Implementation of Solar Powered Voltage Control in Multilevel Inverter by using Proposed Converter

Dr. S. M. Kamali
Professor and Head
Electrical and Electronics Engineering
Mahendra College of Engineering
Minnampalli, Salem

M. Mugundhan
Power Electronics and Drives
Electrical and Electronics Engineering
Mahendra College of Engineering
Minnampalli, Salem

***Abstract-* This paper represents a voltage control technique by using a proposed converter. The proposed converter used here is an Single Ended Primary Inductor converter which can be used for High-Medium power industrial applications. Multilevel inverters offer several advantages compared to the conventional cascade multilevel inverter in terms of lower dv/dt stresses, lower electromagnetic compatibility, smaller rating and better output features. This paper includes 11-level Diode Clamped Multilevel Inverter (DCMLI) using Sinusoidal pulse width Modulation techniques as the control strategies. The control unit here used is an ARTIFICIAL NEURAL NETWORKS. The algorithm has been developed within the carrier-based PWM framework to facilitate its implementation in diode clamped converters with eleven levels. A simulation model of 11-level DCMLI has been designed and developed. By increasing the level of inverter, balancing in line voltage and reduced THD is obtained. The good performance of the proposed modulation technique is demonstrated from simulation results for a eleven-level diode-clamped inverter and the 11-level diode clamped inverter MATLAB/SIMULINK model is designed and exhibited.**

Keywords- SEPIC, DCMLI, PWM, THD, FCMLI, CMLI, ANN, MATLAB/SIMULINK.

I. INTRODUCTION

Now-a-days, modern industrial devices are based on electronic devices such as programmable logic controllers and electronic drives. The electronic devices are sensitive to disturbances and become less tolerant to power quality problems such as voltage sags, swells, flickers and harmonics. Voltage dips are considered to be one of the most harmful disturbances to the industrial equipments. Voltage support at a load can be achieved by reactive power injection to the load at the point of common coupling. The common method for this is to install an mechanically switched shunt capacitors in the primary terminal of the distribution transformer. The mechanical switching may works on a schedule, via signals from a supervisory control and data acquisition (SCADA) system, with some timing schedule, or with no switching at all. The disadvantage of above is that, the high speed transients cannot be compensated. Some sags are not corrected within the limited time schedule of mechanical switching devices. Transformer taps may be used on the system, but tap changing under load is costly[2]. Another power electronic solution to the voltage regulation is the use of DC-DC converters. Converters are a class of custom power devices for providing reliable distribution power quality. They employ a series of voltage boost and buck technology using inductor for compensating voltage sags/swells. The Converter are mainly for sensitive loads that may be drastically affected by fluctuations in system voltage.

II. VOLTAGE CONTROL

Production of an electric energy from a renewable energy sources has led to an increased focus on power electronics systems. Renewable energy sources like solar, wind and wave energy are relying on power converters in order to exchange the power within the grid. These energy inputs are not constant with time always in fluctuating nature and anyone who wants to produce power for the grid has to make sure that their facilities are complying with national grid codes. The grid codes have a strict regulation when it comes to the voltage quality, including limits for rapid voltage variations, flicker and harmonic distortion.

Rapid voltage variations and flicker are matters of control of the inverter system, but harmonic distortion is created by the pulse width modulation and switching of the converter. Different filter circuit topologies can be used in order to reduce the harmonics generated by a switching action in the converter[1]. However, filters for high power converters can be of substantial size and weight and therefore also of great cost since they are made of several expensive metals. Therefore, a lot of effort is made to improve the converter system so that the filter can be reduced while the cried codes and system specifications are still met.

There are mainly two methods to reduces the harmonic distortion. One method is to optimize the switching sequence, with harmonics as the most important constraint. Another method is to use several levels to build the fundamental voltage i.e. converters with three levels or more. In an effort to improve voltage quality and efficiency, a simple control method for improving the voltage utilization factor of an multilevel inverter. It is applied to the multilevel inverter, and the operation principle and features are explained below, which includes Solar powered system[5]. The fluctuating input DC voltage has been converted into stable output voltage by using nine level Multilevel inverter.

III. DC TO DC CONVERTER

A. INTRODUCTION

DC to DC converters are important for an portable electronic devices such as cellular phones and laptop computers, which are supplied with power from batteries primarily. This electronic devices often contain several sub-circuits, each with its own voltage level requirement different from that supplied by the battery or an external supply (sometimes higher or lower than the supply voltage). Also the battery voltage declines when its stored power is drained. Switched DC to DC converters offer a method to increase voltage from a partially lowered battery voltage and also saves space instead of using multiple batteries to accomplish the same thing. Most of the DC to DC converters also regulate the output voltage. Some exceptions include high-efficiency LED power sources, also a kind of DC to DC converter that regulates the current through the LEDs, and simple charge pumps which double or triple the input voltage[8].

B. BASIC TYPES OF CONVERTER

Step-down - A converter where the output voltage is lower than the input voltage. A buck converter is a step-down DC to DC converter, where the output voltage is low. Its design is like the boost converter it have an switched-mode power supply that uses two switches (a transistor and a diode), an inductor and a capacitor. The simplest method to reduce a DC voltage is to use a voltage divider circuit, but voltage dividers waste energy, since they operate by bleeding off excess power as heat; also, output voltage isn't regulated (differs from input voltage). Buck converters, on the other hand, can have an efficiency (easily up to 95% for integrated circuits) and self-regulating, making them useful for tasks such as converting the 12–24 V typical battery voltage in a laptop down to the few volts needed by the central processor unit.

Step-up - A converter where the output voltage higher is than the input voltage. A boost converter (step-up converter) is a power converter with an output DC voltage is greater than its input DC voltage[3]. It is a class of switching-mode power supply (SMPS) contains atleast two semiconductor switches (a diode and a transistor) and atleast one energy storage element. Filters made of capacitors (sometimes in combination with inductors) are normally added to the output of the converter to reduce output voltage ripple or harmonics.

IV. MULTILEVEL INVERTER

The Inverter is an electrical device which converts direct current (DC) into alternate current (AC). The inverter is used for emergency an backup power supply in a home. The inverter is used in some aircraft systems to convert a portion of the aircraft DC power to AC power. The AC power is used mainly for electrical devices like radar, lights, radio, motor, and other devices. Now a day's many industrial applications have begun to require high electrical power. Some application in the industries however require medium or low power for their operation. Using a high electrical power source for all industrial loads may prove beneficial to some motors requiring high power, while it may damage the other loads. Some medium volt electrical motor drives and utility applications require medium voltage[4]. The multi-level inverter is like an inverter has been used since 1975 as alternative in high power and medium voltage situations. Multilevel inverter is based on the fact that sine wave can be changed into a stepped waveform having large number of steps. The steps being supplied from different DC levels with supported by series connected batteries or capacitors. The structure of multi- level inverter allows them to reach high voltages and therefore lower voltage rating device can be used. As the number of levels increases, the synthesized output waveform has more steps, producing a very fine wave and approaching very closely to the desired sine wave. It can be easily understood that as motor steps are included in the waveform the harmonic distortion of the output voltage wave decrease, approaching zero as the number of levels approaches to infinity. Hence Multi-level inverters offer a better choice at the high electric power end because the high volt- ampere ratings are possible with these inverters without the problems of high dv/dt and the other associated ones[7]. The basic types of multilevel topologies used are

(1) Diode Clamped Multilevel Inverters

(2) Flying Capacitors Multilevel Inverter

(3) Cascaded H-Bridge Multilevel Inverter

V. **PRINCIPLE OF OPERATION**

Here the DC source is an renewable energy system. The solar energy is used as an renewable energy system. The output of PV panel is connected to either battery or directly to the converter. DC to DC Converter used here is the proposed converter namely the SEPIC converter. It does the operation of both buck converter and boost converter. So the voltage produced by the source is fixed by the converter and sends the fixed voltage to multi level inverter. MLI used here is diode clamped multilevel inverter (DCMLI). Output from the MLI is not constant and it may affect the ac load. So one part of the output of MLI is taken and sends back to the control unit. Control unit proposed here is Artificial Neural Networks. ANN has two input, one from the reference voltage controller and another from the MLI. Output of ANN is an analog signal for control the dc source pulse either to boost the voltage or to buck the voltage. Then the analog signal converted into pulse by an ramp signal and relation operator. By pulse width modulation technique the analog signal converted into the required pulse. Switches here used are MOSFET and DIODE. Output voltages produced by the converter now an fixed dc voltage. Then the fixed dc voltage sends back to the Diode clamped MLI, and the fixed dc voltage is converted into an fixed ac voltage. AC voltage produced is sends back to the AC load.

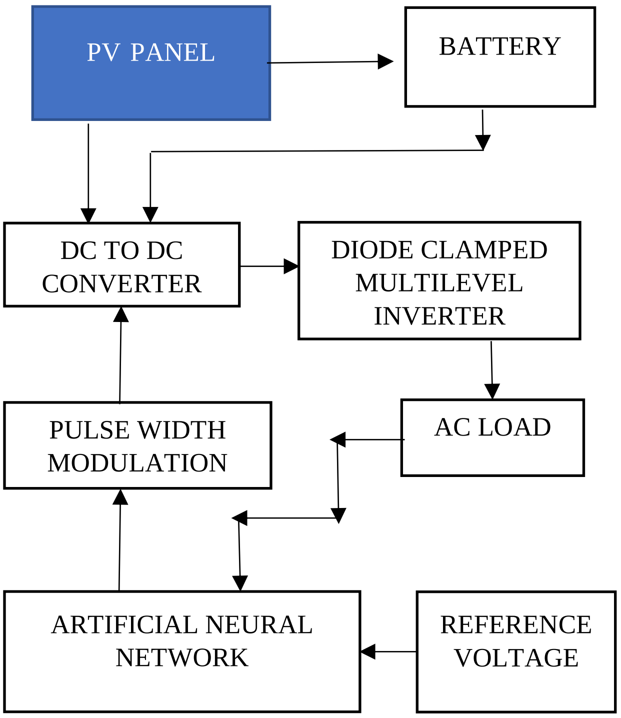

Fig.5 Proposed System Block Diagram

A. SOLAR PANEL

Photovoltaics is the principle of operation of solar energy system This includes number of series cells (Nss) number of Parallel cells (Npp) temperature(Temp), Irradiation(Irradiation).

Nss = 75
Npp = 10
Temp = 273+30
Irr = 100

B. DC TO DC CONVERTER

A DC-to-DC converter is an electronic circuit or electromechanical device that converts a source of direct current (DC) from one voltage level to another voltage level. It is a type of electric power converter system. Power levels range from very low (small batteries) to very large (high-voltage power transmission). A buck converter is a step-down DC to DC converter, where the output voltage is lower than the input voltage. A boost converter is a step-up DC to DC converter, where the output voltage is greater than the input voltage. A SEPIC converter is a type of both step-down and step-up DC to DC converter, where the output voltage is either lower or greater than the input voltage. All dc-dc converters operate by rapidly turning on and off a MOSFET, generally with a high frequency pulse switching[3]. For the SEPIC, when the pulse is high/the MOSFET is on condition, inductor L1 is charged by the input voltage and inductor L2 is charged by capacitor C1. The diode is on off condition and the output is maintained by capacitor C2. When the pulse is low/the MOSFET is on off condition, the inductors output through the diode to the load and the capacitors are charged. The greater the percentage of time (duty cycle) the pulse is low, then higher the output will be. This is because the longer the inductors charge, the higher their voltage will be. However, if the pulse lasts too long period, the capacitors will not be able to charge and the converter will fail.

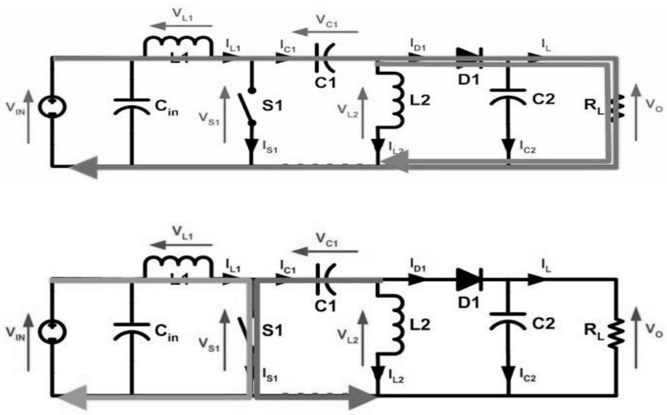

Fig.5.1 Sepic Convereter Operation

C. MULTILEVEL INVERTER

A multilevel inverter is a power electronic device which is capable of produce desired alternating voltage level at the output using multiple lower level DC voltages as an input. Most commonly a two-level inverter is used in order to generate the AC voltage from DC voltage. Capacitors are used in order to limit the voltage instead of diodes in FCMLI. The input DC voltages are divided by the flying capacitors here. The voltage over each capacitor and switch is Vdc[9]. A k level flying capacitor inverter with $(2k-2)$ switches will use $(k-1)$ number of capacitors in order to operate. H-bridge inverters connected in series to provide a sinusoidal output voltage in Cascaded H-Bridge MLI. Each cell contains one H-bridge and the output voltage generated by the multilevel inverter is actually the sum of all the voltages generated by different cell i.e. if there are k cells in a H-bridge multilevel inverter then number of output voltage levels will be 2k+1. Diode clamped multilevel inverters use clamping diodes in order to limit the voltage stress of electrical power devices. It is also known as neutral point converter. A k level diode clamped inverter needs $(2k-2)$ switching devices, $(k-1)$ input voltage source and $(k-1)(k-2)$ diodes in order to operate. Vdc is the voltage present across each diode and each switch.

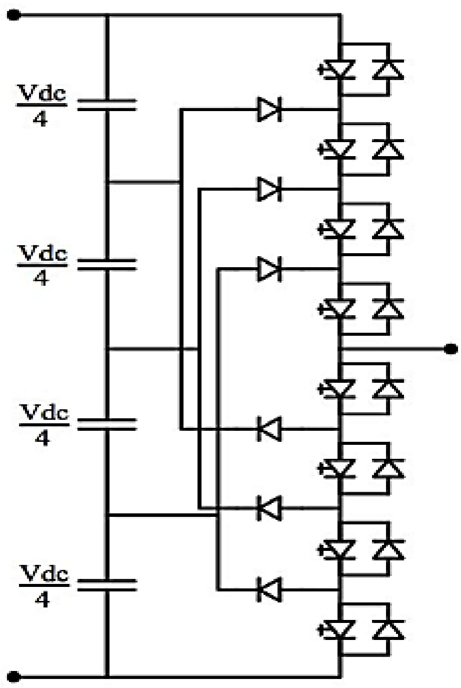

Fig.5.2 Diode Clamped MLI

D. PULSE WIDTH MODULATION

An inverter generates an output of AC voltage from an input of DC voltage with the help of switching circuits to reproduce a sine wave by generating one or more square pulses of voltage per half cycle. If the size of the pulses is adjusted, the output produced is said to be pulse width modulated. With this modulation, some pulses are produced by PWM per half cycle[3]. The pulses close to the ends of the half cycle are always narrower than the pulses close to the center of the half cycle such that the pulse width are comparatively equivalent to the amplitude of a sine wave at that part of the cycle. To change the voltage efficiently, the widths of all pulses are amplified or reduced while keeping the sinusoidal proportionality. With PWM (pulse width modulation), only the on-time pulses are changed during the amplitudes.

E. MOSFET

The MOSFET (Metal Oxide Semiconductor Field Effect Transistor) is one of the Voltage controlled device. This means that a voltage at the gate terminal controls the current flows from the drain terminal to the source terminal. There are three terminals, Gate which was connected to the input device, Drain which connected to the positive, since electrons drain away to the positive, Source where connected to negative (source of the electrons)[1].

F. MICROCONTROLLER

A microcontroller (MCU for microcontroller unit, or UC for μ-controller) is an small computer on a single integrated circuit[4]. A microcontroller is an single integrated circuit contains one or more CPUs (processor cores) along with memory units like ROM, RAM, EPROM and EEPROM, input/output ports, peripherals such as timer, counters, clock generators, ADC, DAC and watchdog.

G. ARTIFICIAL NEURAL NETWORK

Artificial neural network is a replication of human brain. Factors like understanding, recognising, classifying, clustering, error detection and correction are the sixth sense of human brain and this capability is incorporated with the help of artificial neural network[8]. This is an emulation of biological neural system. Neural network can be said to resemble human brain in following the below mentioned things. It acquires knowledge through learning. The knowledge is stored within the inter-neuron connection strengths known as synaptic weights. The artificial neural network is capable of representing both the linear and non-linear relationships.

VI. MATLAB/ SIMULATION

In Matlab programming, functions are used to enclose a computation so that it can be used repeatedly without having to duplicate code wherever it is needed. In addition, a function can protects its calling script from having to worry about its implementation details. In Simulink, subsystems play a similar role[3]. Using subsystems in Simulink has these advantages: It helps reduce the number of blocks displayed in the model window. Functionally related blocks can be kept together. It permits the establishment of a hierarchical block diagram, wherein a Subsystem block is on one layer and the blocks that make up that subsystem are on another layer. The process of creating a subsystem before adding its component blocks usually consists of three major steps: Copy the Subsystem block from the Ports & Subsystems library into your model. Open the Subsystem block by double-clicking it. Simulink opens the subsystem in the current window or a new model window, depending on the model window reuse mode that you selected[9]. In the empty Subsystem window, create the subsystem. Use Inport blocks to represent input from outside the subsystem and Outport blocks to represent external output(output from outside the subsystem). Then the following figures shows the simulation model of an system and also simulation model of an eleven level multilevel inverter.

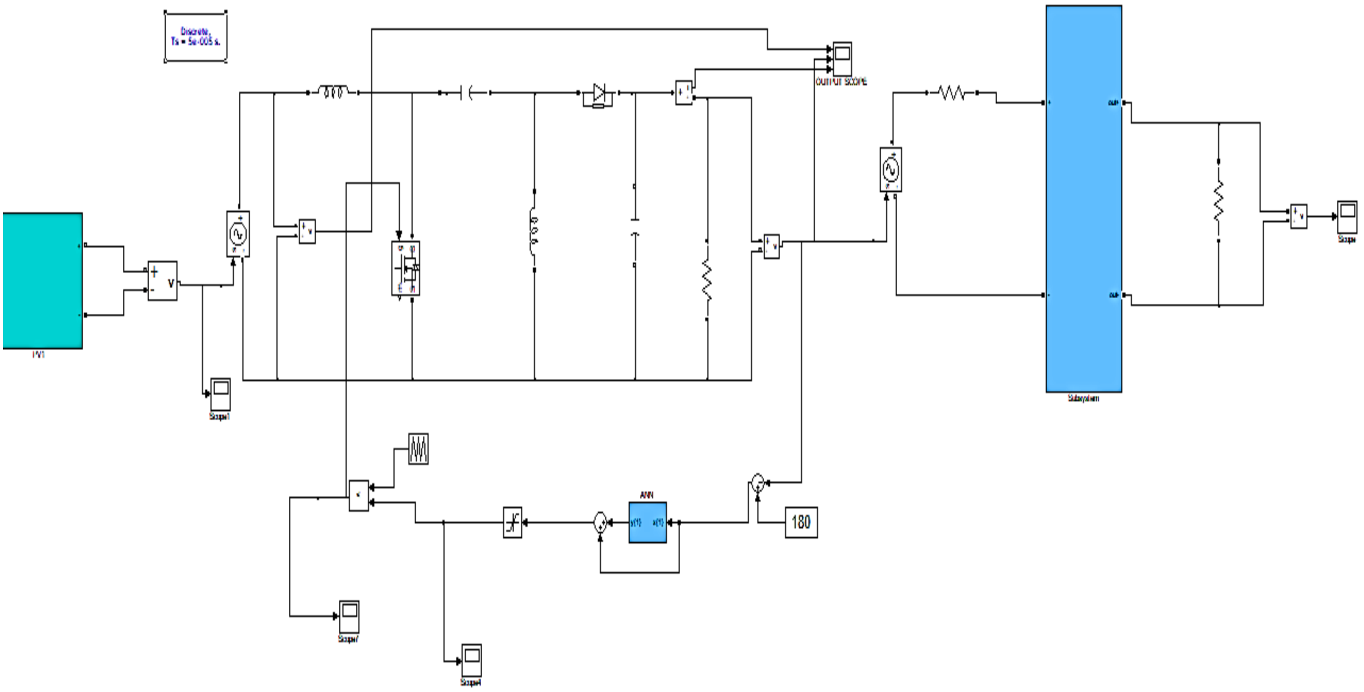

Fig.6.1 Simulation Of The System

CONTROLLER TOPOLOGY	DCMLI	FCMLI	H-BRIDGE MLI
CLAMPING DIODES PER PHASE	30	0	0
DC BUS CAPACITORS	6	6	3
BALANCING CAPACITORS PER PHASE	0	15	0
VOLTAGE UNBALANCE	Low	High	Average
THD % OF INVERTER	20.36 %	21.54 %	22.73 %
THD % OF FILTERED LINE VOLTAGE	0.28 %	0.36 %	0.36 %
POWER RANGE	0.4MVA-4.8MVA	0.3MVA-2MVA	0.45MVA7.5MVA

Fig.6.2 Comparison Of Converter Topology

Voltage control in renewable energy sources are compulsory, because the sources here used is an solar energy a type of renewable energy. The output produced by the source is varying for different period of time. Sometimes it produces low voltage and peak voltage it may affects the load. Load may withstand for only few variation of voltage until sometime it causes serious damage to even for inverter too. This paper 11-level Diode Clamped Multilevel Inverter (DCMLI) using Sinusoidal pulse width Modulation techniques as the control strategies. The algorithm has been developed within the carrier-based PWM framework to facilitate its implementation in diode clamped converters with eleven levels[4]. A simulation model of DCMLI has been designed and developed. By increasing the level of inverter, balancing in line voltage and reduced THD is obtained. The good performance of the proposed modulation technique is demonstrated from simulation results for a eleven-level diode-clamped inverter and the 11-level diode clamped inverter MATLAB/SIMULINK model is designed and exhibited.

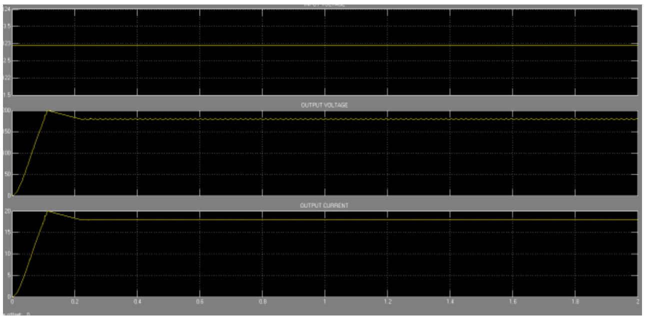

Fig.6.3 Simulation Output

VII. PERFORMANCE OF MLI SYSTEM

Multilevel inverter is based on the fact that sine wave can be changed into a stepped waveform having large number of steps. The steps being supplied from a different DC levels supported by series connected batteries or capacitors. The structure of multi- level inverter allows them to reach high voltages and therefore lower voltage rating device can be used. As the number of levels increases, the synthesized output waveform has more steps, produces a fine wave and approaching very closely to the desired sine wave.

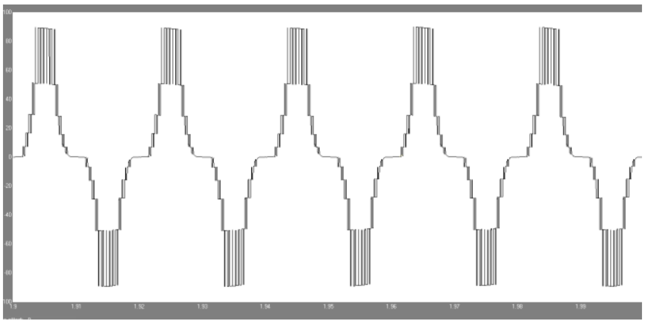

Fig.7 MLI Output

VIII. CONCLUSION

A 11-level diode clamped multilevel inverter has been proposed in this paper with reduced number of switches. This topology needs less number of switches with minimum standing voltage on switches for m levels. Therefore, the DCMLI model multilevel inverter topology reduces the installation area, cost and simple control system. The performance of the diode clamped multilevel inverter has been simulated on MATLAB/SIMULINK and results are compared with the conventional multilevel inverter where it needs almost twice the number of switches.

XI. REFERENCES

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