Grid Connected PV System with Single Source Five Stage Multi Level Inverter

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Abstract- **This five-stage converter helps to nearly double the power handling capacity of the inverter as compared to two-stage converters. Design challenges for grid-connected solar photovoltaic systems related to the power conditioning units are power quality, efficiency, reliability, cost of implementation, etc. This article deals with a single DC-source-based five-level-doubling network high-resolution multilevel inverter topology with the appropriate blend of switches to address most of the practical constraints of central DC source application. A five-stage high-resolution multilevel inverter solution is adapted to double the inverter utilization as well as to increase efficiency. Reactive power handling and fault-blocking capability of the system are also demonstrated in this work. The converter is extensively simulated using MATLAB/Simulink. Experimental results from the laboratory prototype confirm the usefulness of the proposed concepts.**

The main bridge is fed by a common PV array and isolated sources are used to feed auxiliary bridges. Although the power required by these isolated sources is much less, it is reflected in the total system cost. These isolated sources have been removed with the help of a low-gain PI controller. In this converter, only the main bridge is fed by the dc source. For grid-connected solar PV applications, all the main bridges are merged with the help of transformers and fed by a common PV array. As three DC buses are combined, there will be no mismatch during unbalancing. Hence, the system will not deviate from MPPT and power quality will be maintained. Boost converter is used in between PV and inverter. This two-stage converter helps to nearly double the power handling capacity of the inverter as compared to single-stage converters.

Keywords: **Photo Voltaic (PV), Maximum Power Point Tracking (MPPT), Sinusoidal Pulse Width Modulation (SPWM), Total Harmonic Distortion (THD), Sliding Pattern Controller (SMC).**

I. INTRODUCTION

Integration of photovoltaic (PV) systems into the grid has become an important part of sustainable energy solutions that require efficient and reliable energy production systems. Single-phase five-stage multi-level inverter is a construction method for grid-connected photovoltaic systems, aiming to improve energy conversion efficiency and provide uninterrupted line connection. This inverter topology integrates many important components such as PV array, grid interface, DC-DC converter, Maximum Power Point Tracking (MPPT) algorithm and controller. It is also connected with energy storage, multiphase H-bridge inverter and coupling transformer for efficient operation.

The combination of advanced control techniques such as sinusoidal pulse width modulation (SPWM) and sliding type controllers provides precise control and highpower output, making it suitable for many transport applications. The converter solves the harmonic and power quality problem in grid-connected photovoltaic systems. MPPT-controlled DC-DC converters enable energy harvesting from PV modules, while energy storage provides buffers to manage supply and demand fluctuations. Multiphase H-bridge inverters combined with SPWM produce high-quality AC products with low variance, which is important for grid compatibility. The coupling transformer also separates the inverter output and makes it compatible with the grid voltage. In addition, the sliding control type makes the body strong and stable, ensuring that the power transfer is good and the response to changes in the load and environment is not good. This combination not only increases the efficiency and reliability of photovoltaic systems, but also supports the integration of renewable energy into the grid.

II. ANALYSIS OF MULTILEVEL INVERTER

Five-stage multi-level inverters for grid-connected photovoltaic systems combine many important factors for efficient energy conversion and reliable grid connection. Photovoltaic panels produce direct current and are optimized using the Maximum Power Point Tracking (MPPT) algorithm to ensure best performance in different environments. The DC-DC converter increases the voltage to a level suitable for the inverter. The multiphase H-bridge inverter is controlled by sliding mode control (SMC), which converts DC power to AC power at various voltage levels, reducing harmonics and improving power quality.

Seamless synchronization is achieved by using Sinusoidal Pulse Width Modulation (SPWM) technology to synchronize the inverter output with the grid. Energy storage devices such as batteries are used to store excess energy, increase system reliability, and provide backup power when solar power is low. They play an important role in grid connection with photovoltaic systems. They reduce total harmonic distortion (THD) in the output waveform by creating multiple voltage levels, thus providing better power to the grid. Sliding Pattern Controller (SMC) increases the inverter's energy response and robustness to system uncertainties and external disturbances. Coupling transformers are used to match the inverter output to the grid, ensuring safety and efficiency. In addition, the use of SPWM enables precise control of switching states, enabling more efficient and effective switching. The combination of these technologies within a multi-stage inverter framework provides a reliable and cost-effective way to integrate photovoltaic systems into the grid and promote the use of new renewable energy.

III. SYSTEM DESCRIPTION

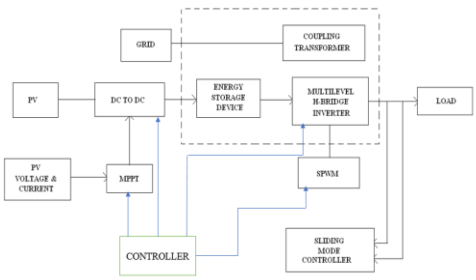

Figure 1. Block Diagram of Proposed System

A five-stage multi-level inverter for grid-connected photovoltaic systems combines many important factors to increase efficiency, reliability and performance. At the heart of the system is a photovoltaic (PV) array that captures solar energy and converts it into electric current (DC) electricity. This DC source is then optimized by MPPT to ensure that the PV array operates at maximum voltage in different situations. The optimized DC power is fed to the DC-DC converter, which adjusts the voltage level to meet the requirements of the inverter. Provide energy storage devices, such as batteries, to store excess electricity from peak solar energy for use during periods when solar energy is low or demand is high. The controller manages the operation of the entire system, coordination of the PV array, energy storage and grid to ensure stability and efficiency.

Convert DC power to alternating current (AC) suitable for line connection. This polyphase inverter uses a five-phase architecture to produce good AC output and reduce harmonics, thus improving overall power quality. Sinusoidal pulse width modulation (SPWM) technology is used to control the modulation of the inverter's power supply, ensuring high efficiency and output waveform shaping. Coupling transformers are used to adjust the voltage level between the inverter and the grid, facilitating integration. Additionally, a sliding mode controller (SMC) is used to control the operation of the drive, thus increasing the dynamic response and stability of the system. The final AC output is sent to the load and the grid to ensure reliability and efficiency when using solar energy.

IV. EXPERIMENTAL SETUP

The experimental setup of a five-phase multilevel inverter in a grid-connected photovoltaic system has several important features. The system starts with a photovoltaic (PV) array that captures solar energy and converts it into direct current (DC). This DC power is fed to a DC-DC converter, which is required to improve the voltage level in further processing. The MPPT (Maximum Power Point Tracking) controller is integrated with the DC-DC converter to ensure optimal performance by adjusting the operating point of the PV array. The regulated DC output is then fed to an energy storage device such as a battery to provide short supply and maintain stable power. Switch to alternating current (AC). The inverter uses SPWM (Sinusoidal Pulse Width Modulation) technology to generate high-quality AC power at various voltage levels, reduce distortion and improve performance.

A sliding type controller is used to improve the dynamic response and robustness of the system and ensure control under various conditions. The AC output of the inverter is passed through a coupling transformer to match the voltage and required phase. Finally, the AC power is delivered to the grid and local load to ensure reliability and efficiency. This configuration not only improves the efficiency and stability of the energy converter, but also improves the overall efficiency of the grid-tied photovoltaic system.

V. COMPARISON OF FIVE STAGE MULTILEVEL INVERTER

Five-phase multi-level inverters for grid-connected photovoltaic systems integrate many components for power management. Photovoltaic modules generate current and are optimized using the MPPT algorithm in the DC-DC converter. Energy is stored in storage devices and controlled by a controller. A multi-level H-bridge inverter driven by SPWM converts DC to AC and ensures grid compatibility of coupling transformers.

Feature	Single Stage Inverter	Five Stage Inverter
Efficiency	Generally High Due to Reduced Switching Loss	Lower Compared to Single Stage
Complexity	Lower Simple Design	More Components and Control Complexity
Cost	Lower Initial Cost	Higher Cost
Output Quality	Higher Total Harmonic Distortion	Lower THD Better Power Quality
Reliability	Generally Higher Due to Fewer Components	Can Be Lower Due to Higher Component Count
Control Requirements	Less Demanding	More Advanced Control Needed

Table1.comparision of single stage and 5 stage multilevel inverter

VI. SIMULATION CIRCUIT

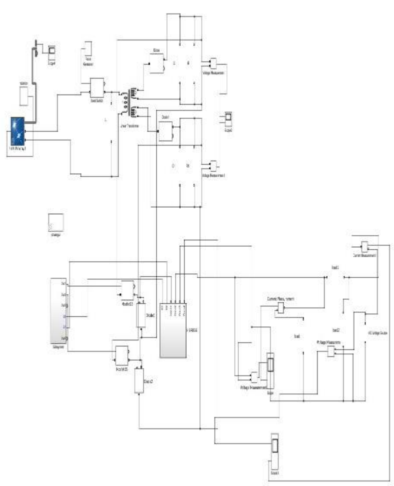

Figure 2. Simulation diagram of proposed circuit

VII. SIMULATION RESULTS

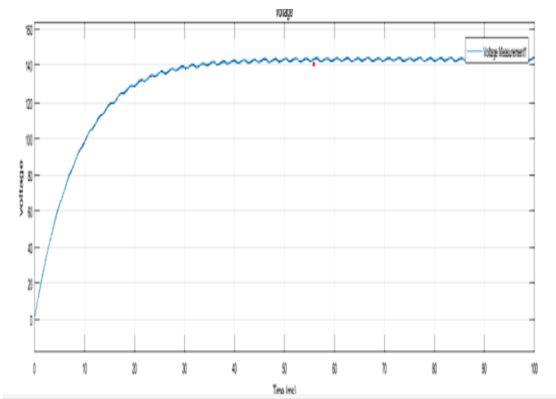

Figure 3. PV Pannel waveform

The simulation output voltage waveform for PV Pannel is shown in figure3.The value of output supply for the proposed converter is 15V of dc voltage.

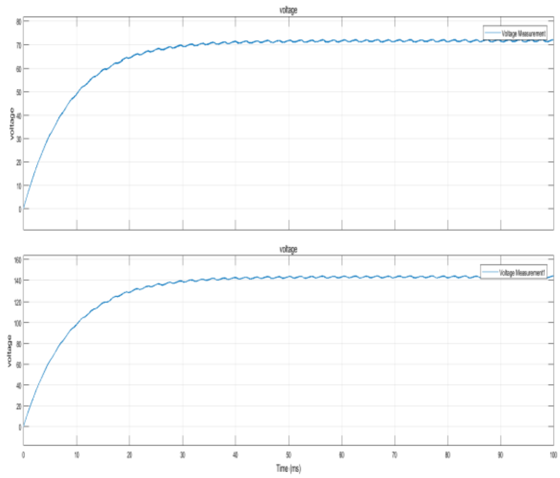

Figure 4. Linear Transformer Waveform

The Simulation Voltage measurement Waveform for Linear Transformer is shown in figure 4. The Value of linear transformer voltage measurement for V1=70V and V2=140V.

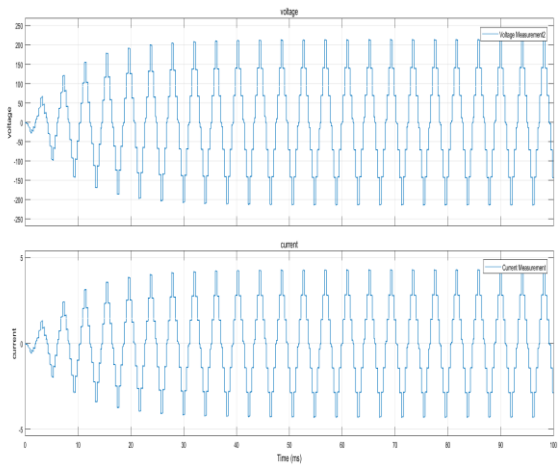

Figure 5.H-Bridge Waveform

The simulation Current and voltage waveform for H-Bridge as shown in figure 4.5 (c). The value of H-BRIDGE current is of 5A and the voltage is of 200V.

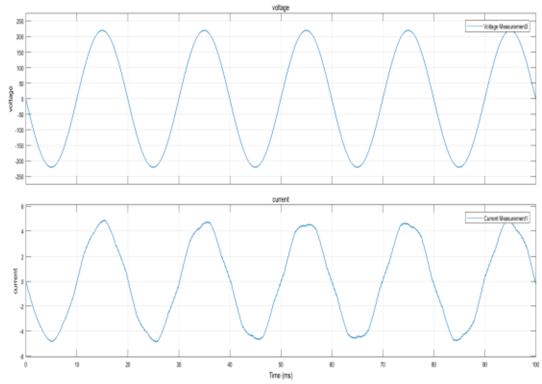

Figure 6. Output Waveform

The simulation waveform for output voltage and current is shown in figure 6. with the respective output voltage 230V and current 5A.

VIII. HARDWARE DESCRIPTION

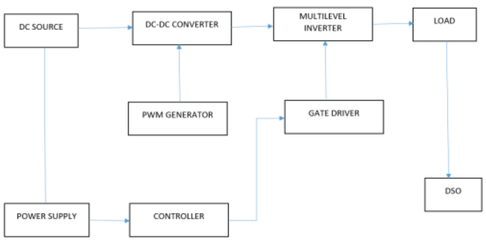

Figure7.Block diagram of hardware system

A five-phase multi-level inverter for grid-connected photovoltaic (PV) systems consists of several key components that work together to provide efficient power conversion and distribution. The system usually starts with DC power from photovoltaic panels. These panels convert sunlight into direct current (DC) power. This DC power is then fed to the power unit; here the voltage is stabilized and controlled to ensure the output is consistent. A pulse width modulation (PWM) generator then produces the high-frequency signal needed to control the DC-DC converter, which steps up or down to meet the inverter's needs. The core is a multi-stage inverter that takes conditioned DC energy and converts it into alternating current (AC) suitable for grid connection. The controller oversees the entire process by checking that the operation of the PWM generator and DC-DC converter is efficient and effective.

The driver gate is used to connect the control signal of the controller to the power converter in the inverter. Use a digital storage oscilloscope (DSO) to monitor and test performance to ensure all components are working properly. Finally, the load (which can be the local grid or the grid itself) receives standard AC power. This configuration helps solve the electricity problem by providing continuous energy to the grid by making the PV system more efficient.

IX. HARDWARE CIRCUIT DIAGRAM

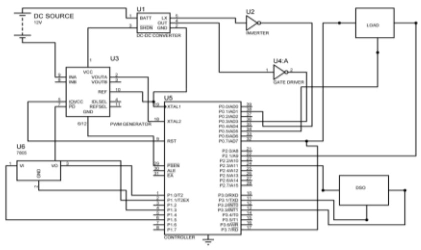

Figure 8. Circuit diagram of Proposed system

Single-phase five-stage multi-level inverter for grid-connected photovoltaic systems is a complex energy conversion system designed to efficiently use solar energy for grid connection. The core of the system consists of many components that are interconnected to make energy transfer efficient and interconnect the grid. PWM (Pulse Width Modulation) generators are used to generate switching signals, DC-DC converters for voltage regulators, controllers to control entire system operation, gate drivers to control inverter switching points, and digital A storage oscilloscope (DSO) for analysis and analysis. analysis. The core of this system is a multi-stage inverter that is responsible for converting the DC power output from the photovoltaic array into the AC power required to connect the grid. Additionally, a load is connected to the output of the inverter to use the AC power produced.

The output of the DC-DC converter is fed to a multilevel inverter, which has several power converters arranged in a cascade configuration. PWM generators generate control signals for these switches based on the desired output waveform. The gate driver can change the output voltage according to the PWM signal. Finally, the output of the inverter is connected to the grid through a filter and load. The control room oversees all operations, ensuring the best power transmission and connection plans. Connecting everything is important for the system to run smoothly, promoting solar energy use and integration.

X. HARDWARE PROTOTYPE

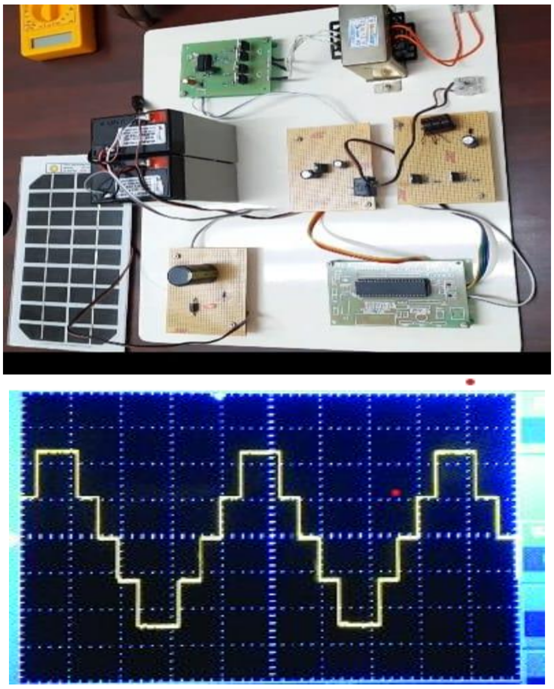

Figure 9. Hardware Prototype for five stage multilevel inverter with real time signal.

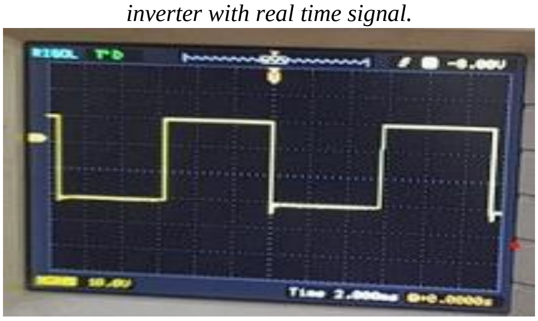

Figure 10. Real Time signal of MOSFET switch

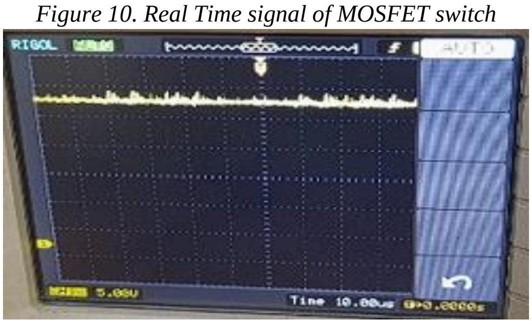

Figure 11. Real Time signal of Boost Converter

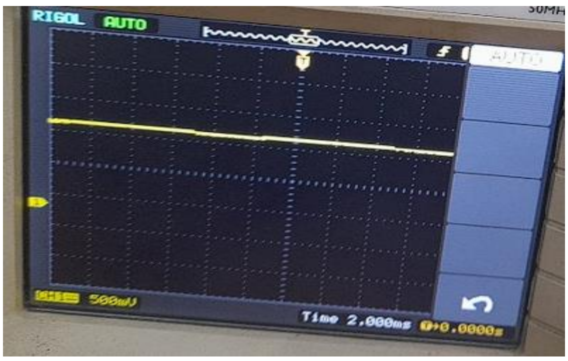

Figure 12. Real time signal of solar PV

Table 2. Comparision of THD value in percentage

Parameters	Values
PV array	1KW
Internal resistance Ideal switch	0.001 ohm
Diode resistance	0.001 ohm
Initial current of MOSFET	0 A
Load resistance	750 ohm
Load inductance	0.8e^-3 H
Peak amplitude of AC voltage source	220 V
Frequency of AC voltage source	50 Hz

Table3. Parameter values of hardware kit

Inverter Type	Voltage THD in %
2 stage multilevel inverter	26%
5 stage multilevel inverter	15%

THD CALCULATION

The total harmonic distortion (THD) is the square root of the sum of the squares of the harmonic voltages divided by the fundamental voltage, which most be under 5% which is expectable for the current wave form :

$$\text{THD} = \frac{\sqrt{V_2^2 + V_3^2 + V_4^2 + \cdots + V_n^2}}{V_1}$$

XI. CONCLUSION

In summary, single-source five-stage multi-level inverters for grid-connected photovoltaic systems show significant improvements in efficiency, reliability and integration. With key components such as integrated photovoltaic (PV) arrays, line connections, DC-DC converters, maximum power point tracking (MPPT), controllers, energy storage, multiphase H-bridge inverters, coupling transformers, sinusoidal pulse width modulation (SPWM), load and sliding mode controller, the system exhibits good performance and power management. MPPT-equipped DC-DC converters extract the best power from the PV array, while energy storage provides stable energy even when the sun changes.

The multiphase H-bridge inverter controlled by SPWM converts DC power into high-quality AC power supply suitable for the tie line to ensure small difference and high efficiency. Adaptive control improves the dynamic response and stability of the system under different operating conditions. Integrating these components into an integrated system provides a versatile and reliable solution for grid-connected optoelectronic applications. The use of coupling transformers to ensure the suitability of voltage and isolation between the inverter and the grid, thus protecting photovoltaic systems and electrical equipment. Overall, this system provides a good way to use solar energy and helps achieve sustainable energy use by increasing energy efficiency and productivity.

XII. FUTURE SCOPE

Its components include PV modules, grid, DC-DC converter, Maximum Power Point Tracking (MPPT), Controllers, energy storage, multi-level H-bridge inverters, coupling transformers, sinusoidal pulse width modulation (SPWM), load and sliding mode controllers for wide application It has facilities. An important aspect of future development is improving performance and reliability with improved equipment and new designs. With continuous research into high-quality photovoltaic materials and better solutions such as next-generation batteries or supercapacitors, the overall performance of photovoltaic systems can be well improved. Additionally, advances in MPPT algorithms and sliding mode controllers enable more accurate and faster peak power generation, thus increasing energy harvesting from PV modules even in different environments. The field is the integration of smart devices and Internet of Things (IoT) capabilities. Future iterations of the system may include real-time monitoring, predictive maintenance, and grid management to improve grid efficiency and performance.

The use of advanced communication systems and data analysis allows effective balancing of products, detection of faults and stable and reliable distribution of electricity. Additionally, the use of solid-state transformers and bi-directional inverters can facilitate the use of renewable energy by facilitating the interaction between the grid and the power supply. Based on the demand for renewable energy, these advances are important to improve the stability, efficiency and availability of grid-connected photovoltaic systems.

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