Vol.3 Issue.6, Pg.: 69-77
June 2015

INTERNATIONAL JOURNAL OF RESEARCH IN COMPUTER APPLICATIONS AND ROBOTICS
ISSN 2320-7345

A CASCADED H-BRIDGE MULTILEVEL INVERTER WITH BATTERY BALANCING DEDICATED TO PV

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Abstract: - The Photo Voltaic (PV) energy system, used in this project, is a very new concept in use, which is gaining immense popularity due to increasing importance to research on alternative sources of energy over depletion of the conventional fossil fuels all around the world. The systems which are being developed extract energy from the sun in the most efficient manner and suit them to the available loads without affecting their performance. In this project presents a simulation of a single phase PV cell fed h-bridge multilevel inverter with battery balancing. In this a PV cell single-phase multilevel inverter with battery balancing is proposed. The input of each individual inverter is directly connected to a battery. The combination of batteries can be controlled according to the batteries voltages to implement the battery-balancing function and also harmonic elimination is done to get minimum THD. Simulation of this single phase multilevel inverter with battery balancing and harmonic elimination is done using MATLAB/ Simulink. Simulation results show that the battery-balancing discharge function is achieved to get minimum THD.

Keywords: THD-Total harmonic distortion PV- Photo Voltaic

I. INTRODUCTION

A single-phase multilevel inverter with battery balancing is proposed. The voltage source inverters produce a voltage with levels either 0 or ±V dc they are known as two level inverters. To obtain a quality output voltage or a current waveform with a minimum amount of ripple content. As the number of voltage levels increases, the harmonic content of output voltage waveform decreases significantly. Battery systems are affected by many factors, a key one being the cells unbalancing. Without the balancing system, the individual cell voltages will differ over time, battery pack capacity will decrease quickly. That will result in the failure of the total battery system. Thus cell balancing acts an important role on the battery life preserving. Different cell balancing methodologies have been proposed for battery pack. In this paper, the general structure of multi-level converter is to synthesize a near sinusoidal voltage from several levels of dc voltages .The operational principle of the proposed system is first described, and then, the design equation is derived.

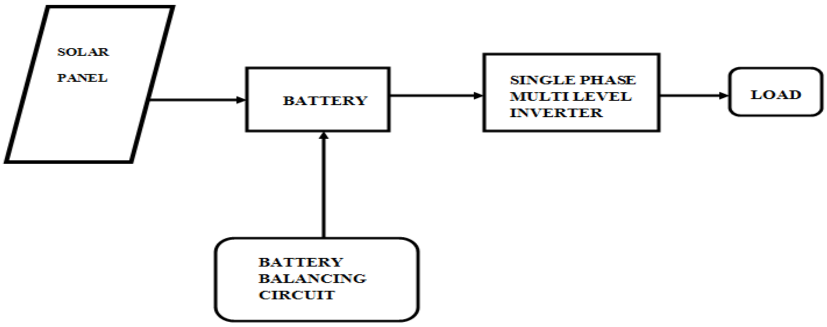

Fig .1 overall block diagram

II. SYSTEM DESCRIPTION

Among topologies of multilevel inverters, the cascaded multilevel inverter with separate dc sources is superior to the other multilevel structures in terms of its structure which is simple and modular. The characteristics of a cascaded multilevel inverter are achieved. In addition, the battery-balancing function is implemented. Fig.2 shows the conventional $2N + 1$-level multilevel inverter composed of N individual full-bridge inverters and N batteries. The set of the batteries can be defined as

$B = \{B_1 B_2 \ldots . B_N\}$ (1)

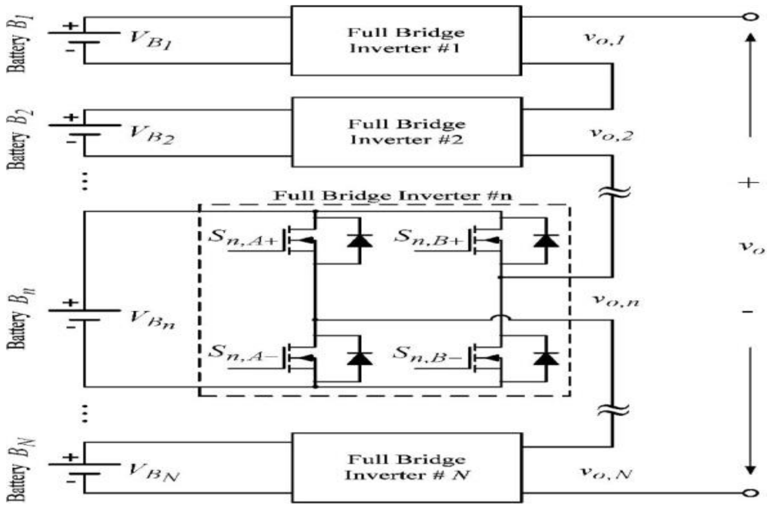

Fig.2 2N + 1-level inverter with battery balancing

Each individual full-bridge inverter has a separate battery source *Bn*. Thus, the individual full-bridge inverter can provide three different voltage outputs $-V_{B_n}$ 0, and $-V_{B_n}$by different combinations of the four switches *Sn,A+*, *Sn,A−*, *Sn,B+*, and *Sn,B−* as shown in Table I. The output voltage *Vo* of the multilevel inverter is equal to the sum of the voltages of the individual full-bridge inverters, shown as

$V_O = \sum_{n=1}^{N} V_{B_n}$ (2)

where $-V_{b_n}$is the voltage of battery B_n.The set of the batteries providing the output voltage in the multilevel inverter can be defined as

$B_{sel} = \{B_1 B_2 B_3 \ldots \ldots \ldots . B_n \ldots \ldots \ldots \ldots . B_N\}$ $M \leq N$ (3)

Clearly, a sine wave can be generated by programming a suitable sequence with a positive/negative polarity control. If the characteristics of all of the batteries are equal, the switching pattern-swapping scheme can be adopted to achieve battery balancing. Unfortunately, any two batteries are different. In order to solve this problem, this system proposes a new battery-balancing method for a cascaded multilevel inverter.

Table 1
Relationships of the output voltages of individual full-bridge inverters and their switch states

Output Voltage Vo,n	switching state
$+V_{B_n}$	ON: *Sn,B*+, *Sn,A*−,& OFF: *Sn,A*−,*Sn,A*+,
0	ON: *Sn,A*+, *Sn,B*+,& OFF: *Sn,A*−, *Sn,B*-, or ON: *Sn,A*-, *Sn,B*−,& OFF: *Sn,A*+, *Sn,B*+,
$-V_{B_n}$	ON: *Sn,A*+, *Sn,B*−,& OFF: *Sn,B*+,*Sn,A*- ,

First, the battery set *B* is sorted, and the sorted battery set *B* sort can be shown as

$B_{sort} = \{B_1^*, B_2^*, B_3^* \ldots B_n^* \ldots B_N^*\}$ (4)

in which the relation of battery voltages is $V_{B_n^*} \leq V_{B_n^*}$ n=1,2, . . . , *N*. This means that the battery with the highest voltage is denoted as B_1^*, the battery with the second highest voltage is denoted as B_2^*, and the battery with the lowest voltage is denoted as B_N^*.
Using the Fourier series analysis, the root mean-square (rms) voltage and the *h*th harmonic *H*(*h*) of the quasi-sinusoidal wave can be expressed .$V_h, \text{rms}(\alpha_{B_1^*}\alpha_{B_2^*} \ldots \ldots \alpha_{B_n^*})$
h=1,3,5,7

$$= \frac{4}{\sqrt{2}h\pi}[V_{B_1^*} \cos h(\alpha 1) + V_{B_1^*} \cosh(\alpha 2) \quad + V_{B_1^*} \cosh(\alpha 3) + \cdots . + V_{B_1^*} \cos(\alpha N)] \qquad (5)$$

According to (5), the switching angles $\alpha 1$, $\alpha 2$, . . αN can be found such that the THD is minimized and the rms of the fundamental frequency is close to the reference voltage v1,rms_ref .
After that *M* batteries for output voltage are decided according to the switching angles $\alpha 1$, $\alpha 2$, . . . , αN. Finally, these *M* batteries with higher voltage are chosen and shown

$B_M = \{B_1^*, B_2^*, B_3^* \ldots . B_M^*\}$ (6)

The output voltage of the multilevel inverter can be expressed as

$v_O = \sum_{I=1}^{M} V_{B_1^*} = V_{B_1^*} + V_{B_1^*} \ldots \ldots . V_{B_M^*}$ (7)

As shown in Fig.3, a quasi-sinusoidal wave can be generated. Assume that the load current I_L is constant during a half-cycle of a sinusoidal wave; the discharge capacities Q_{Bn} of battery B_n can be expressed as

$Q_{B_n} = I_L \ (\pi - 2\alpha_n)$ (8)

Angle and $\alpha_n \leq \alpha_{n+1}$. Clearly, the where α_n is the *n*th switch discharging capacity of a battery with higher voltage is greater than that of a battery with lower voltage. Thus, the battery-balancing function is achieved.

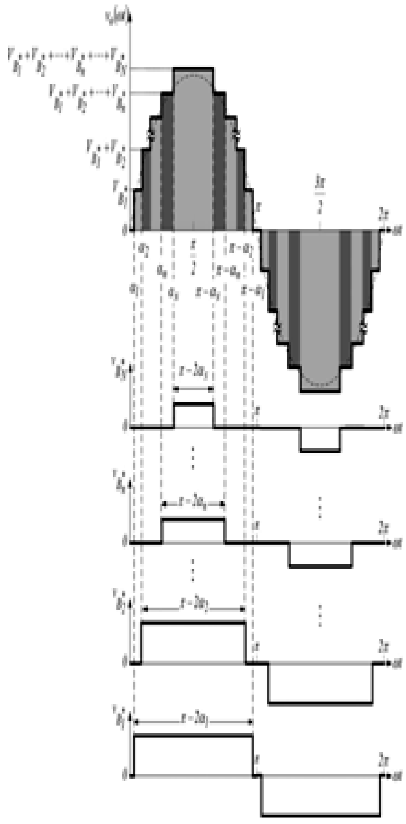

Fig .3 Output voltage waveform of the proposed multilevel inverter.

Fig. 3 shows the block diagram of the realized 11-level inverter that comprises five individual full-bridge inverters and a controller.

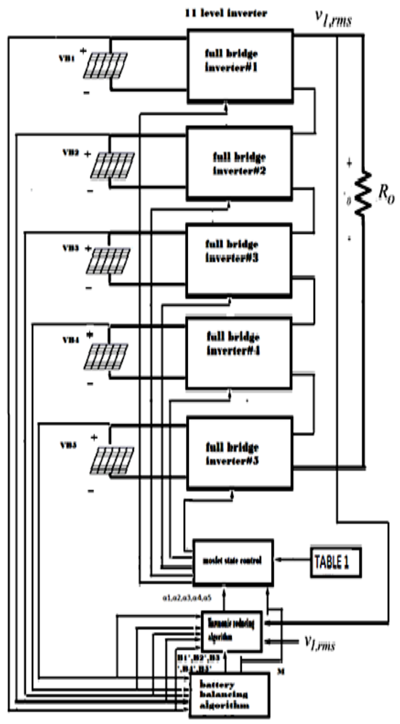

Fig.4 system block diagram

The controller is a combination of battery-balancing algorithm, a harmonic-reducing algorithm, and a MOSFET state control algorithm .The controller is meant to achieve battery balancing and selective harmonic elimination by using (5) and to decide the suitable switching angles $\alpha1, \alpha2, \alpha3, \alpha4, \text{and}\alpha5$.. Fig. 5 shows the program flowchart of the realized prototype. First, battery voltages $V_{B_1} V_{B_2} V_{B_3} V_{B_4} V_{B_5}$ are measured at ωt = 0and π and then sorted as $B_{sort} = \{B_1^*, B_2^*, B_3^* \; B_4^* B_5^*\}$

For example, if the battery voltage relationships are, $V_{B_4} \geq V_{B_3} \geq V_{B_2} \geq V_{B_1} \geq V_{B_5,}$ the sorting result is$B_1^* = B_4 . B_2^* = B_3 . B_3^* = B_2 \; B_4^* = B_1 . B_5^* = B_5$. . By using the Newton–Raphson method, we can find a set of switching angles$\alpha1, \alpha2, \alpha3, \alpha4, \text{and}\alpha5$.

Since finding a set of switching angles $\alpha1, \alpha2, \alpha3, \alpha4, \text{and}\alpha5$ by using the Newton–Raphson method requires complex computing, the real-time decision and control are difficult to be realized. A lookup table is built for the controller to solve this problem.

Then, M batteries form output voltage is decided according to to $\alpha1, \alpha2, \alpha3, \alpha4, \text{and}\alpha5$. That is, $M = 1$, $M = 2$, and $M = 3$ $M = 4$, and $M = 5$ when $0 < \omega t \leq \alpha1$ or $(\pi - \alpha1) < \omega t \leq \pi$, $\alpha1 < \omega t \leq \alpha2$ or $(\pi - \alpha2) < \omega t \leq (\pi - \alpha1)$, $\alpha2 < \omega t \leq \alpha3$ or $(\pi - \alpha3) < \omega t \leq (\pi - \alpha2)$, $\alpha3 < \omega t \leq \alpha4$ or $(\pi - \alpha4) < \omega t \leq (\pi - \alpha3)$, $\alpha4 < \omega t \leq \alpha5$ or $(\pi - \alpha5) < \omega t \leq (\pi - \alpha4)$, and $\alpha5 < \omega t \leq (\pi - \alpha5)$ After that, all switch states can be obtained according to $\alpha1$, $\alpha2$, $\alpha3$ $\alpha4$, $\alpha5$,M, and TableI. Fig.5 shows flowchart for realized system.

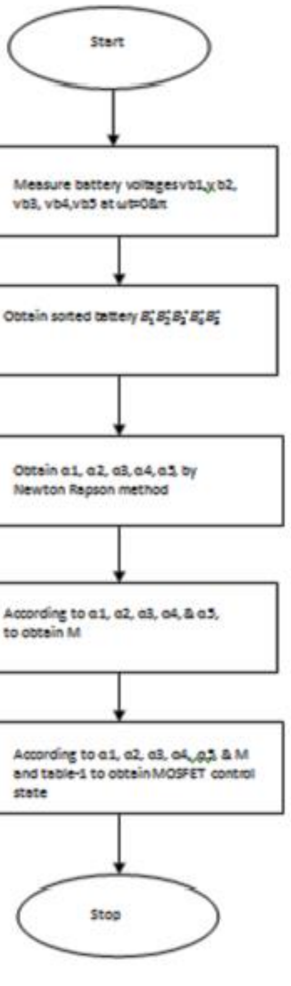

Fig.5 Program flowchart of the realized system

According to this algorithm, the relation of battery discharge capacities is $QB1 < QB2 < QB3 < QB4 < QB5$. Finally, functions of the battery balancing and the harmonic reduction in the realized 11-level inverter.

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III SIMULATION

Simulink (Simulation and Link) is an extension of MATLAB by Math works Inc. It works with MATLAB to offer modeling, simulating, and analyzing of dynamical systems under a graphical user interface (GUI) environment. The construction of a model is simplified with click-and-drag mouse operations. Simulink includes a comprehensive block library of toolboxes for both linear and nonlinear analyses. Models are hierarchical, which allow using both top-down and bottom-up approaches. As Simulink is an integral part of MATLAB, it is easy to switch back and forth during the analysis process and thus, the user may take full advantage of features offered in both environments.
Overall system simulation is done using MATLAB software Fig.6 shows simulink model of overall system.

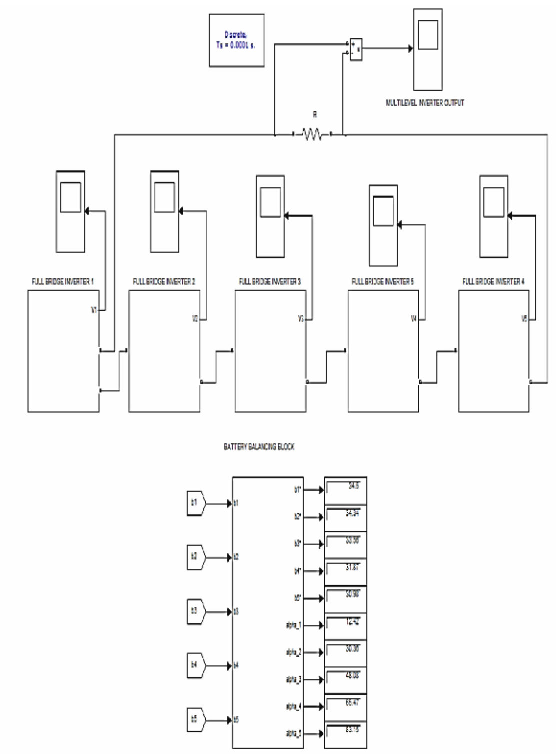

Fig.6 Simulink model of overall system

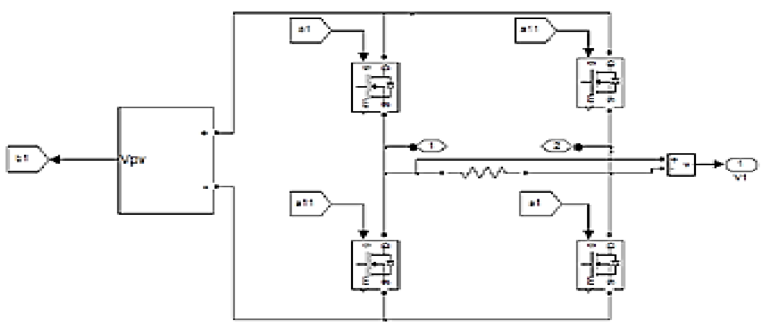

Fig.7 Full bridge inverter simulink model

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Fig.7shows PV cell fed full bridge inverter .From PV cell it inverter gets battery voltage.

According to battery voltages the switching angle is decided to get minimum THD. Fig.8 shows battery balancing block.

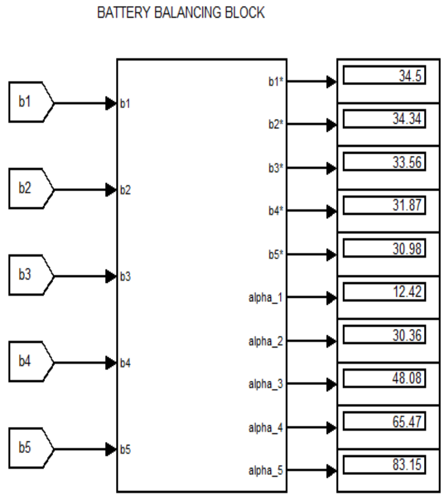

Fig.8 Battery balancing block

Here we can see that battery voltages are sorted and switching angle is decided according to that.fig.9 shows battery balancing subsystem.

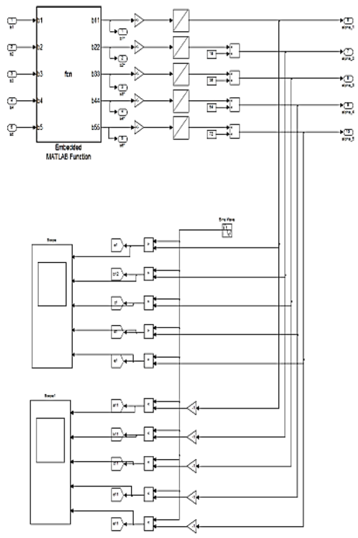

Fig .9 Battery balancing subsystem

IV SIMULATION RESULT:

Whole system is simulated using MATLAB. Fig.10 shows simulation result of single phase PV cell fed11-level multilevel inverter

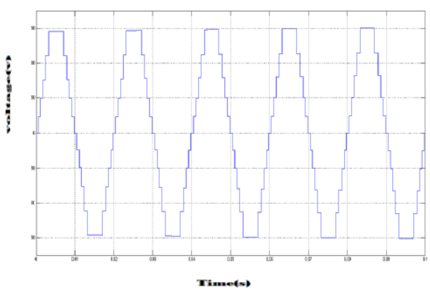

Fig .10 output for single phase PV cell fed11-level multilevel inverter.

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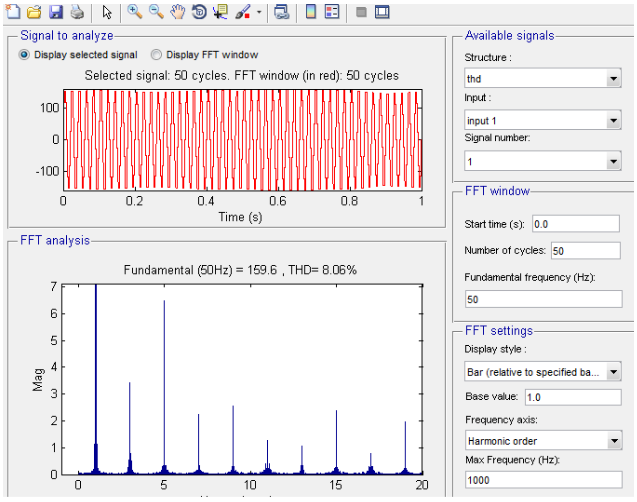

Fig.11THD of Multilevel inverter

Fig 11 shows minimum THD of multilevel inverter. The first run of the program gives the seeds or close angle values for the minimum THD for multilevel inverter.

V CONCLUSION:

In this project, a single-phase PV cell multilevel inverter with battery balancing has been proposed and proved successful. The input of each individual inverter is directly connected to a battery. The combination of batteries can be controlled according to the batteries' voltages to implement the battery-balancing function. A system was designed and implemented to verify the feasibility and excellent performance. Simulation results show that the battery-balancing discharge function was achieved as we wanted. Additionally, the switch angle is controlled to contain the ac output voltage with minimal THD.

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