ABSTRACT:
The world constraint of fossil fuels reserves and the ever rising environmental pollution have impelled strongly during last decades the development of renewable energy sources (RES). Photovoltaic (PV) power supplied to the utility grid is gaining more and more visibility, while the world’s power demand is increasing. The photovoltaic (PV) field has given rise to a global industry capable of producing many gigawatts (GW) of additional installed capacity per year. In this project a single phase five level inverter which is suitable for interfacing a photovoltaic system to the grid is presented. This five level inverter uses a Pulse Width Modulation scheme using two reference signals. For low-voltage dc energy sources, a power conditioning system (PCS) is needed to convert the energy sources to a higher-voltage dc before making it to ac for grid tie applications. Fuel cells and Solar photovoltaic (PV) are perhaps the most well-known and prospective energy sources with low voltage dc output. The five level inverter offers much less total harmonic distortion compared to the conventional H-bridge inverter. The control system is verified through simulation using MATLAB/SIMULINK.

I. INTRODUCTION
In the last years, new energy sources have proposed and developed due to the dependency and constant increase of costs of fossil fuels. On other hand, fossil fuels have a huge negative impact on the environment. In this context, the new energy sources are essentially renewable energies. It is estimated that the electrical energy generation from renewable sources will increase from 19%, in 2010, to 32%, in 2030, leading to a consequent reduction of CO2 emission [1]. Among these renewable energy sources, solar photovoltaic energy is one of the fastest growing. In photovoltaic systems, solar energy is converted into electrical energy by photovoltaic (PV) arrays. PV arrays are very popular since they are clean, inexhaustible and require little maintenance. Photovoltaic systems require interfacing power converters between the PV arrays and the grid. Solar-electric energy demand has grown consistently by 20%–25% per annum over the past 20 years, which is mainly due to the decreasing costs and prices. 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 to be fed into the grid. A general overview of different types of PV inverters is given in and. There are several PV system configurations. These configurations are the centralized technology, string technology, multi-string technology and AC-module technology. The number and type of power converters that is used to interconnect the PV system to the grid is dependent of the technology that is used. The multi-string technology has several different groups of PV arrays.

In this paper, a single phase multistring seven-level inverter is used instead of a conventional five-level pulse width-modulated (PWM) inverter because it offers great advantages, such as improved output waveforms, smaller filter size, lower electromagnetic
interference, lower total harmonic distortion (THD), and other.

II. PROPOSED TOPOLOGY

In the conventional proposed topology of single-phase five-level inverter uses only five controlled switches, one or two dc sources and one auxiliary circuit where conventional inverter like cascaded multilevel inverter uses eight switches and two dc sources for same numbered voltage levels, so ultimate size and cost of proposed scheme is lower. And also it offers advantages like improved output waveforms, lower total harmonic distortion, lower filter inductor size, lower electromagnetic interference.

II. MULTISTRING FIVE LEVEL INVERTER TOPOLOGY

The proposed inverter consists of auxiliary circuit, single phase full bridge inverter and PV string 1, 2. An auxiliary circuit consisting of four diodes and one controlled switch as shown in figure 2 connects DC bus to the conventional full bridge inverter. DC bus consists of two identical capacitors. Control scheme consist of two identical reference signals Vref1 and Vref2 which are sinusoidal along with proper valued offset corresponding to triangular carrier signal used to produce pwm signals for switches, so output voltage contain five voltage level i.e. Vdc/2, Vdc, zero, -Vdc/2, -Vdc. A PI controller is used to produce sinusoidal output current. A filtering inductance Lf is used for current filtering which is to be injected into the grid. The injected current must have low THD. A sinusoidal PWM is used in order to generate sinusoidal current. It is obtained by comparing a high frequency carrier signal with low-frequency sinusoidal signal, which is the reference signal.

A. PWM modulation

Modulation index for a five-level PWM inverter is given as

\[ M = \frac{Am}{2Ac} \]

Where, Ac is the peak-to-peak magnitude of carrier signal and Am is the magnitude of reference voltage Vref. Here we used two identical reference signals, so putting Vref1 = Vref2 = Vref = Am, while Ac replaced by Vc. So,

\[ M = Vref/2Vc \]

If M>1, then it is over modulation, and higher order harmonic introduced in phase current waveform. So M is to be maintained between zero and one.

\[ V_o(\theta) = A_0 + \sum_{n=1}^{\infty} \left[ A_n \cos n\theta + B_n \sin n\theta \right] \]

If there are P pulses per quarter period, and coefficients Bn and An would be zero when P is an odd number, where n is an even number.

Where,

\[ A_n = \frac{2Vdc}{m!} \sum_{n=1}^{p} \sum_{i=1}^{n} (-1)^{i-1} \sin(n\alpha_{m+1}) \]

Here m is a pulse number and \( \alpha \) is the phase displacement angle.
III. OPERATING PRINCIPLE OF MULTISTRING FIVE LEVEL INVERTER

Parallel connected PV strings [2-3] 1 and 2 produces $V_{pv}$ voltage at dc bus. Now proposed inverter should produce five voltage levels i.e. 0, $+V_{pv}/2$, $+V_{pv}$, $-V_{pv}/2$, $-V_{pv}$. By switching S4 switch of auxiliary circuit, it is possible to generate two voltage levels i.e. $+V_{pv}/2$, $-V_{pv}/2$. As S4 is switched properly, capacitor voltage is reflected in the output, which is half of the dc bus voltage. While single phase full bridge inverter generates three output voltage level i.e. $V_{pv}$, 0, $-V_{pv}$[4]. Two reference signals $V_{ref1}$ and $V_{ref2}$ will compared with the carrier signal simultaneously. With reference to figure 3, if $V_{ref1}$ exceeds the peak amplitude of carrier signal $V_{carrier}$, then $V_{ref2}$ will be compared with the carrier signal until it reaches zero. At this point onward, $V_{ref1}$ takes over the comparison process until it exceeds $V_{carrier}$. Table 1 illustrates output voltage according to switching pattern. S4–S6 will be switch at the rate of carrier signal frequency, while S7 and S8 will operate at a frequency that is equivalent to the fundamental frequency.

<table>
<thead>
<tr>
<th>S4</th>
<th>S5</th>
<th>S6</th>
<th>S7</th>
<th>S8</th>
<th>INVERTER OUTPUT</th>
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<tbody>
<tr>
<td>ON</td>
<td>OFF</td>
<td>OFF</td>
<td>OFF</td>
<td>ON</td>
<td>$+V_{pv}/2$</td>
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<tr>
<td>OFF</td>
<td>ON</td>
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<td>OFF</td>
<td>ON</td>
<td>$+V_{pv}$</td>
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<td>OFF</td>
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<td>ON</td>
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<td>ON</td>
<td>ON</td>
<td>$-V_{pv}/2$</td>
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<td>OFF</td>
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<td>ON</td>
<td>OFF</td>
<td>$-V_{pv}$</td>
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</tbody>
</table>

IV. CONTROL SYSTEM IMPLEMENTATION

One of the problems in the PV generation systems facing problem regarding the amount of electric power generation by the solar arrays which is variable with respect to the solar radiation intensity. The quick response MPPT algorithm is able to make good use of the solar energy. In this paper, the perturb-and-observe algorithm is used to obtain maximum power from the PV arrays and transfer it to the inverter, because this method require less number of sensors and also easy to implement. The PI feedback controller used for the inverter [5]. As shown in figure 4, grid current $I_g$ is sensed and fed back to a comparator. Comparator compares $I_g$ with reference current $I_{ref}$. $I_{ref}$ is obtained by multiplying utility grid voltage $V_g$ with variable $m$. Therefore

$$I_{ref} = V_g \times m$$

Variable $m$ is the sum of $m_1$, $m_2$ i.e.

$$m = m_1 + m_2$$

Variables $m_1$, $m_2$ are obtained from the MPPT algorithm. Variables $m_1$, $m_2$ correspond to the MPPT algorithm for strings 1, 2 respectively. The values of $m_1$, $m_2$ varies with respect to the irradiance level. If the irradiance level is high, the corresponding values $m_1$ and $m_2$ are also high. In this paper, we are dealing with constant radiation.

So values of $m_1$ and $m_2$ are taken as constant, it will lead to high value of $m$. Because $I_{ref}$ is proportional to $m$, a high value of $I_{ref}$ is obtained. As a result, the inverter’s output current $I_g$ will be high as it follows $I_{ref}$ to minimize the instantaneous error between $I_g$ and $I_{ref}$. The instantaneous current error is fed to a PI controller. The integral term in the PI controller improves the tracking by reducing the instantaneous error between the reference and the actual current [6]. The resulting error signal $u$, which forms $V_{ref1}$ and $V_{ref2}$, is compared with a triangular carrier signal, and intersections are made to produce PWM signals for the switches.
V. MULTISTRING SEVEN LEVEL INVERTER

Figure shows multistring seven level inverter connected to PV consists of three PV strings and two auxiliary circuits and a full bridge inverter.

VI. MATLAB/SIMULINK RESULTS

Fig.6. Simulink model of single phase multistring five level inverter for grid connected PV system

Fig.7. Simulink waveform of single phase multistring five level inverter

Fig.8. Simulink waveform of input pulses for single phase multistring five level inverter

Fig.9. Simulink waveform of grid voltages for single phase multistring five level inverter connected to grid

Fig.10. Simulink waveform of grid currents for single phase multistring five level inverter connected to grid

Fig.11. FFT analysis of multistring seven level inverter

THD=38.69%

Fig.12. Simulink model of PV fed multistring seven level inverter
REFERENCES


CONCLUSION

This paper has presented a single-phase multistring seven level inverter feeding power to grid under constant radiation condition. A novel PWM control scheme with two reference signals and a carrier signal has been used to generate the pwm switching signals. The configuration is suitable for PV application and later expansion is possible by connection with one auxiliary circuit. In addition, it gives low filter inductor size, improved power quality, efficiency and output waveforms.