International Journal of Research
Available at https://edupediapublications.org/journals
p-ISSN: 2348-6848
e-ISSN: 2348-795X
Volume 04 Issue 09
August 2017

The balance of PV energy and user demands in grids by using a new configuration of a three level NPC Inverter.

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ABSTRACT

In this paper a grid-connected solar PV system integrated with battery storage using a new configuration of three level NPC inverter has been designed using MATLAB/SIMULINK. Three-level space vector modulation technique is proposed efficiently that can generate controlled ac voltage under unbalanced dc voltage conditions. The proposed system having the capability of MPPT and ac side current control and also ability of controlling battery charging and discharging this will result better efficiency and balanced power flow control. The results of simulation are given to investigated the effectiveness of proposed methodology at several scenarios, including battery charging and discharging with different levels of the solar irradiation.

Keywords— Solar photovoltaic (PV), NPC Multi level inverter, battery storage.

I. INTRODUCTION

Rapid increase in energy prices and recent geopolitical events renewable energy sources such as solar PV energy and wind energy generation are becoming more promising alternatives to replace conventional generation[1][2].there are two conversion methods to transfer the power from renewable energy resource to grid ; single stage energy conversion and double stage energy conversion. In the double stage energy conversion two converters are required to convert dc to ac usually in the first stage dc to dc converter is used in the second stage dc-ac inverter is used, the function of the dc to dc converters to facilitate the MPPT of the PV array to produce appropriate dc voltage for the dc to ac inverter. In the single stage energy conversion one converter is sufficient to convert the dc into ac these can reduce the cost and improves the overall efficiency .however more complex control is required. solar PV system is integrated with three level NPC inverter having a capability of MPPT and ac side current control,and also ability of controlling the battery charging and discharging it improves the efficiency and flexibility of power flow control.

II. SOLAR PV

Solar cells are essentially a very large area p-n junction diode, where such a diode is created by forming a junction between the n-type and p-type regions. As sunlight strikes a solar cell, the incident energy is converted directly into electrical energy. Transmitted light is absorbed within the semiconductor by using the energy to excite free electrons from a low energy status to an unoccupied higher energy level. When a solar cell is illuminated, excess electron-hold pairs are generated by light throughout the material hence the p-n junction is electrically shorted and current will flow.

The equivalent circuit of a solar cell is represented by four components: a light-induced current source, a diode parallel to the source, a series resistor and a shunt resistor. The light-induced current is due to the separation and drift of the photon-generated electron–hole pairs under the influence of the built-in field .

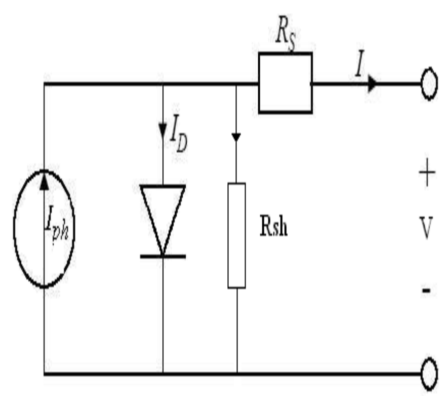

Fig 1 . equivalent model of solar cell

The model of solar cell is shown in Fig 1.The corresponding voltage vs. current (V-I) equation is:

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$$I = I_{Ph} - I_O\left[\exp\left\{\frac{q*(V+IR_S)}{AKT}\right\}\right]-1$$

Where, I and V are the solar cell
Out put current and voltage
I_{ph} is the generated photo-current
I_o is the reverse saturation current of diode
The parameter A is the diode ideality factor
T is the absolute temperature in Kelvin
K is the Boltzmann's constant (1.380×10^{-23} J/K)
Q is the elementary charge (1.602×10^{-19} C)
R_s is internal series resistance

III. GRID CONNECTED PV SYSTEM

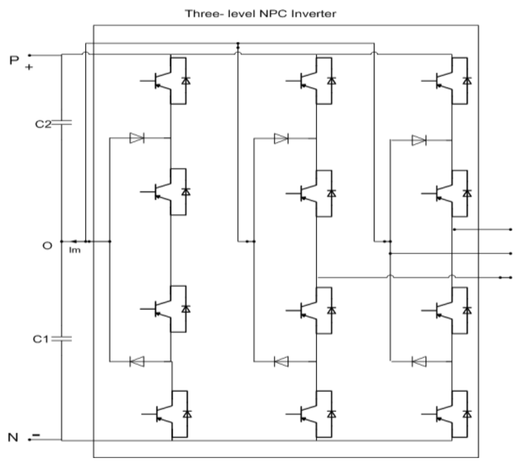

Fig 2 Three level NPC Inverter

Due to advantages over the conventional two level inverters, multi level inverter topologies used in high power applications. The main advantage of these inverter are improving quality of waveforms and increase in dc-link voltage for a given blocking voltage capacity of the semi conductors, the Three-level NPC inverter has attracted popular attention.NPC inverter is used in the several applications such as ac motor drive,HVDC Transmission,STATCOM ,active power filters as well as renewable energy interfacing applications[3][4].
some inherent problems limited to practical applications such has voltage drifts and voltage ripples of neutral-point. thus there is a need to equal voltage sharing among dc capacitors to keep the average of neural-point voltage is zero.this paper is mainly focus on the neutral –point balancing control strategies under the SVPWM alogorthim[5][6].the strategy utilizes to eliminate voltage drifts and minimize voltage ripples simultaneously.

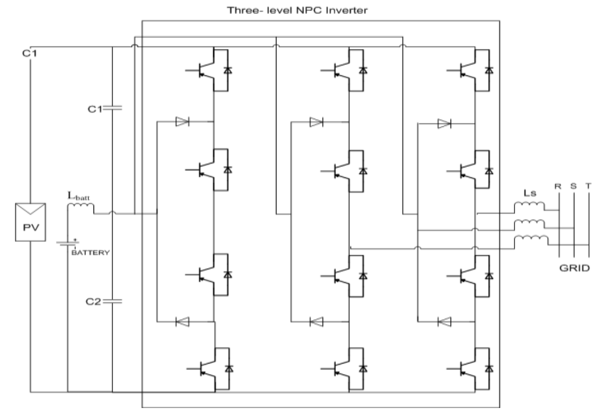

Fig 3 Solar PV and Battery storage connected to grid

Grid-connected three-phase solar PV system integrated with battery storage using only one three-level converter having the capability of MPPT and ac-side current control, and also the ability of controlling the battery charging and discharging. this will result in a lower cost, better efficiency and increased flexibility of power flow control. There no extra converter is required to connect the battery storage grid connected PV system, these can be reduced the cost and improve the overall efficiency of the system particularly for medium and high power applications [6 7]. Three level inverters are widely used in several applications such as motor drives STATCOM, HVDC and active power filters and renewable energy applications.

Fig3 shows the diagram of the basic configuration. In the proposed system, power can be transferred to the grid from the renewable energy source while allowing charging and discharging of the battery storage system as requested by the control system. The proposed system will be able to control the sum of the capacitor voltages (VC1+VC2 =Vdc) to achieve the MPPT condition and at the same time will be able to control independently the lower capacitor voltage (VC1) that can be used to control the charging and discharging of the battery storage system.

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IV. RESULTS AND DISCUSSION

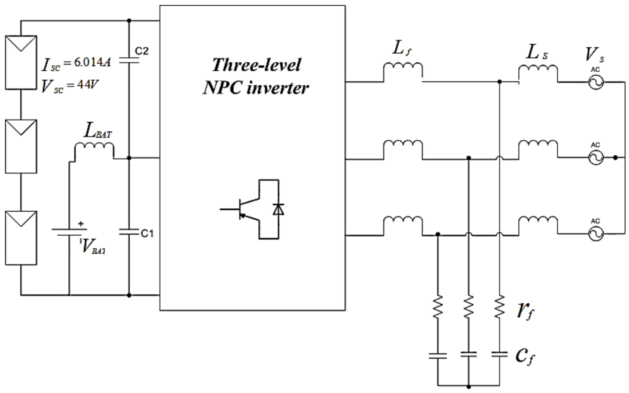


Fig 4 block diagram for simulated system

Table 1 parameters of simulated system

Three different scenarios have been simulated to investigate the effectiveness of the proposed topology and the control algorithm using a step change in the reference inputs under the following conditions:

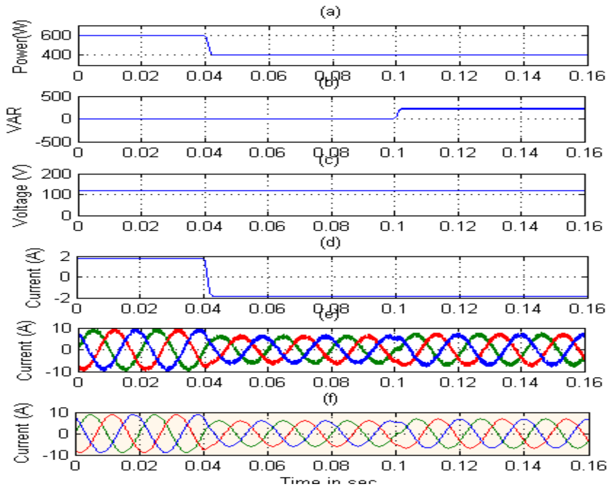
1) The effect of a step change in the requested active and reactive power to be transferred to the grid when the solar irradiance is assumed to be constant.

2) The effect of a step change of the solar irradiation when the requested active and reactive power to be transmitted to the grid is assumed to be constant.

3) With this practical application in mind, the proposed system is simulated using a slope controlled change in the requested active power to be transferred to the grid when the solar irradiance is assumed to be constant.

4.1.SIMULATION RESULT 1

In this scenario the effect of a step change in the requested active and reactive power to be transferred to the grid when the solar irradiance is assumed to be constant. it is assumed that the solar irradiation will produce I_{SC}=5.61A in the PV module according to The MPPT control block, determines the requested PV module voltage Vdc,which is 117.3 V to achieve the maximum power from the PV system that can generate 558 W of electrical power.



V_{bat}	Vs (line)	L_{bat}	C_1,C_2	L_f	L_S
60V	50V	5mh	1000uF	500uH	900uH
R_f	C_f	Kp	K_i	G_1	G_2
3 ohm	14Uf	2.9	1700	1	200

Fig 5 Simulated results for the first scenario

In fig 5(a) and 5(b) The requested active power to be transmitted to the grid is initially set at 662 W and is changed to 445 W at time t= 40 ms and the reactive power changes from zero to 250 VAr at time t=100 ms. Fig.5 (c) shows that the PV voltage has been controlled accurately (to be 177.3 V) to obtain the maximum power from the PV module. Fig.5(d) shows that battery is discharging when the grid power is more than the PV power, and it is charging when the PV power is more than the grid power. shows that before time t =40 ms, the battery discharges at 1.8 A since the power generated by the PV is insufficient. After time t =40 ms, the battery current is about –1.8 A, signifying that the battery is being charged from the extra power of the PV module. Fig. 5(e) shows the inverter ac-side currents, and Fig. 5(f) shows the grid-side currents.

4.2.SIMULATION RESULT 2

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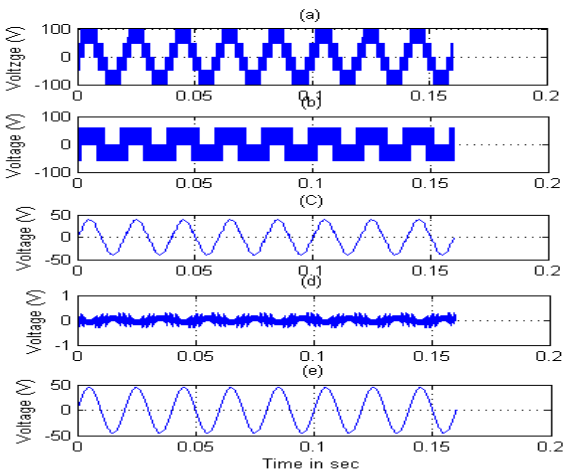

Fig 6 Simulated NPC inverter waveforms

Fig. 6(a) shows the line-to-line voltage Vab, and Fig 6(b) shows the phase to midpoint voltage of the inverter Vao. Fig. 6(c) and6(e)shows Vao, Von, and Van after mathematical filtering to determine the average value of the PWM waveforms 6(d) Filtered Von-Filtered midpoint voltage reference to neutral.

4.3. SIMULATION RESULT 3

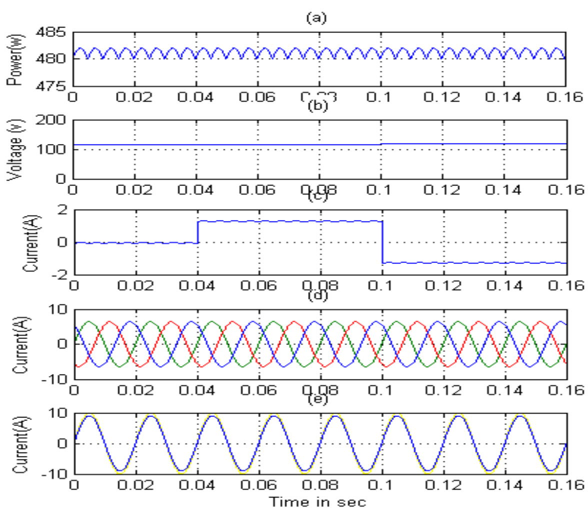

Fig 7 simulated results for second scenario.

In this scenario the effect of a step change of the solar irradiation when the requested active and reactive power to be transmitted to the grid is assumed to be constant. In the second scenario, it is assumed that the solar irradiation will change such that the PV module will produce I_{SC}=4.8,4, and 5.61 A. The MPPT control block determines that Vdc needs to be 115.6, 114.1, and 117.3 V to achieve the maximum power from the PV units which can generate 485, 404, and 558 W, respectively. The requested active power to be transmitted to the grid is set at a constant 480 W and the reactive power is set to zero during the simulation time

. Fig. 7(a) shows that the inverter is able to generate the requested active power. Fig. 7(b) shows that the PV voltage was controlled accurately for different solar irradiation values to obtain the relevant maximum power from the PV modules.

Fig. 7(c) shows that the charging and discharging of the battery are correctly performed. The battery has supplemented the PV power generation to meet the requested demand by the grid. Fig 7(d) illustrates that the quality of the waveforms of the grid-side currents are acceptable, which signifies that the correct PWM vectors are generated by the proposed control strategy. By using the proposed strategy, the inverter is able to provide a fast transient response. Fig 7(e) shows the grid phase current.

4.4.SIMULATION RESULT 4

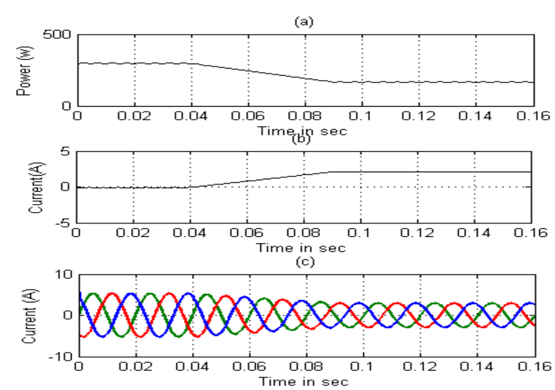

Fig 8 Third scenario simulated diagram.

In this scenario for the practical application in mind, the proposed system is simulated using a slope controlled change in the requested active power to be transferred to the grid when the solar irradiance is assumed to be constant. Fig 8(a) shows that the active power transmitted to the grid reduces and follows the requested active power. Fig 8(b) shows the battery current which is about 0.1 A before t=40 ms and then because of the reduced power transmission to the grid with a constant PV output, the battery charging current is increased and finally fixed at about 2.2 A. Fig8(c) shows the ac inverter currents slowly decreasing starting from 3.4Arms at t=40 ms and finally stays constant at 1.9Arms at t=90 ms.

V. CONCLUSION

Energy storage systems are promising solution regarding the integration of fluctuating renewable into grids. In this paper a three-level NPC inverter that can integrate both renewable energy and storage on the dc side of the inverter has been presented. Three-level vector modulation technique is proposed that can generate the correct ac voltage under unbalanced dc voltage conditions .a new control algorithm for the proposed system has also been presented in order to control the solar PV, battery and grid system. While MPPT operation is achieved simultaneously. The results demonstrate that the proposed system is able to control ac-side current and battery charging and discharging currents at different solar irradiation.

VI. REFERENCES

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