A Three Level NPC Inverter for Unified Solar PV and Battery Storage System

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***Abstract*—an integration of solar PV and battery storage using a three level npc inverter for grid applications. Effectiveness of the proposed methodology is to balance the ac power produced from the solar panel. MPPT is used to find the maximum power fall on PV cell. The MPPT is used to decide which mode to be enabled depends on the solar power available. Here, direct mode represents the power directly produced by solar pv given to grid application. Indirect mode means two battery unit is used to produce simultaneous power to the inverter in absence of solar energy. Here, to connect battery bipolar connection is used. Both relays are connected to the boost converter, which is responsible to stabilize the dc power generated from PV panel. It is also called as dc-dc converter, to step up the voltage when the voltage is not enough for the grid application voltage. The npc inverter function is to improve the output voltage and current waveform. The npc inverter produces three phase sinusoidal voltage /current with fluctuations .at the time, inverter receives the signal from PIC controller. The controller is responsible for correct the ac voltage using multicarrier pulse width modulation**

***Index Terms*— Energy resources, MPPT, multilevel inverter, MPWM, boost converter**

I. INTRODUCTION

There are many difficulties in the production of electricity due to demand. In order to increase the production of electricity, renewable energy is used. To handle the renewable energy in efficient manner, two important things have to be considered a) converter and b) inverter.

Multilevel inverters have been widely applied in high-power applications. It has been developed to overcome the shortcomings in solid state switching device ratings so that they can be applied to high-voltage electrical systems. That makes unique power electronics topologies suitable for flexible ac transmission systems (FACTS) and custom power applications. The use of a multilevel converter to control the frequency, voltage output real and reactive power flow at a dc/ac interface provides significant opportunities in the control of distributed power systems.

One kind of multilevel inverter is neutral point clamped inverter. The npc inverter improves the output voltage and also reduces the size of the filter. The multilevel inverter is better than the two level inverters like low harmonic distortion of the ac currents, low switching losses. To control the operation of multilevel inverters, a technique called multilevel pulse width modulation (MPWM) is used. The unique function of multi voltage source inverters allows operating at high voltages.

Dc voltage deviation occurs due to the unbalanced dc capacitors due to tolerances, inconsistency in the switching device characteristics and three phase operation. To solve the problems many strategies have been introduced to balance the neutral point voltage. MPWM have been introduced .here, proper switching sequence can be chosen based on analysis of the predicted voltage unbalance.

The basic operation of npc inverter is divided in to two cycles. One is positive half cycle and another is negative half cycle. In positive half cycle the six switches work and at negative cycle, the remaining six switches work. So the switching loss is reduced.

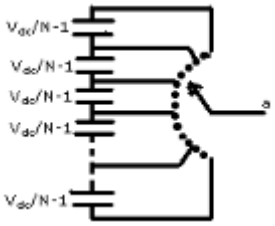

Figure 1 Diagram of NPC inverter

The important concept in this paper is a three level NPC inverter with a combination of these systems on the dc side.

The remainder of the paper is organized as follows section II describes the multilevel pulse width modulation and MPPT algorithm. Section III presents the structure of multilevel inverter. Section IV represents the proposed system and working of controller. Section V describes the simulation result using MATLAB/SIMULINK. Section VI describes the conclusion and prototype set up.

II. CONCEPT OF MPWM AND MPPT

MPWM uses the concept of sub harmonic pulse width modulation, which has the intersection of triangular wave and modulated wave's comparison is made between the two waves, then it generates the output voltage. It requires a carrier much higher frequency than modulation frequency. If the carrier frequency is very high, the result will be a sinusoidal fundamental output with high-frequency harmonics, but minimal low frequency harmonics. For m level inverter m-1carrier with same frequency is considered and also same peak to peak amplitude are disposed continuously.

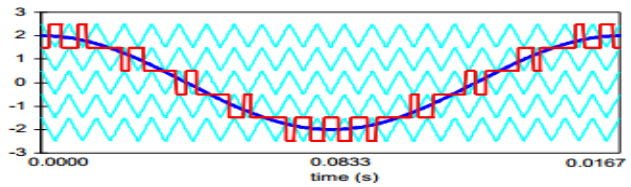

Figure 2 Multilevel carrier based waveform

This method takes average maximum and minimum of three reference voltage to get modulated waveform. The reference is continuously compared with each carrier signal. If the reference is greater than the carrier signal the active device is switched on otherwise the device in off state.

MPPT algorithm is one which includes the charge controllers for extracting maximum available power from PV module under some conditions. The voltage at which PV module can produce maximum power is called peak power voltage. Power varies with solar radiation and temperature. The converter has the capability of MPPT and ac side current control and also having the ability of controlling the battery charging and discharging. This algorithm works effectively in the lack of renewable energy. The process starts by reading the current and voltage which falls on the panel, then it compare the value of each panel from 1 to N-1 cell. If the power is high, it moves to next function. Otherwise the loop back to starting stage.

The Maximum Power Point Tracker (MPPT) is needed to optimize the amount of power obtained from the photovoltaic array to the power supply. The inputs of the MPPT consisted of the photovoltaic voltage and current outputs. The adjusted voltage and current output of the MPPT charges the power supply. A MPPT is used for extracting the maximum power from the solar PV module and transferring that power to the load. A dc/dc converter acts as an interface between the load and the module. By changing the duty cycle the load impedance as seen by the source is varied and matched at the point of the peak power with the source so as to transfer the maximum power.

III STRUCTURE OF MULTILEVEL INVERTER

The three level three phase neutral point clamped inverter is heart of the unified solar PV and battery storage system. The inverter structures consist of twelve switches and six unidirectional switches connected to the midpoint of the source. The capacitor used before the npc inverter split the neutral voltage to maintain half voltage either positive or negative. The neutral voltage is compensated by MPWM.

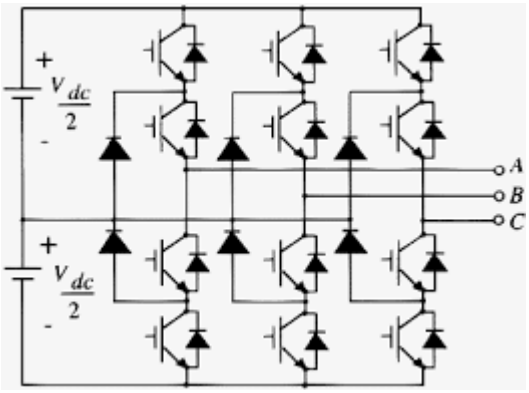

Figure 3 Three level NPC inverter

A NPC inverter includes the DC power source to output DC voltage having a neutral point. An NPC convert DC voltage in to AC voltage in three phases PWM control. When a mode is selected , consider to a first and a second PWM modes by comparing amplitude of voltage reference with a predefined value that is defined by a minimum pulse width, a first voltage reference means to add a predefined bias value at which a changes to positive/negative within a fixed period to voltage references in respective phases in a first PWM mode, a second voltage reference means to fix the voltage reference in one phase by a value with minimum pulse width when voltage reference in one phase is smaller than a described value that is defined by the minimum pulse width in a next PWM mode and correct voltage references of other two phases so as to make line voltage to a value corresponding to the voltage reference, and a modulation frequency varied over to lower PWM control modulation frequency in the first PWM mode and to suppress power loss caused by switching in the first PWM mode.

IV PROPOSED SYSTEM

This paper is concerned with the design of grid-connected three-phase solar PV system integrated with battery storage uses a boost converter and only one three-level inverter. MPPT have the ability to control the battery charging and discharging.

A modulation technique [MPWM] can generate pulse for NPC inverter to perform switching operation. This will provides lower cost, better efficiency and also increased flexibility of power flow control. A Photo Voltaic (PV) system means the conversion of sunlight directly into electricity. The basic device of a PV system is cell. Cells are grouped together to form panels or arrays.

The voltage and current available at the terminals of a PV may directly feed small loads. Many applications require electronic converters for process the electricity from the PV. These converters may be used to regulate the voltage and current at the load and also control the power flow in grid systems. It is mainly used to track the maximum power point (MPP) of the device. In order design a PV systems, one first needs to know how to model the PV device that is attached to the converter.

PV devices present a nonlinear I–V characteristic with several parameters that need to be adjusted from experimental data of practical devices. The mathematical model of the PV device may be useful in the study of the dynamic analysis of

converters, in the study of MPP tracking (MPPT) algorithms, and mainly to simulate the PV system and its components using circuit simulators. The important note is using only a single battery to perform the function as better.

The solar power plant produces the power to the micro controller which gives the control signal to the relay unit. The relay unit decides where the power is stored in the battery either active power or reactive power battery. Then, the inverter converts the direct current into alternating current. The control strategy is applied to the inverter for controlling purposes. MPPT control scheme is applied in the inverter circuit. The final output power is used for the grid application or any other real time application.

PIC controller and decoupling structure, the inverter requested voltage vector calculated. It transfer the specified amount of power to the grid, the battery will be charged using a surplus energy from the PV or will be discharged to support the requested power. The switching operation of the inverter depends on the MPWM (multi level pulse width modulation).the appropriate selection of vector depends on the timing calculation.

The MPPT block determines the requested dc voltage across the PV to achieve the MPPT condition. This voltage can be determined by using another control loop, with slower dynamics using the measurement of the available PV power. After evaluating the requested voltage, the appropriate waves in the can be determined .the selection of the carrier signal will determine which capacitor is to be charged or discharged.

Based on the control system diagram on the ac side, the requested power is either direct or indirect mode. It is applicable at the time excess power generation by source. The system function depends on the integration solar panel with a NPC inverter through the single battery and a boost converter for grid application using a multilevel pulse width modulation. The converter has the capability to perform MPPT function. The capacitor used behind inverter is assumed to be constant. The capacitor in the circuit divides the dc source to operate the in direct and indirect mode.

The direct mode represents the flow of power directly from source and also the indirect mode specifies the power generated by PWM unit to achieve uninterrupted supply.

The block diagram represents the function of the whole circuit which is mainly used for stabilize the ac voltage wave without any ripples.

Here, two batteries are used for storing the excess energy generated by the solar panel. A bidirectional link is used for storing and supplying the power. When the null energy is in battery1 at the time battery 2 is enabled. otherwise it simply stores the energy. These function decided by the PIC controller.

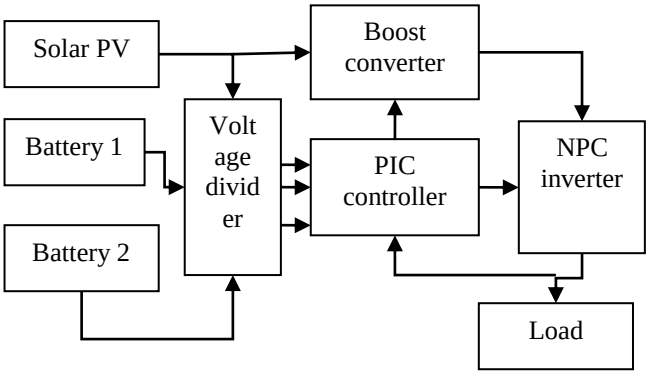

Figure 4 Block diagram of the circuit

V SIMULATION RESULT

The simulation results are examined using a software MATLAB/SIMULINK. The MATLAB is a high performance language for technical computing integrates computation, visualization and programming in an easy-to-use environment where problems and solutions are expressed in familiar mathematical notation. MATLAB serves as a best tool for signal analysis. Open the Simulink library browser. You need MATLAB running before you can open the Simulink browser. Start MATLAB, and then in the matlab command window, enter Simulink the Simulink library opens. From the Simulink library browser menu, select file> new > model.

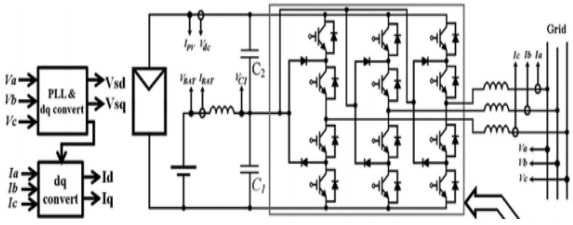

Figure 5 circuit diagram

Simulation steps

(1) Generation of solar irradiance
(2) Boost converter output
(3) NPC inverter step output for single phase
(4) Three phase signal (correct ac)
(5) Utility grid current and voltage

A. Generation solar irradiance

The light and heat energy falls on the PV panel, the waveform shows the irradiance. The irradiance may be varied depends on the weather conditions in real time. In the circuit we use current and voltage sensor to measure power. The maximum power is tracked until finding requested power continuous. Otherwise the reference value is given to the PID controller. The energy is stored in an energy storage unit. After the battery unit, the circuit has the boost converter, inverter and utility grid section. A separate unit is placed above the block to reduce total harmonic distortion occur in ac.

For the simulation the input value of irradiance is 1000KW/m^2.

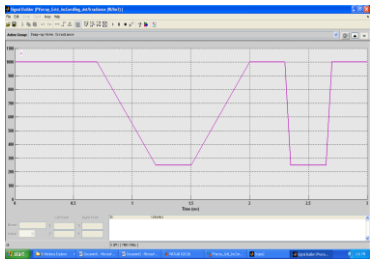

Figure6 input waveforn

B. Boost converter output

In the case limited amount of power generation, it determines how much voltage to be step up for the grid application.

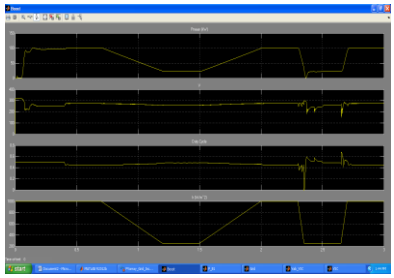

Figure 7 dc to dcconverter output

C. NPC inverter output

The direct current is transformed into alternating current using NPC inverter without switching loss. At the midpoint of capacitor always generate zero voltage. So it does not affect the voltage.

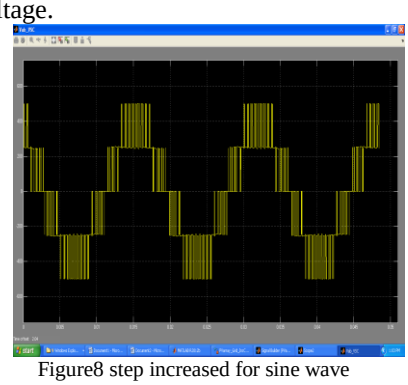

Figure8 step increased for sine wave

D.Three phase generation

After applying the dq transformation, the three phase voltage is controlled to generate correct ac without fluctuations. Here the function is performed by the phase locked loop, which is used to achieve the output as similar to input.

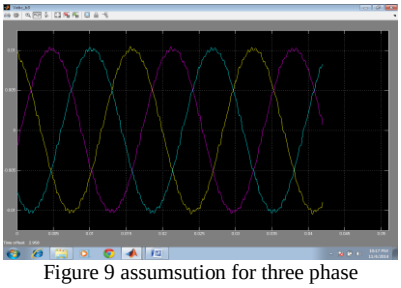

Figure 9 assumsution for three phase

E. Utility grid current and voltage

The output waveform of grid application, it can get the power supply without any loss. Here, the utility grid is the application used in simulation.

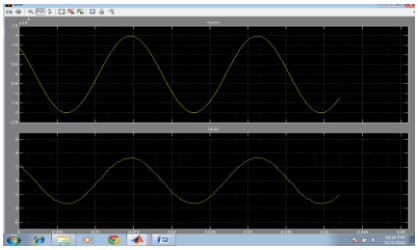

Figure 10 grid output

VI HARDWARE DESCRIPTION

A.SOLAR PANEL

The specification of the solar panel for this paper has the maximum power of 3W.

B. Energy storage unit

The rechargeable batteries used for this paper is 6V lead acid accumulator, which is used to store the electrical energy by some chemical reactions.

C. Voltage divider

It is used to prevent the pic controller from maximum voltage to 5V, which is acceptable by ADC port.

D. PIC16F778A

Used for compare the actual and reference voltage used for modulating multi level inverter. The system is controlled by the peripheral interface controller for generating the pulse depends on solar and energy storage unit .

E. Boost converter

To step up the received voltage depends the requirement of
Application.

VII CONCLUSION

A novel topology for a three-level NPC voltage source inverter that can integrate both renewable energy and battery storage on the DC side of the inverter has been presented. An effective Multilevel pulse width modulation (MPWM) method for multi-level inverter fed induction motor is proposed based on SPWM method for two-level inverter. A theoretical framework of a novel extended unbalance three-level modulation technique that can generate the correct ac voltage under varying dc voltage conditions has been proposed. A new control algorithm for the proposed system has also been presented in order to control power flow between solar PV, battery, and grid system, while MPPT operation for the solar PV is achieved simultaneously. The effectiveness of the proposed topology and control algorithm was tested using simulations and results are presented. The results demonstrate that the proposed system is able to control ac-side current, and battery charging and discharging currents at different levels of solar irradiation. The hardware set up was implemented using the same simulation circuit and the load is regulated. Through the hardware output, unity power factor is achieved.

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