Solar Energy Interfacing to Grid by Using Five-Level Inverter

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Abstract
Reorganizations in power sector alongside different renewable vitality advancement arrangements have expanded the significance of small grid connected photovoltaic (PV) systems using single-stage inverters. To enhance the execution Five-Level inverter are favored more than two levels. This paper proposes a solitary stage Five-Level inverter for grid connected (PV) system. The yield current of the inverter can be balanced by voltage of the photovoltaic (PV) exhibit. This control plan depends on SPWM topology. Plans in view of SPWM which don't require the administration of a stage bolted circle for interfacing the inverter to the grid are progressively being utilized for such applications. Execution assessment of the five-level inverter is done on MATLAB stage. The feasibility of the proposed plan is affirmed by performing reenactment and results acceptance. In this paper, a solitary stage Five-Level inverter which is reasonable for interfacing a photovoltaic system to the grid is introduced. The Five-Level inverter utilizes a Pulse Width Modulation plan utilizing two reference signals for Five-Level inverter. The reference signs are indistinguishable to each other with a counterbalance comparable to the amplitude of the carrier signal. A PI controller is utilized to keep the current infused into the grid sinusoidal furthermore to keep the DC join voltage consistent under shifting barometrical conditions. This is checked through reproduction utilizing MATLAB/SIMULINK.

Keywords
Converter, Grid, Solar Energy, High Frequency Transformer, Diode Clamped, 5-level Inverter

I. Introduction

The extensive use of fossil energizes has brought about the worldwide issue of greenhouse emissions. Also, as the supplies of fossil energizes are drained later on, they will turn out to be progressively costly. Hence solar light based vitality is turning out to be more imptive generation since it delivers less contamination and the expense of fossil fuel vitality is rising, while the expense of solar based exhibits is diminishing. Specifically, little limit appropriated power generation systems utilizing solar light based vitality might be broadly utilized as a part of private applications sooner rather than later [1-2]. The power change interface is imptive generation to grid connected solar oriented power generation systems since it changes over the DC power produced by a solar oriented cell exhibit into AC power and nourishes this AC power into the utility lattice. An inverter is fundamental in the power transformation interface to change over the DC energy to AC power [2-4]. Since the yield voltage of a solar powered cell cluster is low, a DC-DC power converter is utilized as a part of a little limit solar oriented power generation system to help the yield voltage so it can coordinate the DC transport voltage of the inverter. The power change effectiveness of the power transformation interface is imptive generation to protect there is no misuse of the vitality produced by the solar based cell exhibit. The dynamic gadgets and uninvolved gadgets in the inverter create a power misfortune. The power misfortunes because of dynamic gadgets incorporate both conduction misfortune and exchanging misfortune [5]. Conduction misfortune results from the utilization of dynamic gadgets, while the exchanging misfortune is relative to the voltage and the present changes for every exchanging and exchanging recurrence. A channel inductor is utilized to prepare the exchanging music of an inverter, so the power misfortune is relative to the measure of exchanging music. The voltage change in every exchanging generation ion for a Five-Level inverter is lessened keeping in mind the end goal to enhance its energy transformation proficiency [6, 5] and the exchanging anxiety of the dynamic gadgets. The measure of exchanging music is additionally lessened, so the power misfortune brought on by the channel inductor is likewise diminished. Along these lines, Five-Level inverter innovation has been the subject of much research in the previous couple of years. In principle, Five-Level inverters ought to be planned with higher voltage levels keeping in mind the end goal to enhance the transformation productivity and to diminish consonant substance and electromagnetic impedance (EMI). Customary Five-Level inverter topologies incorporate the diode-bridge [6-10], the flying-capacitor [1-3] and the course H-span [4-8] sorts. Diode-clamped and flying capacitor Five-Level inverters use capacitors to build up a few voltage levels. Be that as it may, it is hard to control the voltage of these capacitors. Since it is hard to make a asymmetric voltage technology in both the diode-clamped and the flying-capacitor topologies, the power circuit is muddled by the expansion in the voltage levels that is important for a Five-Level inverter. The routine vitality sources are quick draining nowadays. So the interest for renewable vitality sources has been expanded. Among the renewable vitality sources photovoltaic systems can be considered as a decent wellspring of vitality in light of its consistency and cleanliness. The power created by photovoltaic system is DC. To change over this DC control a photovoltaic inverter is utilized. Enhancing the yield waveform of the inverter lessens the consonant substance in the current infused into the network in a system connected system. For this a Five-Level inverter is considered here. Such Five-Level inverter decreases the electromagnetic impedance furthermore in lessening the channel size.

II. Related Work

This paper proposes another solar power generation system, which is made out of a dc/dc power converter and another seven-level inverter. The dc/dc power converter incorporates a dc–dc help converter and a transformer to change over the yield voltage of the solar powered cell exhibit into two autonomous voltage sources with various connections. This new seven-level inverter is designed utilizing a capacitor determination circuit and a full-connect power converter, connected in course. The capacitor determination circuit changes over the two yield voltage wellsprings of dc–dc power converter into a three-level dc voltage, and the full-connect power converter further changes over this three-level dc voltage into a seven-level air conditioning voltage. Along these lines, the proposed solar based power generation system produces a sinusoidal yield current that is in stage with the utility voltage and is nourished into the utility. The notable components of the proposed seven-level inverter are that lone six power electronic switches are utilized, and one and only power electronic switch is exchanged at high recurrence whenever. a model is created and tried to check the execution of this proposed solar based power generation system. The broad utilization of fossil powers has brought about the worldwide issue of nursery outflows. In addition, as the supplies of fossil fills are exhausted later on, they will turn out to be progressively costly. In this manner, solar light based vitality is turning out to be more vital since it delivers less contamination and the expense of fossil fuel vitality is rising, while the expense of solar oriented exhibits is diminishing. Specifically, little limit disseminated power generation systems utilizing solar based vitality might be generationally utilized as a part of private applications sooner rather than later. The power change interface is vital to system connected solar powered power generation systems since it changes over the dc power produced by a solar light based cell exhibit into air conditioning power and nourishes this air conditioner power into the utility grid. An inverter is important in the power change interface to change over the dc energy to air conditioning power. Since the yield voltage of a solar light based cell cluster is low, a dc–dc power converter is utilized as a part of a little limit solar based power generation system to help the yield voltage, so it can coordinate the dc transport voltage of the inverter. Productivity of the power transformation interface is vital to guarantee that there is no misuse of the vitality created by the solar powered cell cluster. The dynamic gadgets and inactive gadgets in the inverter create a power misfortune. The power misfortunes because of dynamic gadgets incorporate both conduction misfortunes and exchanging misfortunes. Conduction misfortune results from the utilization of dynamic gadgets, while the exchanging misfortune is relative to the voltage and the present changes for every exchanging and exchanging recurrence. A channel inductor is utilized to handle the exchanging sounds of an inverter, so the power misfortune is corresponding to the measure of exchanging music The writing audit displayed in this section begins with the structure of a 3-stage network connected PV system to give peruses a thought regarding the usefulness of a regular PV inverter. Since the PV inverter is interfaced to a utility lattice, it is critical that the interconnection is as per the utility codes and benchmarks. Photovoltaic systems require interfacing power converters between the PV exhibits and the grid. These power converters are utilized for two noteworthy errands. To begin with, is to infuse a sinusoidal current into the lattice. What's more, second is to decrease the sounds content in the system infused voltage and current. Regularly there are two power converters. The first is a DC/DC power converter that is utilized to work the PV clusters at the most extreme power point. The other one is a DC/AC power converter to interconnect the photovoltaic system to the network. The established single or three-stage two level VSIs is regularly utilized for this power converter sort. In any case, different topologies have been proposed is the Five-Level VSI. Multilevel converter topologies are an extremely intriguing decision for understanding this goal.

III. Electrical Characteristics of Silicon PV Cells

PV cells are semiconductor devices, with electrical characteristics similar to a diode. The PV cell operates as a current source when it comes in contact with a UV light source. A PV cell will behave differently depending on the size of the PV panel or type of load connected to it and the intensity of sunlight (illumination). This behavior is called the PV cell characteristics. The characteristics of a PV cell are described by the current and voltage levels when different loads are connected. When the cell is exposed to sunlight and is not connected to any load, there is no current flowing and the voltage across the PV cell reaches its maximum. This is called an open circuit (V_{open}) voltage. When a load is connected to the PV cell, current flows through the circuit and the voltage drops. The current is maxi- mum when the two terminals are directly connected with each other and the voltage is zero. The current in this case is called a short-circuit (ISC) current, as shown in Fig. 1. Comparisons can be made to the electrical characteristics of different PV cells as these measurements are made at standard test conditions (STC), which are defined as a light intensity of 1000 W/m2 and a temperature of 25°C.

The light intensity as well as temperature affects the PV cell characteristics. Current is directly proportional to light intensity. Voltage also changes with fluctuating light levels, but the change in the voltage is less. Voltage is more affected by changes in the temperature of the PV cell than the current. An increase in cell temperature decreases the voltage and increases the current by a very small amount. How these influences affect an I-V curve is illustrated in fig. 2. It can be observed that changing (decreasing) the light intensity has a much greater effect than changing (increasing) the temperature. This is true for all commonly used PV materials.

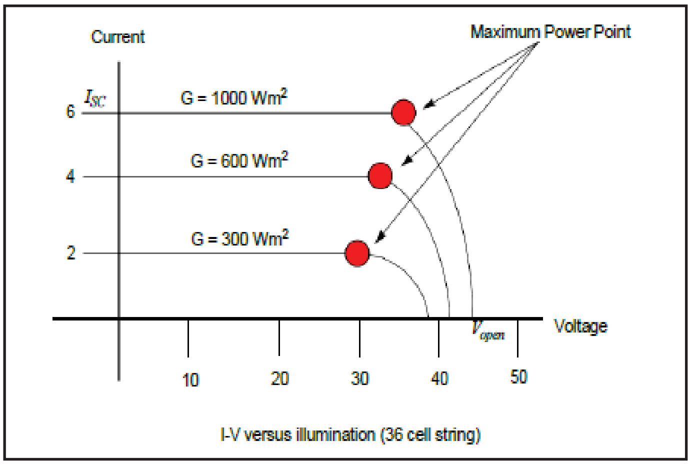


Fig. 1: PV Module Electrical Characteristics

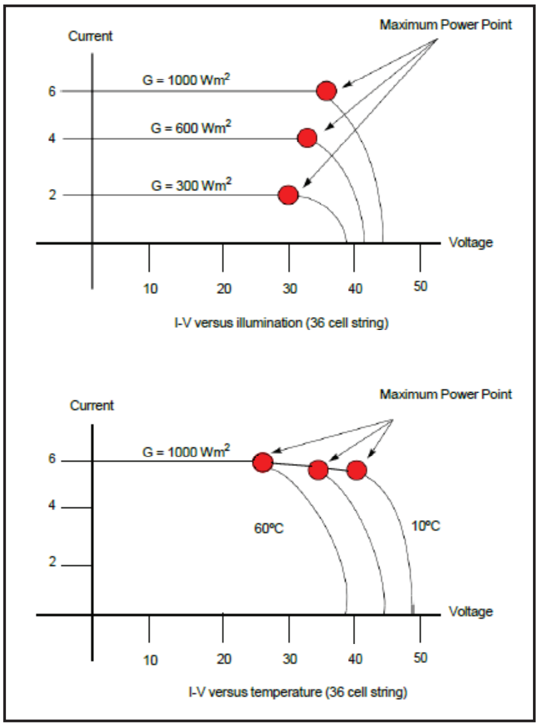


Fig. 2: PV Module Electrical Characteristics with Light Intensity

and Temperature

IV. Solar Powered System Specifications, Demands, and Standards

Interfacing a solar inverter module with the power grid involves two major tasks. One is to ensure that the solar inverter module is operated at the Maximum Power Point (MPP). The second is to inject a sinusoidal current into the grid. Since the inverter is connected to the grid, the standards given by the utility companies must be obeyed. The EN61000-3-2, IEEE1547 standards, and the U.S. National Electrical Code (NEC) 690, are worth considering. These standards deal with issues like power quality, detection of islanding operation, grounding, and so on. These inverters must be able to detect an islanding situation, and take appropriate action in order to prevent bodily harm and damage to equipment connected to the grid. Islanding is the continued operation of the inverter when the grid has been removed intentionally, by accident, or by damage. In other words, if the grid has been removed from the inverter; the inverter should then stop supplying power to the grid or energizing the grid. The most common solar technologies today are the mono crystalline and multi-crystalline silicon modules. A PV cell can be modeled as shown in fig. 1, and its electrical characteristics are shown in fig. 2. The MPP voltage range for these PV modules is normally defined in the range from 27V to 45V, at a power generation of approximate 200W, and their open-circuit voltage is below 45V. In order to capture the maximum energy from the PV module, solar inverters must guarantee that the PV module is operated at the MPP. This is accomplished by the maximum power point control loop known as the Maximum Power Point Tracker (MPPT). It also involves PV output voltage ripple at the terminals of the PV module being sufficiently small, in order to operate around the MPP without too much variation in PV current.

V. Five-Level Inverter

The most common MLI topologies classified into the three types are 1) Diode clamped Five-Level inverter (DCMLI), 2) Flying capacitor MLI (FC-MLI), 3) Hybrid MLI. The hybrid and asymmetric hybrid inverter topologies have been developed according to the combination of existing Five-Level inverter topologies or applying the different DC bus levels respectively. Among with these types of MLI, Cascade Five-Level inverter is very much suitable for solar grid integration application. Several modulation and control techniques have been developed for Five-Level inverters including selective harmonic elimination PWM (SHE-PWM), sinusoidal PWM (SPWM), space vector PWM (SVM), and similar variations of the three main algorithms. SPWM control method is very popular in industrial applications owing to its harmonic reducing opportunities by using several phase shifting options on carrier signal. In the SPWM, a sinusoidal reference voltage waveform is compared with a triangular carrier waveform to generate gating signals for the switches of inverter. Several multi carrier techniques have been developed to reduce the THD ratios, based on the classical SPWM with triangular carriers. Another alternative modulation technique is SVM strategy, which has been used appropriately in Five-Level inverters. The SVM and SHEPWM methods are fundamental frequency switching methods and perform one or two commutations of the power semiconductors during one cycle of the output voltages to generate a staircase waveform. This paper presents the Five-Level inverter topologies and their control methods according to Solar Grid integration application, based on a well surveyed literature summary. A comprehensive study has been performed on commonly used and hybrid Five-Level inverters and the most appropriate SPWM control scheme. The controller plays an important role in controlling and maintaining the proper functioning of the whole system by limiting the system parameter in specified ranges. With the advancement of power electronics and emergence of new Five-Level converter topologies [13], it is possible to work at voltage levels beyond the classic semiconductor limits, so Five-Level inverters have been widely used for high-power high-voltage DG applications. Due to higher number of sources, lower EMI, lower % THD in output voltage and less stress on insulation, they are widely used. A converters or regulators are used to step up the PV-array voltage close to the specified dc-link voltage, as shown in Figure1. The converter is operated in by-pass mode when the PV-array voltage is higher than the dc-link voltage, and the inverter will function as an MPPT [6]. The MPPT will switch operation modes between converter (buck or boost) when the output voltage of a PV array is close to the dc-bus voltage. Total harmonics distortion is reduced in the output wave form without decreasing in inverter output power. In power quality [3], the five-level inverters can appropriately replace the existing system that uses traditional five-pulse converters without the need of the transformers. An inverter converts DC input voltage into AC output voltage of variable magnitude and frequency.

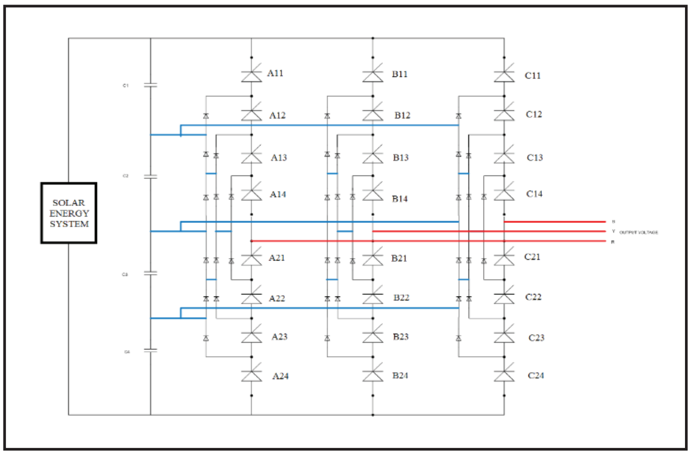


Fig. 3: Five Inverter with Solar Grid Connected

VI. Proposed Power Converter Structure

The base configuration of the proposed grid connected photovoltaic system is presented in fig. 1. This system consists of several PV modules, DC/CD power converters, a multilevel DC/AC power converter and a power transformer. For the PV modules arrangements a multi-string technology is used. Each string of the PV array is connected to a DC/DC converter with a MPPT algorithm. The output of these converters is the DC power supply of the multilevel DC/AC power converter. The proposed multilevel inverter uses a four-wire voltage source inverter and two single-phase voltage source inverters.

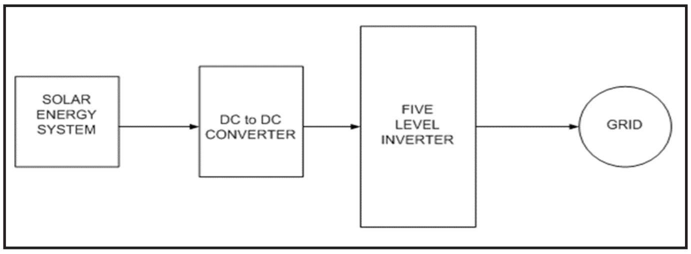


Fig. 4: Configuration of the proposed grid connected photovoltaic system

Fig. 5 presents the configuration of this power converter. In order to obtain different DC voltages, at the output of the DC/DC power converters, the PV strings are not equally distributed. To fulfil this purpose, the four-wire voltage source inverter must have an input DC voltage which is the double of the input DC voltage of both single-phase voltage source inverters. Considering a VDC input voltage for the two single-phase voltage source inverters, the four-wire voltage source inverter must have an input DC voltage of 2VDC. In this way, the multilevel inverter is able to generate a seven level shaped output voltage wave. Using equal DC voltages for all inverters only a Five-Level shaped output voltage wave could be obtained. With this different DC voltage arrangement one can obtain the following multilevel inverter output voltage combinations: -3VDC, -2VDC, -VDC, 0; +VDC, +2VDC, +3VDC. The output of the AC/DC power converter is connected to a Le-Blanc transformer, and the secondary windings of this transformer are connected to the grid.

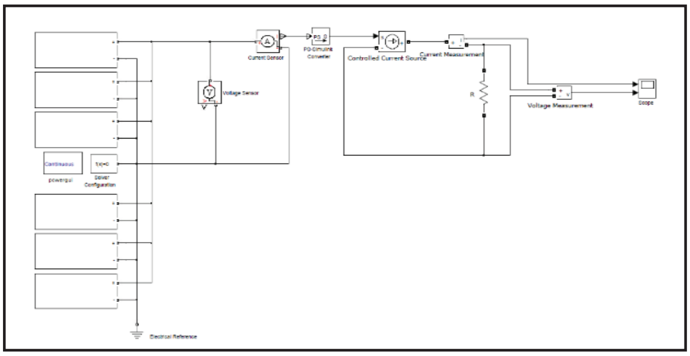


Fig. 5: Multilevel DC/AC Converter

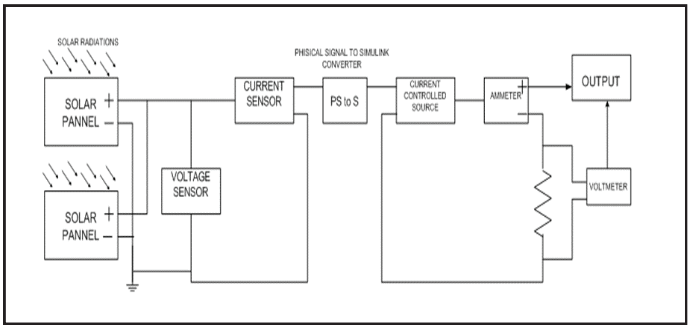
The proposed multilevel inverter generates two output voltages that must be shifted by 90 degrees. The Le-Blanc transformer is used to obtain a three-phase balanced voltage system at the output of the power converter system. The LeBlanc connection transformer is an asymmetrical winding transformer, which is usually used to transform a three-phase voltage system into a two-phase supply.

VIII. The Diode Clamped Five Level inverter

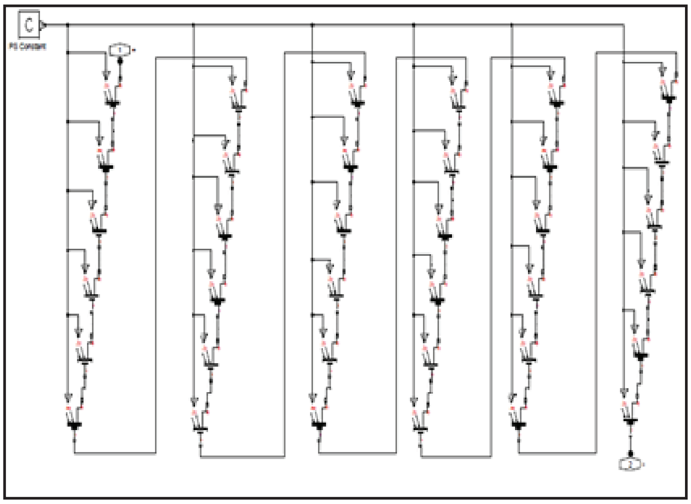
The most commonly used multilevel topology is the diode clamped inverter, in which the diode is used as the clamping device to clamp the dc bus voltage so as to achieve steps in the output voltage. Thus, the main concept of this inverter is to use diodes to limit the power devices voltage stress. The voltage over each capacitor and each switch is V_{dc}. An n level inverter needs (n-1) voltage sources, 2(n-1) switching devices and (n-1) (n-2) diodes. By increasing the number of voltage levels the quality of the output voltage is improved and the voltage waveform becomes closer to sinusoidal waveform.

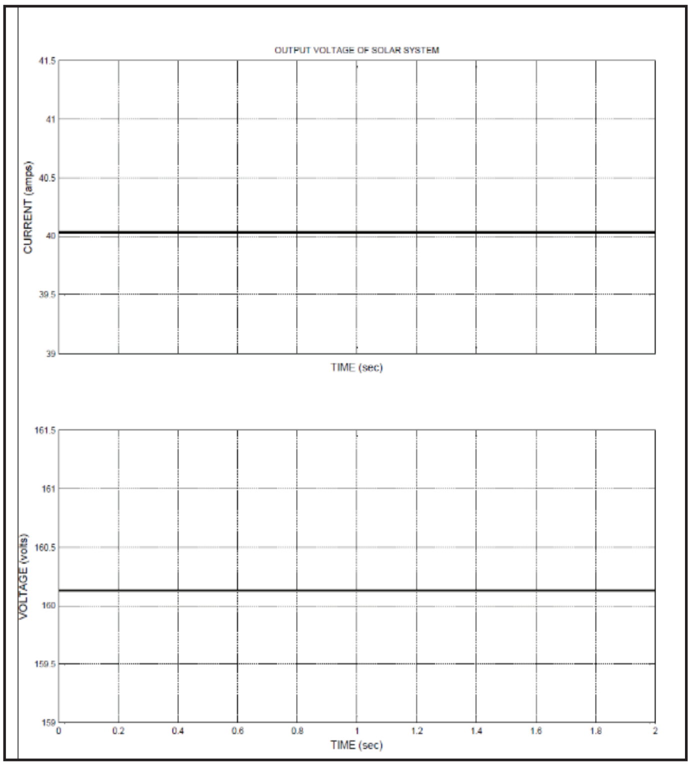
VII. Simulation Results

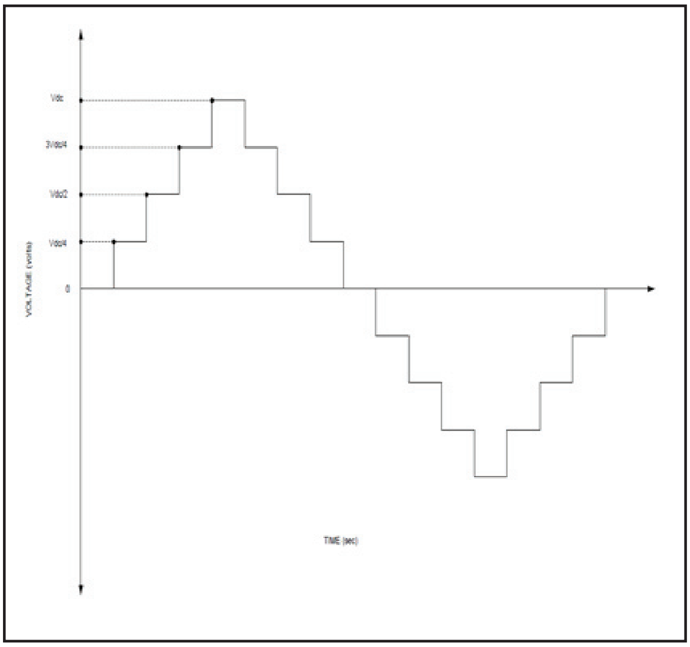
The proposed power converter structure and control system have been implemented in Matlab/Simulink and its Sim Power System Toolbox. The multilevel operation of the power converter can be seen in Figs. From this last figure it is also possible to confirm the multilevel operation of the proposed power converter and also allows confirming the five level shape of the output voltage waveform of full power converter.

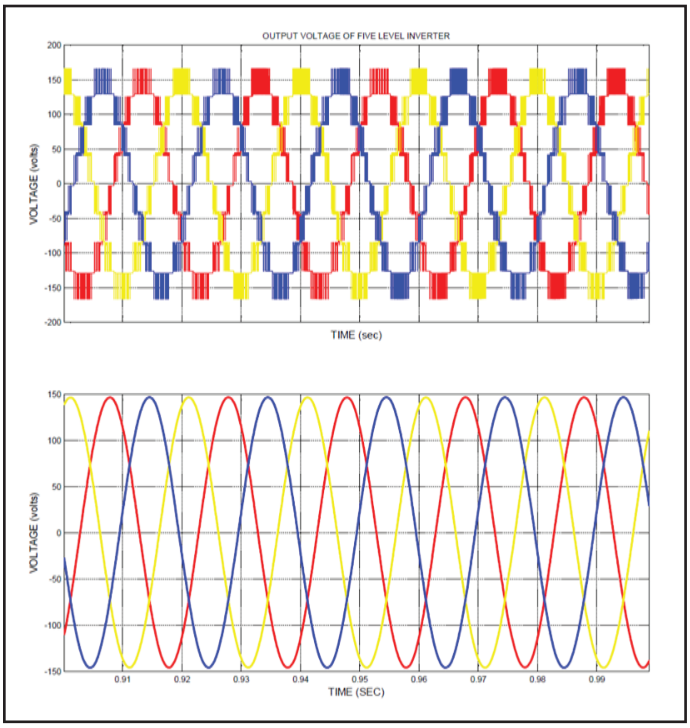


Switches / Voltage	A11	A12	A13	A14	A21	A22	A23	A24
V5=Vdc	1	1	1	1	0	0	0	0
V4=3Vdc/4	0	1	1	1	1	0	0	0
V3=Vdc/2	0	0	1	1	1	1	0	0
V2=Vdc/4	0	0	0	1	1	1	1	0
V1=0	0	0	0	0	1	1	1	1









VII. Conclusion

A new power conversion structure for a grid-connected photovoltaic system has been presented. This conversion structure was developed for a multi-string technology configured PV system. At the output of each PV array string is connected a DC/DC power converter with a MPPT algorithm. To obtain an AC signal a DC/AC multilevel with two single-phase voltage source inverters and a four wire voltage source inverter is used. Considering distinct input DC voltages for the two single-phase inverters and for the four wire inverter, allows to extend the number of achievable voltage levels at the multilevel inverter output. To achieve this characteristic, the DC/DC power converter connected to the single-phase voltage source inverter must generate a V voltage, while the DC/DC power converter connected to the four wire inverter must generate a 2V voltage. In this way, a seven level shaped output voltage signal is obtained. The multilevel inverter generates two 90º shifted output voltages. To obtain a grid connected three phase balanced system LeBlanc transformer was used.

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