AN ANALYSIS OF TRADITIONAL INVERTER AND Z- SOURCE INVERTER

Thokal Prashant Vijay
Regd No: 221120023
Research Scholar
Department Of Electrical Engineering
SJJT University, Rajasthan

Dr. Kasa Chiranjeevi
Guide
Department Of Electrical Engineering
SJJT University
, Rajasthan.

Dr. Maram Ashok
Professor & Principal
Malla Reddy Institute Of Engineering And Technology
Hyderabad

Abstract

A combination of factors including the inevitability of a decline in fossil fuel supplies and the negative impacts on the environment has increased interest in finding renewable energy alternatives. Solar and wind power, two examples of renewable energy, are much superior than fossil fuels. Manufacturing improvements have reduced the cost of materials and improved energy collection, propelling solar photovoltaic (PV) modules to the forefront of the renewable energy industry. As an additional illustration of solar energy use, the electricity produced by PV panels is clean, flexible, and pollution-free. The power conversion step is necessary for the PV source to interact with the existing electrical utilities since it is a low voltage dc source. The high dc voltage required to link the central inverter is achieved by connecting many panels in series and/or parallel in big solar power systems. A significant drop in system output power may occur if even a single PV module experiences poor solar irradiation or low cell temperature due to a shift in ambient circumstances. A traditional grid tie inverter becomes a dynamic reactive power compensator, by regulating the output voltage of the inverter. The ZSI overcomes the restrictions and conceptual boundaries of the VSI (voltage source snverter) and CSI (current source inverter). The ZSI has a separate LC network used to combine the converter network to the source and thus gives unique features as compared to traditional VSI and CSI.

Keywords: *Solar, wind power, fossil fuel, photovoltaic, VSI, CSI, traditional grid.*

Introduction

The Voltage Source Inverter (VSI) and the Current Source Inverter (CSI) are two traditional types of inverters. For the VSI, a dc voltage source paralleled with a large capacitor feeds a three-phase bridge (consisting of six switches). This dc voltage source can be a battery, fuel cell or solar cell. For the CSI, a dc current source feeds a three-phase bridge (consisting of six switches). This dc current source can be a large inductor which is fed from a battery, fuel cell or solar cell. Despite widespread use, these two traditional inverters have problems. For example, for the VSI, the ac output voltage is lower than the input dc voltage, thus, it can only perform a buck dc-ac power conversion. On the other hand, for the CSI, the ac output voltage is greater than the input dc voltage, thus, presenting a voltage boost dc-ac power conversion. Therefore, in applications where both voltage buck and boost are needed, an additional dc-dc converter should be placed before both VSI and CSI, which significantly increases the complexity and cost of the system. To overcome this problem, and many other problems of traditional inverters, in 2002, the topology of the Z-source inverter was proposed by Peng.

Unlike other inverters, the Z-source inverter can provide shoot-through states to boost the input dc voltage when both switches in the same phase leg are on, and, because of this feature, the reliability of the inverter is greatly improved. In comparison to traditional inverters, the Z-source inverter is more reliable, has lower costs and higher efficiency. In recent years, the Z-source inverter has received wide attention in research and industrial applications, including motor drives, photovoltaic systems and the traction drive of fuel cell-battery hybrid electric vehicles. Besides, some investigations have also presented new methods for performance improvement of the Z-source inverter, such as reduction of Z-source capacitor voltage stress, minimization of inductor current ripple, and improvement of voltage boost ability. For this purpose, the formulas of the inductor current ripple, capacitor voltage ripple, voltage stress on the devices and capacitors, switching device power and switching loss, are calculated. Simulation results are also presented to validate the analysis.

Literature Review

Maalandish et al. (2018) describe a multi-phase interleaved converter that is split into two halves and equipped with a few switches, diodes, inductors, and capacitors in each. By adding more VM stages in between the phases, the high voltage gain may be improved. In the absence of a transformer, the gain is quite high. In addition, the switch in the converter is subjected to low voltage, which contributes to the converter's high efficiency. Ripple in the input current is minimal because of the interleaved method. It is questionable whether or not to use this converter as a front-end converter for microinverter applications due to the large number of stages involved. To raise the voltage of the SPV module from its low starting point.

Ghosh (2019). This approach combines features from both the improvised binary sequence (IBS) MPPT algorithm and the standard perturb and observe MPPT technique. Since the maximum power point of a solar module varies depending on factors like temperature and solar radiation, this algorithm provides the IBS algorithm with some much-needed leeway. Using the IBS method, the starting operating point may be determined. The P&O algorithm then takes over to manage the gradations and adjustments. In the event that sudden changes in operating circumstances are detected, the algorithm will start again by resetting all of its settings and reapplying the IBS algorithm.

Voltage Source Inverters (VSI)

The most common VSI system configurations are enumerated. Explained the voltage source converter as a device which receives DC voltage at the source and converts to an AC voltage on the load side. Depending on the application the AC voltage can either be constant or variable. The converter circuit can operate as either inverter or as a rectifier. A voltage source inverter should have a constant voltage source at the input. An inverter can require a large capacitor to be connected at the input to make the source voltage inflexible. The dc voltage which can be obtained from solar photovoltaic array can either be constant or flexible. The output of the inverter can be single phase or multiphase and the wave form at the output can have square wave, sine wave, PWM wave or stepped wave. Due to the DC voltage at the converter input, the power semiconductors conduct in forward-biased. Therefore, the use of IGBTs and other devices such as MOSFETs, IGCTs, BJTs and GTOs are preferred because of their asymmetric blocking capability. In the past, the forced commutated thyristor converters were used before they became outdated. There is a free reverse current when a diode is connected to the device. It is important to know that the AC generated voltage wave is not affected by the load factors in a voltage source converter. Some of the applications in which voltage source inverters are being used are;

- AC power supply from PV array or battery
- AC uninterruptible power supply (UPS)
- Active harmonic filter
- Induction heating
- AC motor drives
- Static VAR generator (SVG) or compensator

A Current Source Inverter (CSI) is a type of DC-AC Inverter that converts DC input current into AC current at a given frequency. The frequency of the output AC current depends on the frequency of the switching devices such as thyristors, transistors, etc. It is also known as a current-fed inverter (CFI) and the input current of this inverter remains constant. In an ideal CSI, the output current is independent of the load. However, the output voltage is dependent on the nature of the load. Current source inverters are ideal for various applications such as speed control drives for AC motors, synchronous motor starting, plasma generators, induction heaters, UPS units, IM motors, lagging Var compensators, and power factor correction units.

A current source inverter consists of a DC current source (which can be a battery connected to an inductor, or other switching devices such as thyristors, IGBTs, MOSFETs, etc), filters, and an AC load. It is available in single-phase and three-phase configurations.

Z source Inverter

Z-source inverters (ZSI) have piqued people's interest because of their ability to embrace input voltage while a constant output ac voltage. They have the potential to solve problems with current inverters – particularly in topics concerning renewable energy usage. The ZSI system is made up of an impedance network that serves as a source for the traditional VSI system. To reduce the voltage tension on the inverter bridge, a variety of PWM techniques have been proposed. The traditional space-vector modulation (SVM) is modified so that it can be applied to the ZSI. The voltage tension, voltage gain, performance, average switch and current ripple, system of the updated SVM techniques are now compared (SDP). The harmonic at the output is critical so as to minimise in inverter applications. The traditional twolevel inverter SPWM technique is used to outsource these modulation techniques. On refering the DC relation voltage usage, and THD values the different modulation techniques are compared to one another. For leakage current reduction, a comprehensive review of various modulation strategies is presented, and a new modulation strategy based on space vector topology is proposed.

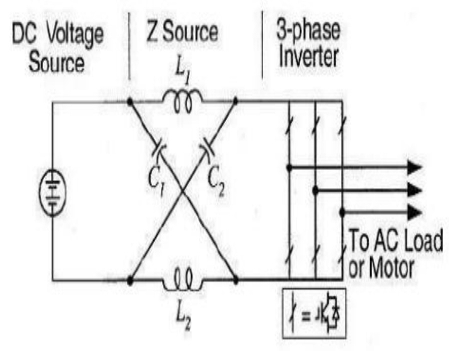

Figure: ZSI Circuit Diagram

The impedance network frontend of Z-source inverter topology, is made up of two inductors and two capacitors. Unlike a voltage-source inverter, which can only operate in 6 active and 2 zero state. It can also operate in shoot-through states, in which the upper switch and lower switch in single or more phase legs are gated on at the same time. The Z-source inverter is more resistant to EMI and parasitic device switch because shoot-through events no longer cause inverter failures.

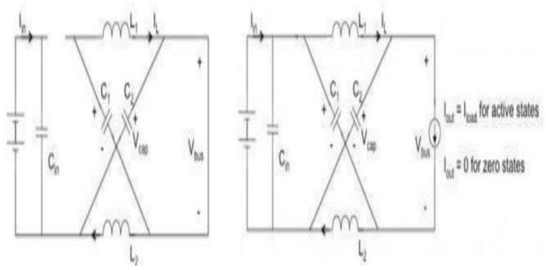

Figure: Shoot through State and Non-shoot Through state

Methodology

Solar cells prepared by the use of crystalline silicon are often called traditional, conventional, or first-generation solar cells, and remained the most common type up to the present time. At present solar cells have been manufactured by different semiconductors, using various device configurations and employing single crystal, poly-crystal, and amorphous thin-film structure. In monocrystals, the periodicity holds out throughout the material. In polycrystalline crystals, the periodicity does not extend throughout the material but is interrupted at grain boundaries. Grains or crystallites are smaller than the size of the pattern unit which forms the periodicity. The size of the grains may extend from macroscopic dimension to several Angstroms. When the size of the grain becomes comparable with the size of the pattern unit, the periodicity of the structure is completely disturbed, it is no longer single or Polycrystalline it becomes an amorphous substance. When a ray of light incident on the dewdrops, three phenomena maybe occur viz., reflection, refraction, or diffraction. Under these phenomena, incoming solar radiations were received and influence the efficiency. With Polycrystalline, Mono-crystalline, and Amorphous Silicon PV module .

Simulation Results And Discussion

The software simulation on few H6 topologies is carried out to compare the overall performance with the proposed inverter topology using MATLAB/Simulink software. The SEPIC converter simulated with the IC algorithm to check the effectiveness in tracking the MPP, and its performance. So, the first sub-section discusses the stand-alone SEPIC converter simulation and its results. Secondly, the sub-section discusses the stand-alone proposed new converter simulation and its results. Since the new dc-dc NIS converter in this thesis is already discussed elaborately in Chapter 4, the proposed new dc-dc converter simulated for the variable load and variable solar irradiation condition, and then connected as the frond-end dc-dc converter for the new inverter proposed, moreover, the same is simulated to validate the performance with the proposed NIS dc-dc converter.

Simulation of the SEPIC Converter with the IC Algorithm

First, the simulation is carried out to analyze the DC-DC converter stage to extract the maximum power from the PV module. Table 5.4 presents the SEPIC converter parameters for the simulation for the various test condition such as a change in solar irradiation and change in load condition. The MATLAB/Simulink model for the simulation is presented in Figure 5.16. The resistive load parameters and the various parameters of the SEPIC converter are respectively. From Figure 5.18, it is observed that the converter takes a finite time to reach the steady-state output voltage. The simulation results validated for the two test cases. In test case 1, the performance of the MPPT algorithm is tested by varying the sun irradiation from 1000 W/m2 to 800 W/m2 at 0.15 s, and then to 600W/m at 0.3 s by keeping the constant load at 100Ω. During the change in insolation, the load parameters are oscillating over a period and reach the steady-state slowly.

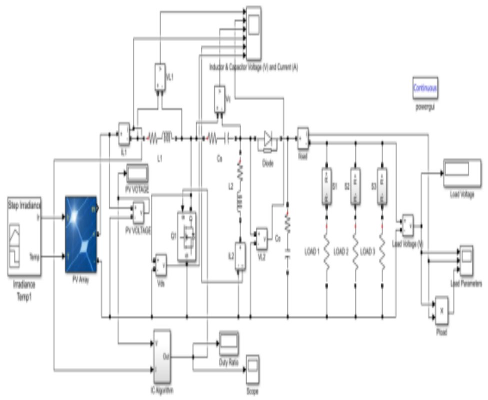

Figure 5.3 MATLAB/Simulink Model of the SEPIC Converter for the Stand-Alone Simulation

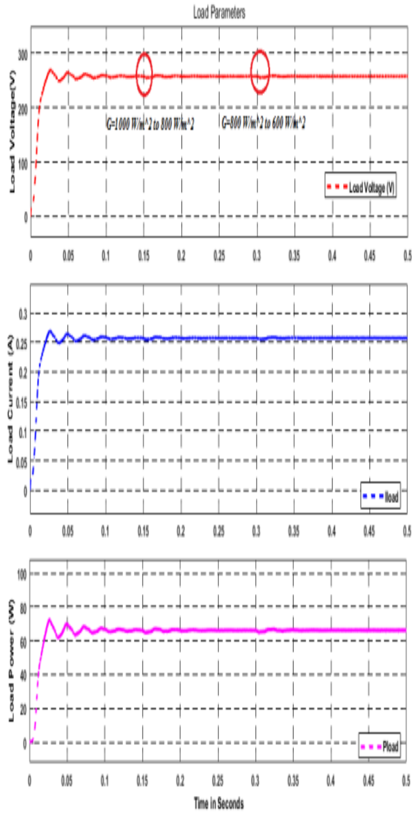

Figure 5.4 Simulation Waveforms for the Different Solar Irradiation with Constant Load; (a) Load Voltage in Volt., (b) Load Current in Amp., (c) Output Power in Watt.

The converter designed to produce the output voltage of 325 V for the grid-connected applications. However, the converter fails to boost the voltage, and the duty cycle reached nearer to unity. The effects of reaching the duty cycle nearer to unity discussed in the literature. The SEPIC converter cannot achieve the required voltage gain at a low duty cycle. The algorithm works fine, and it keeps tracks the maximum power under a change in irradiation conditions. The inductor voltages of the converter are equal in magnitude and opposite. The converter 's coupling capacitor blocks the dc current, and the average inductor current is zero.

The voltage stress across the switch is equaled to the output voltage of the converter. It results in higher conduction loss, selection of high RDS-ON switch, high cost, and lower efficiency.

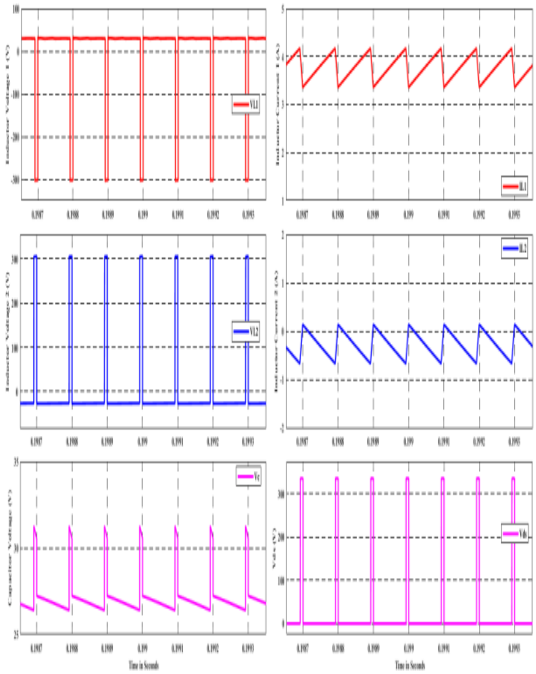

Figure Simulation Results of the Converter for the Different Irradiation at Constant Load; (a) Inductor (L1) Voltage in Volt. & Inductor (L1) Current in Amp., (b) Inductor (L2) Voltage in Volt. & Inductor (L2) Current in Amp., (c) Voltage across the Coupling Capacitor in Volt., (d) Switch Voltage in Volt.

In test case 2, the performance of the MPPT controller validated by changing the load from 100 Ω to 150 Ω at 0.2 s, and then to 200 Ω at 0.4 s by keeping the constant solar irradiation at 1000 W/m2. The resistive load parameters and the various parameters of the SEPIC converter are shown in Figure 5.19 and Figure 5.20 respectively. Like case 1, the converter exhibits more oscillation on the load parameters and reaches the steady-state slowly. Like case 1, the converter fails to boost the voltage to 325 V, and the duty cycle of the converter reached nearer to unity (97%). The SEPIC converter cannot achieve the required voltage gain at a low duty cycle. The inductor voltages of the converter are equal in magnitude and opposite.

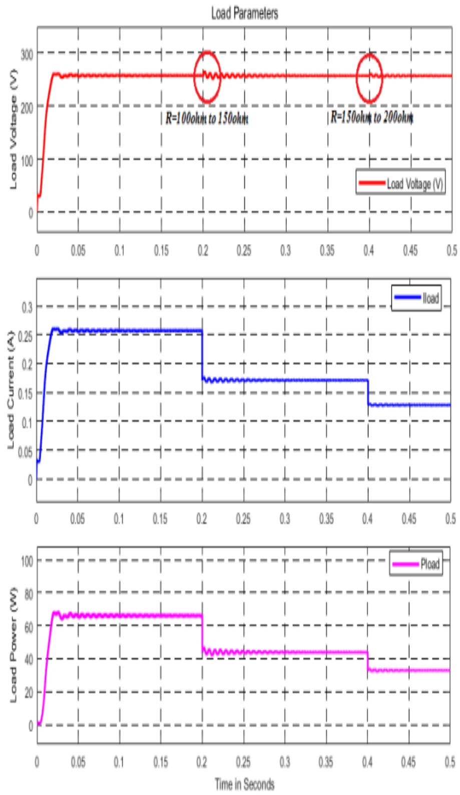

Figure Simulation Waveforms for the different Load with Constant Solar Irradiation; (a) Load Voltage in Volt., (b) Load Current in Amp., (c) Output Power in Watt.

The converter 's coupling capacitor blocks the dc current, and the average inductor current is zero. The switching voltage stress across the MOSFET switch is more than the output voltage of the converter. It results in higher conduction loss, selection of high RDS-ON switch, high cost, and lower efficiency. The gate pulses generated after fixing the threshold for the inductor ripple current. If the inductor ripple current is high, the EMI issue increased. Whereas, if the inductor ripple current is low, the possibility of unstable gating operation. So, fix the ripple current as 20-40% of the rated input current. In this thesis, 30% of the rated input current fixed for the inductor ripple current. The switching voltage stress is more than the dc output voltage of the converter. The efficiency and the voltage gain of the converter are not up to the level of grid-connected applications. The features such as discontinuous input current, low voltage gain, high voltage stress, and low efficiency show that the SEPIC converter is not suitable for the grid-tied applications.

Since the power output of a solar system and its efficiency varies according to the location so, the study performed at a particular location is not generalized to all the sites. To study the effect of temperature and relative humidity on photovoltaic performance in outdoor conditions ambient temperature and module surface temperature, ambient humidity, and module surface humidity data were collected in Ajmer.

between power, ambient temperature, and relative humidity was estimated. Daily and seasonal changes of temperature were discussed, followed by extreme temperatures in different parts of the world. From the energy band diagram and equivalent circuit of the p-n junction, the temperature effect on open circuit voltage and short circuit current were studied. The type of installation of the PV system can influence the temperature of the module. Similarly, relative humidity is the important source of the depletion in solar cell current, voltage, power, and efficiency. From the recorded environmental data, the humidity varies with temperature variation, so also is the rate at which the solar system can supply power to an external circuit. Correlation coefficient R and the coefficient of determination R2 of the humidity with current, voltage, power and efficiency, have been calculated. A very strong positive correlation between ambient temperature and module temperature was found. It shows that the ambient temperature surrounding the module influence how hot the module will get. Module temperature and module surface humidity have a very strong negative correlation coefficient R (-0.9230) which means that as module surface humidity expands, Module temperature scale downs. A strong negative correlation occurs between module surface humidity and current, which means high module surface humidity, goes with low current. Voltage versus Module temperature has a correlation coefficient R (-0.8877), and R 2 linear coefficient of determination as (0.7881), which is a strong negative correlation. From the results, it is clear that humidity is in an inverse strong correlation with current, voltage, and power. Power is maximum below 35% humidity level and after that humidity drastically affects the power of the Solar Module.

Temperature and Solar Irradiance

The irradiance from the sun is a kind of electromagnetic energy. It is quantified by calculating the power received per unit area of Earth's surface. An examination of the source of energy's inherent form is necessary for extracting its full potential. Because the nuclear process in the sun is the source of the energy, the output from the sun's surface is relatively constant. However, solar irradiation varies seasonally and spatially throughout the year. If we take into account the orientation of the sun with respect to

Earth's surface, we can see that it is the primary factor influencing solar radiation. Based on time, temperature, and sun irradiation, the graph compares the suggested method to the current method. The charts provide a comparison study of the new method and the current incremental conductance. The suggested study thus produces greater results than the current method. When using the suggested method, solar irradiance is maximized in relation to temperature.

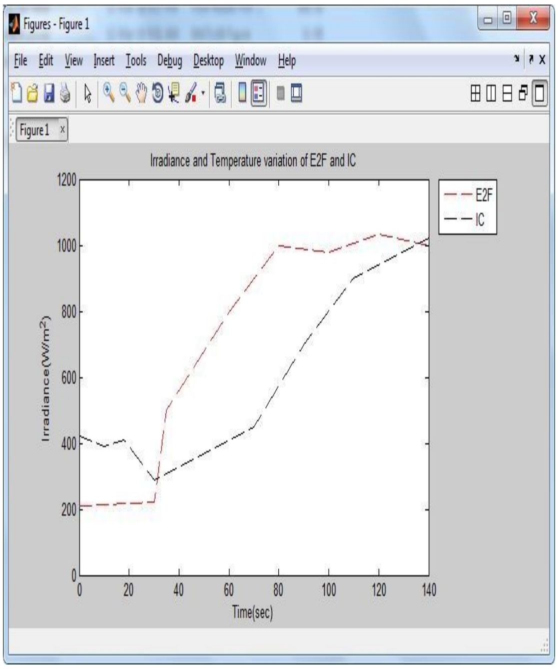

Figure: Comparative analysis for time vs temp vs irradiance

Three Phase Voltage Output

A stable output is achieved by using the Maximum Power Point Tracking (MPPT) method on the converter and a recently designed Indirect Sliding Mode Controller to manage the inverter's output (ISMC). Here, we evaluate the suggested and existing methods in relation to the three-phase voltage output. Point Common Coupling (PCC), the point when the PV system, the load, and the grid all converge, is used to assess the process in this simulation. Multiple electrical loads or customers may be linked to the electrical system, which is the basis of the PCC. As per IEEE standard 519, this junction must be within convenient walking distance of both the utility and the end user, so that both may take direct measurements

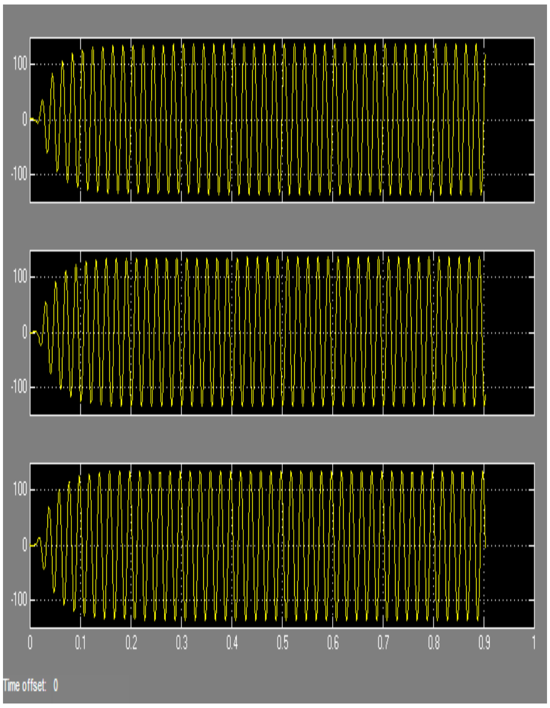

Figure: Comparative analysis for time vs temp vs irradiance

Conclusion

In recent years, it has become increasingly typical to use renewable energy sources like wind and solar PV. The configuration of PV power systems may be either single-stage or two-stage, with the latter being more typical. The most typical of them is the two-stage voltage source inverter (VSI) design for DC/DC and DC/AC. There are several conceivable configurations. Despite this, single stage topologies with a central inverter are more popular in a variety of applications than two stage topologies since they are less complicated and more economical. describes several forms of power converters, each with a distinct converter topology and coming from various sorts of impedance source networks. These devices are superior than typical converters because they have the potential to overcome such disadvantages. In, we provide them a thorough examination from the perspective of engineering application, which includes a study of their basic topologies, modelling, control, and modulation methods.

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