ISSN No: 2348-4845
International Journal & Magazine of Engineering, Technology, Management and Research
A Peer Reviewed Open Access International Journal

A Single Phase Multistring Seven Level Inverter for Grid Connected PV System

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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 giga watts (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

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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.

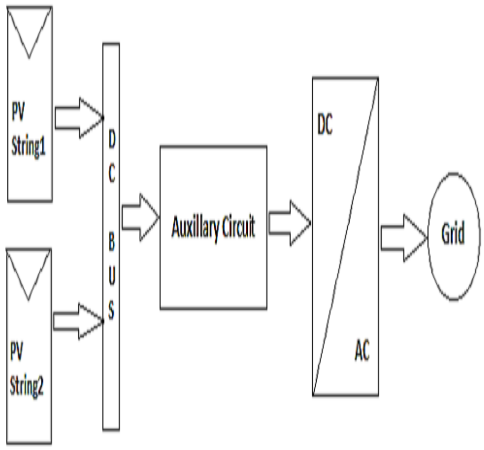

Fig.1. Multistring Inverter configuration

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 sinusoid signal, which is the reference signal.

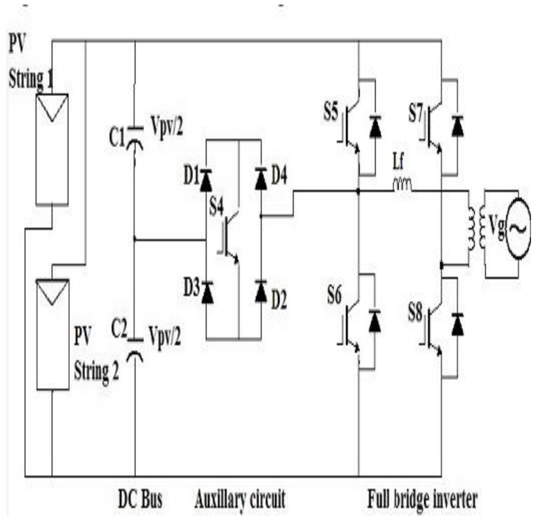

Fig. 2. Configuration of multistring inverter

A.PWM modulation

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

$$M=Am/2Ac$$

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.

$$Vo(\theta) = A_0 + \sum_{n=1}^{\infty}(A_n \cos n\theta + B_n \sin n\theta)$$

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.

$$Vo(\theta) = \sum_{n=1,3,...}^{\infty} An \cos n\theta$$

Where,

$$An = -\left(\frac{2Vdc}{n\Pi}\right)\sum_{m=0}^{P}\sum_{i=1}^{4}\left((-1)^{int(i/2)}\sin(n\alpha_{m+1})\right)$$

Here m is a pulse number and α is the phase displacement angle.

III.OPERTAING PRINCIPLE OF MULTISTRING FIVE LEVEL INVERTER

Parallel connected PV strings [2-3] 1 and 2 produces Vpv voltage at dc bus. Now proposed inverter should produce five voltage levels i.e. 0, +Vpv/2, +Vpv, −Vpv/2, −Vpv. By switching S4 switch of auxillary circuit, it is possible to generate two voltage levels i.e. +Vpv/2, −Vpv/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. Vpv, 0,-Vpv[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 Vcarrier, 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 Vcarrier. 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 1.Output voltage according switching pattern

S4	S5	S6	S7	S8	INVERTER OUTPUT
ON	OFF	OFF	OFF	ON	+Vpv/2
OFF	ON	OFF	OFF	ON	+Vpv
OFF	ON OFF	OFF ON	ON OFF	OFF ON	0
ON	OFF	OFF	ON	OFF	-Vpv/2
OFF	OFF	ON	ON	OFF	-Vpv

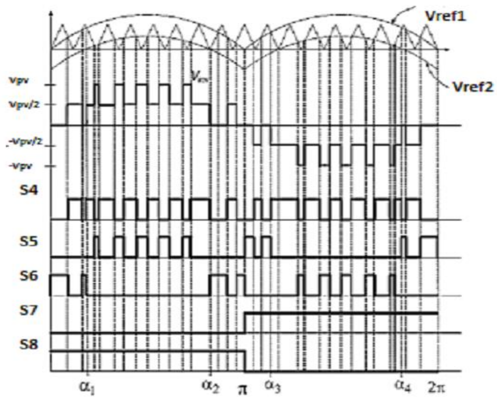

Fig.3. Inverter output voltage and switching pattern.

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 Ig is sensed and fed back to a comparator. Comparator compares Ig with reference current Iref. Iref is obtained by multiplying utility grid voltage Vg with variable m. Therefore

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

Variable m is the sum of m1, m2 i.e.

$$m = m_1 + m_2$$

Variables m1, m2 are obtained from the MPPT algorithm. Variables m1, m2 correspond to the MPPT algorithm for strings 1, 2 respectively. The values of m1, m2 varies with respect to the irradiance level. If the irradiance level is high, the corresponding values m1 and m2 are also high. In this paper, we are dealing with constant radiation.

So values of m1 and m2 are taken as constant, it will lead to high value of m. Because Iref is proportional to m, a high value of Iref is obtained. As a result, the inverter's output current Ig will be high as it follows Iref to minimize the instantaneous error between Ig and Iref. 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 Vref1 and Vref2, is compared with a triangular carrier signal, and intersections are made to produce PWM signals for the switches.

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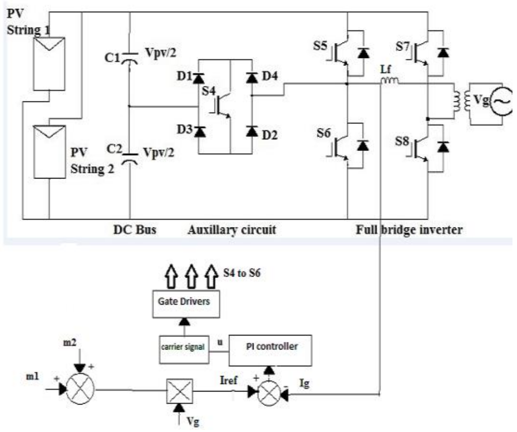

Fig.4. Control system algorithm and implementation in proposed technology

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

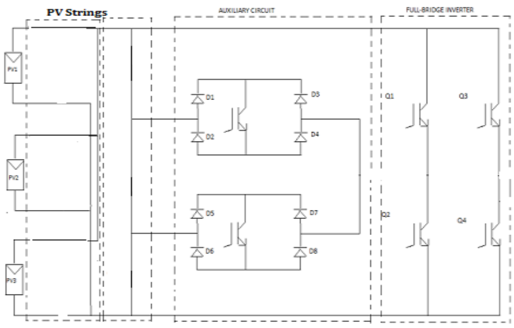

Fig.5. PV fed multistring seven level inverter

VI.MATLAB/SIMULINK RESULTS

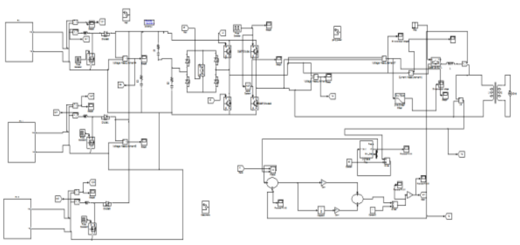

Fig.6. Simulink model of single phase multistring five level inverter for grid connected PV system

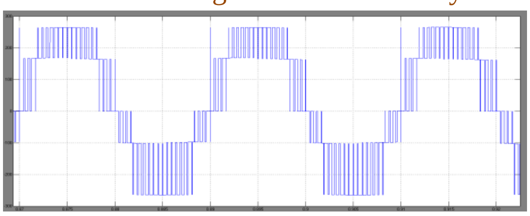

Fig.7. Simulink waveform of single phase multistring five level inverter

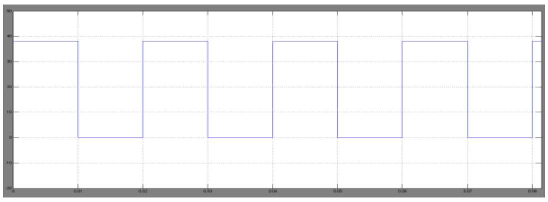

Fig.8. Simulink waveform of input pulses for single phase multistring five level inverter

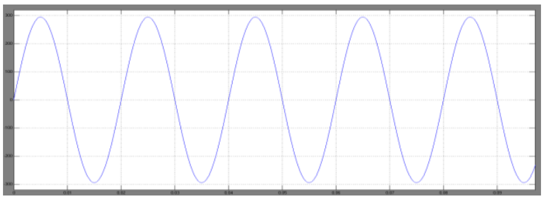

Fig.9. Simulink waveform of grid voltages for single phase multistring five level inverter connected to grid

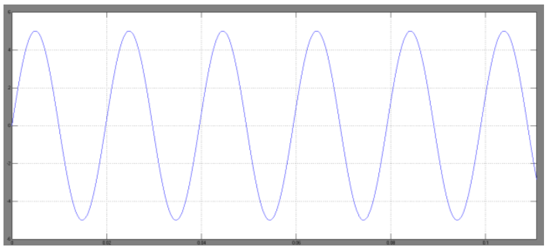

Fig.10. Simulink waveform of grid currents for single phase multistring five level inverter connected to grid

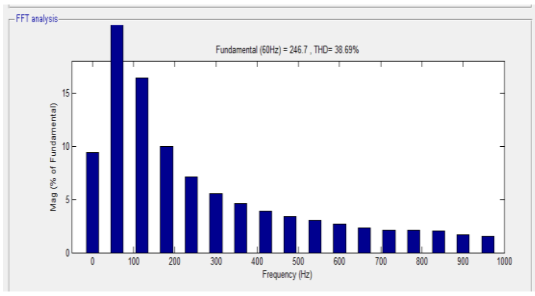

Fig.11. FFT analysis of multistring seven level inverter THD=38.69%

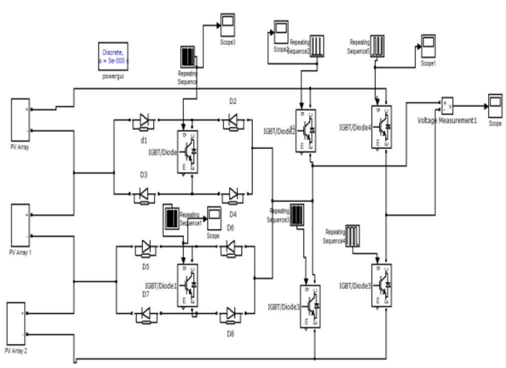

Fig.12. Simulink model of PV fed multistring seven level inverter

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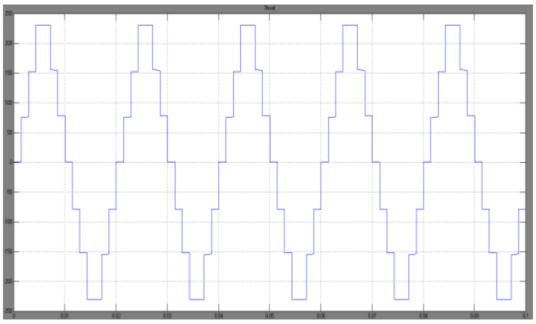

Fig.13. Simulation waveform of model of PV fed multistring seven level inverter

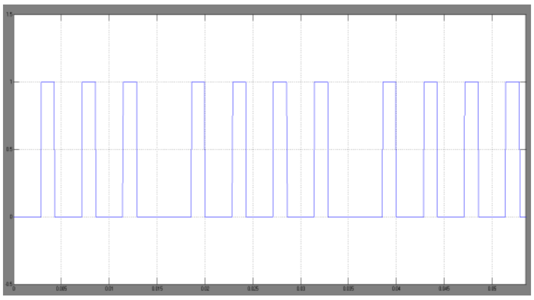

Fig.14. Simulation waveform switching pulses of PV fed multistring seven level inverter

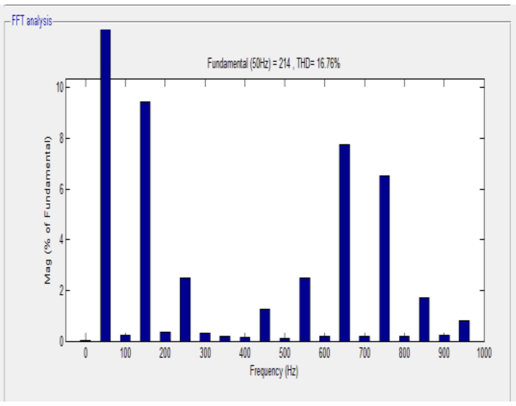

Fig.15. FFT analysis of multistring seven level inverter THD=16.76%

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.

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