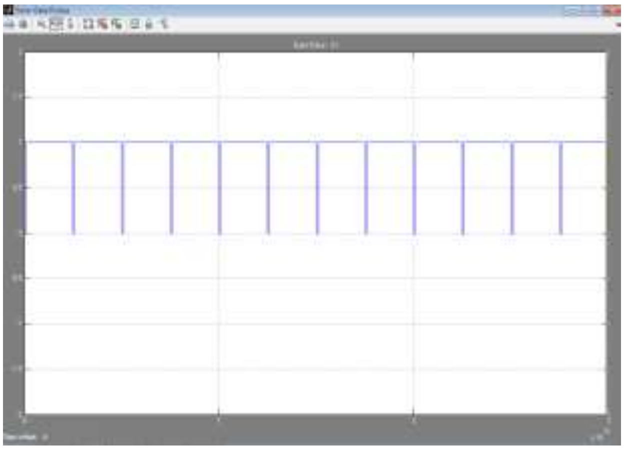

Figure 9: MPPT Gate Pulse

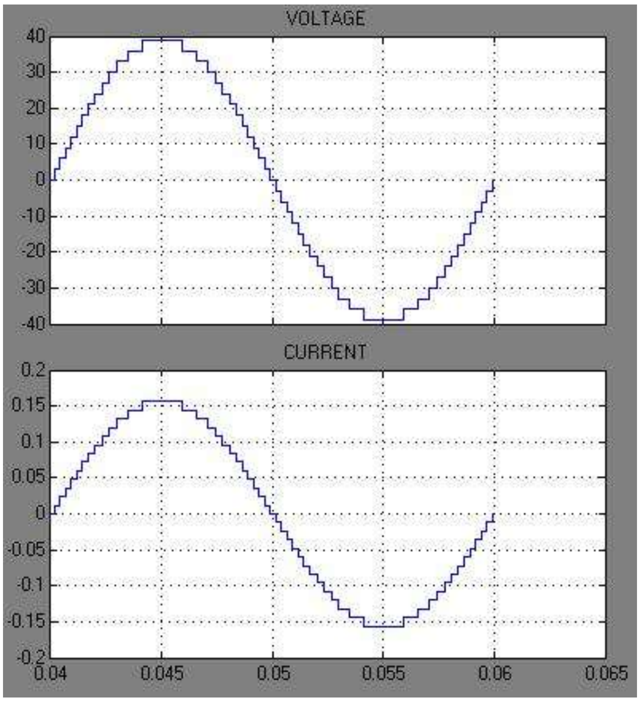

Figure 10: Output of Hybrid H-bridge inverter for 27 levels

5. Conclusion

Thus modeling is performed for multilevel inverter with 27 levels by obtaining the maximum power from PV system and thereby designing the system with reduced number of switches and complexity. The simulated output step signal forms sinusoidal waveform with less number of harmonics. The high efficiency inverter output can be used for various applications like induction motor, Brushless DC motor etc

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