Comparative Analysis of PV based Multilevel Inverter with and without Battery Management Algorithm

Bensly. V
P.G Scholar / Dept. of EEE
Govt college of Technology
Coimbatore, India

Raja Gopal. N
P.G Scholar / Dept. of EEE
Govt college of Technology
Coimbatore, India

Dr. V. Gopala Krishnan
Asso. Prof / Dept. of EIE
Govt college of Technology
Coimbatore, India

Abstract — **All the energy storage systems contains large number of discharge batteries. To increase the overall capacity of battery bank, the batteries are connected in shunt. In normally the discharge rate of each battery is different. Therefore, the battery bank system requires a battery-management algorithm, to adjust each battery voltage almost to be equal. In this paper, the combination of batteries can be controlled according to the batteries voltages to implement the battery-management function and then compare the output waveform of single phase multilevel inverter with and without battery balancing algorithm. In order to verify the performance of battery management algorithm, a seven-level inverter is designed. The circuit model comprises of three individual full bridge inverters and a controller. The controller is meant to achieve battery management and to decide the suitable switching angles $\alpha 1$, $\alpha 2$, and $\alpha 3$. A look up table is built for the controller to find these switching angles. Finally, the battery management algorithm in the seven-level inverter can be achieved and the performance of the system can be compared successfully with and without using this algorithm. The system is modeled and simulated using MATLAB / Simulink software.**

Keywords— A multilevel inverter, Battery management algorithm.

I. INTRODUCTION

With the increased energy demand and cost of energy, we need more renewable energy sources. The renewable energy sources are normally interfaced to the power electronic inverters and energy storage systems. To maintain the systematic organization of these energy storage systems, and the multilevel inverter systems the battery management algorithms are required. The battery management algorithm not only has the inherited advantages of single phase multilevel inverter but also offers more control flexibilities to fulfill system reliability and power quality requirement with proper management and control. Natural storage systems are commonly equipped with storage battery banks, to regulate output fluctuations. Therefore, it requires battery management. In this paper a battery management algorithm is used to control the voltage levels of the battery sources which are used in the input side of the single phase multilevel inverter

II. PROBLEMS IN THE EXISTING SYSTEM

In recent years, environmental concerns and the continuous depletion of fossil fuel reserves have spurred significant interest in renewable energy sources. However, renewable energy sources such as wind turbines and photovoltaic are intermittent in nature and produce fluctuating active power. Interconnecting these intermittent sources to the utility grid on a large scale could affect the voltage/frequency control of the grid and lead to severe power quality issues [1]–[3]. An energy storage system which contains a large capacity of the battery bank is indispensable for countering uneven compensation. To obtain better battery storage performances, many battery charging strategies have been presented [4]. In order to reduce energy loss in battery bank system and increase the overall battery capacity, the battery bank is series connected for a high-voltage dc power supply [5]. Because of the series connection, the internal impedance and the self-discharge rate are different in each battery, and individual batteries will overcharge or over discharge in a series-connected battery pack, resulting in smaller storage. Therefore, the power conversion system requires a battery-management circuit, to adjust each battery voltage almost to be equal. There have been some battery-management circuits made to control the battery capacity, and these can be classified as dissipative battery-management circuits [6], [7] and non- dissipative battery-management circuits. The simplest dissipative battery-management circuit is made by shunting a resistor across each cell in the string to make the cell maximum voltage equal to prevent voltage unbalance. This dissipative circuit is not good for energy preservation. The non-dissipative battery management algorithm approach is based on dc/dc converters, such as the fly-back converter [8], the buck–boost converter [9], the switch-capacitor converter, etc. To increase the overall capacity of battery bank, the batteries are connected in shunt. In normally the discharge rate of each battery is different. Therefore, the battery bank system requires a battery-management algorithm, to adjust each battery voltage almost to be equal. In this paper, the combination of batteries can be controlled according to the batteries voltages to implement the battery-management function and then compare the output waveform of single phase multilevel inverter with and without battery balancing algorithm.

Fig 1 shows the normal renewable energy systems. The principle of this system is to transfer energy from the higher voltage cell to the lower voltage cell or to the whole stack with less power loss; it is more energy efficient. However, an additional battery-management circuit not only increases circuit's complexity and cost but also reduces efficiency.

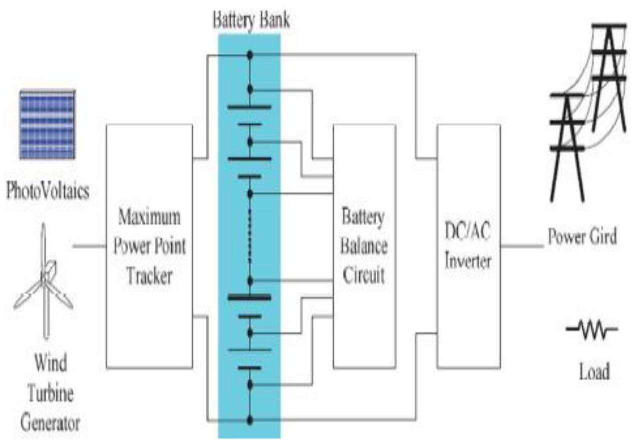

Fig. 1. Renewable energy systems

To solve this problem, a single-phase multilevel inverter with battery management is proposed. Additionally, the switch angle is controlled to contain the ac output voltage with minimal total harmonic distortion (THD). Finally, a prototype is realized to verify the feasibility and excellent performance.

III. MULTILEVEL INVERTERS

Multilevel inverter topologies were first described 20 to 25 years ago for high-voltage grid interface and motor drive applications [10]. The three basic topologies all share the useful features of having reduced semiconductor voltage ratings, and AC waveforms with low total harmonic distortion (THD).

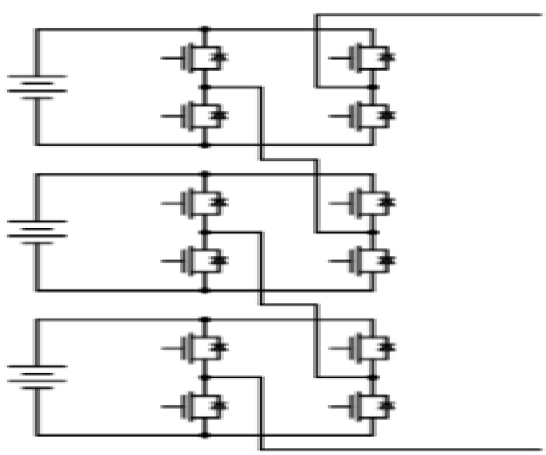

Fig. 2. Cascaded multilevel inverter

Of the various multilevel topologies, the cascaded H-bridge inverter shown in Fig. 2 is perhaps best suited to battery-based applications.

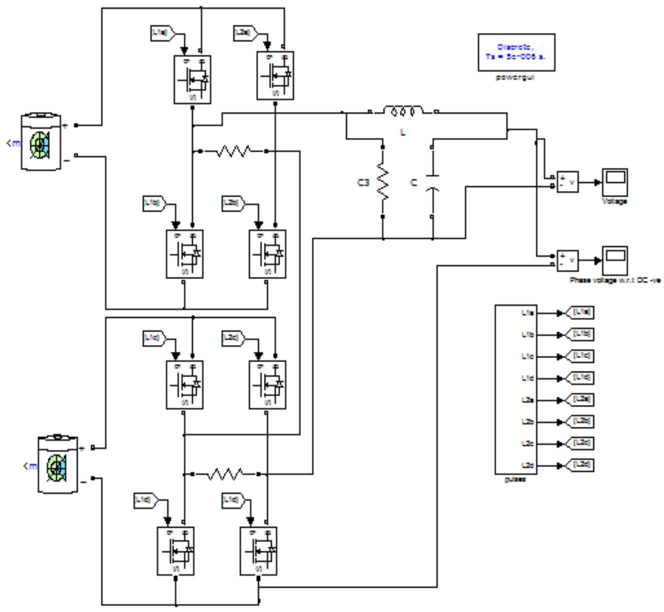

Fig. 3. Multilevel Inverter without battery management algorithm

The inverter can accommodate multiple DC sources, and has a highly modular structure. Using this configuration, a different level of power can be drawn from each DC source independently. In this manner, battery modules can be balanced while charging or discharging. Fig 3 shows the multilevel inverter without battery management algorithm. In this paper the full bridge inverters are connected in cascade and the source of the circuit is lead-acid battery having the voltage levels around 30V to 40V. The output of each full bridge inverters are combined and filtered by using LC filter and get the final output waveform.

IV. PROPOSED SYSTEM MODEL

In order to verify the performance of the proposed single phase multilevel inverter with battery management algorithm, a seven level inverter for providing battery source is designed and implemented. Fig. 4 shows the block diagram of proposed system.

Output voltage(V)	Switching State
+V	ON: S_1 , S_4 & OFF S_2 , S_3
0	ON: S_1, S_2 & OFF S_3 , S_4 or ON: 3 , S_4 & OFF S_1 , S_2
-V	ON: S_2, S_3 & OFF S_1 , S_4.

Table. 1. Switching states of 2N+1 level inverter

The block diagram of the realized seven level inverter that comprises three individual full-bridge inverters and a controller. The controller is meant to achieve battery management algorithm and to decide the suitable switching angles *a1, a2, and a3*. The controller includes a battery management algorithm and a MOSFET state control algorithm.

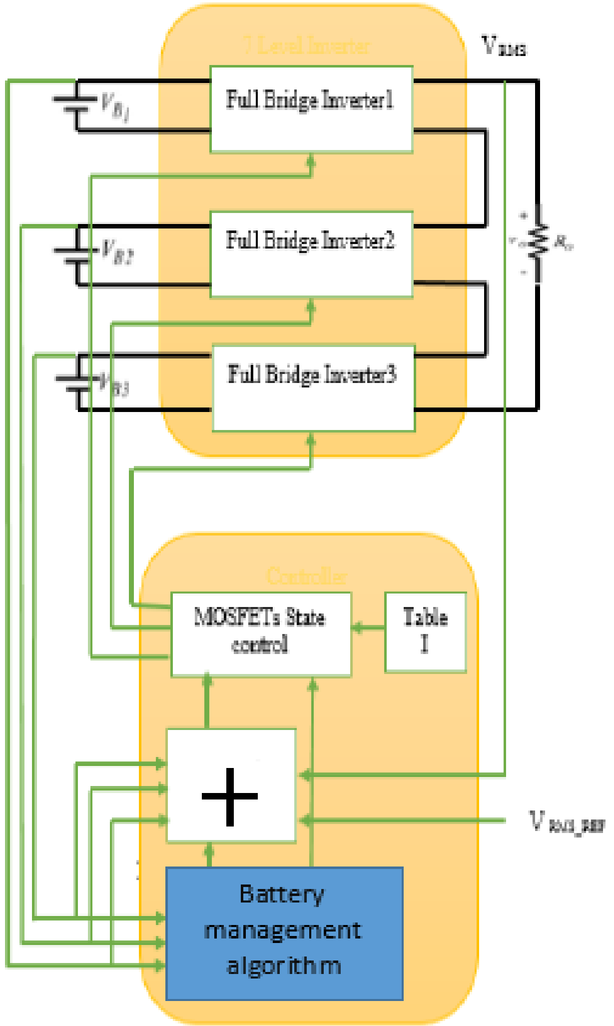

Fig. 4. Block diagram of proposed system

Fig. 5 shows the overall process of the algorithm. Initially we can measure the battery voltages and then arrange the batteries according to the battery voltages, i.e. b11, b22, b22. Then we find out the switching angles, by using the look up table method. The switching angles are *a1, a2, a3*. M is the number of batteries used in the system. Here we use three batteries and the voltage levels of batteries is between 30 volts to 40 volts. Finally by using the switching angles, M and Table 1 we can obtain the MOSFETs state control. Table. 1 contains the switching states of the 2N+1 level inverter.

V. SIMULATION RESULTS

In this paper, 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-management function. A single-phase multilevel inverter with battery management algorithm 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-management function. Each separate battery source is connected to a single-phase full-bridge, or H-bridge, inverter. Each inverter level can generate three different voltage outputs, +V, 0, and –V by connecting the dc source to the ac output by different combinations of the four switches, S_1, S_2, S_3, and S_4. Each separate battery source is connected to a single-phase full-bridge.

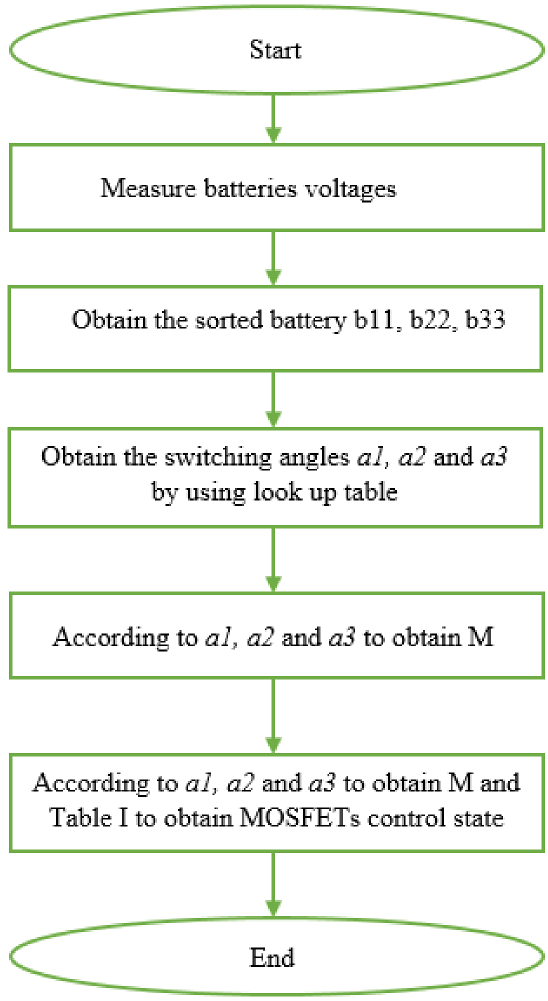

Fig. 5 Flowchart of Battery management algorithm

Mat lab simulation circuit of the seven level inverter with battery management is shown in Fig. 6 and the sub circuit is shown in Fig. 7. To obtain +V, switches S1 and S4 are turned on, whereas –V can be obtained by turning on switches S2 and S3. By turning on S1 and S2 or S3 and S4, the output voltage is 0. The ac outputs of each of the different full-bridge inverter levels are connected in cascade such that the synthesized voltage waveform is the sum of the inverter outputs.

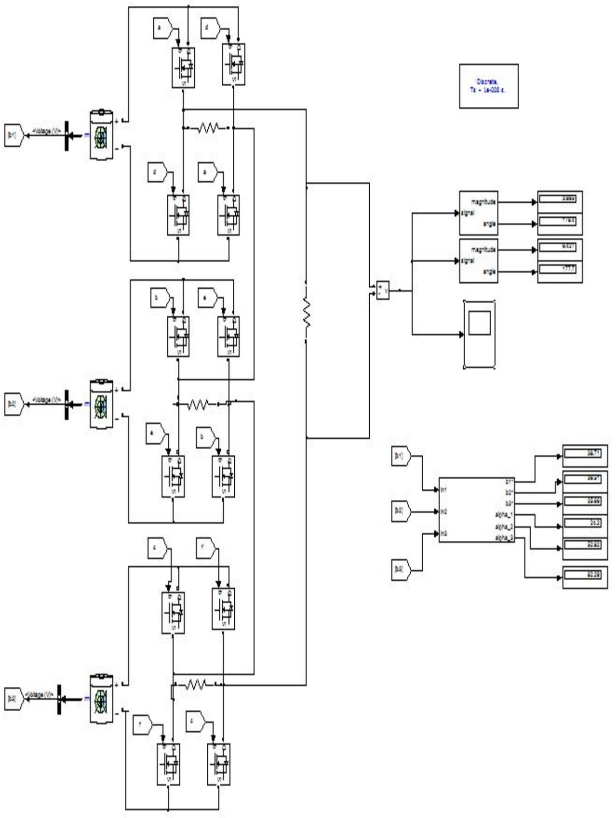

Fig. 6. Mat lab simulation circuit of proposed system

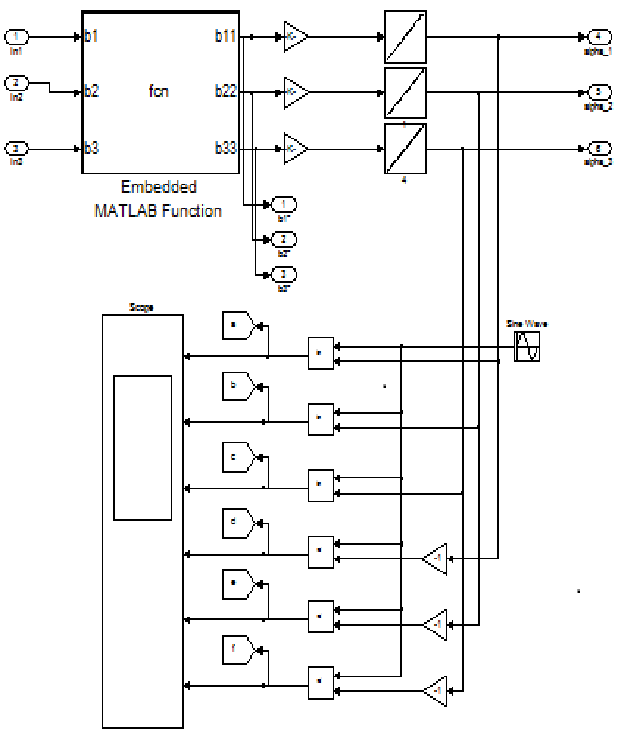

Fig. 7. Sub circuit used in the main circuit

The number of output phase voltage levels m in a cascade inverter is defined by m = 2s+1, where s is the number of separate battery sources. The program used for sorting the batteries according to the voltage levels is given below. It is shown in fig. 8. The system generated input switching pulses, to the seven level inverter is shown in Fig. 9. The output waveform of a multilevel inverter with battery management algorithm is shown in Fig. 10.

```
function [b11,b22,b33] = fcn(b1,b2,b3)

if(b1>b2 && b1>b3 && b2>b3)
     b11=b1;
     b22=b2;
     b33=b3;
elseif(b1>b2 && b1>b3 && b3>b2)
     b11=b1;
     b22=b3;
     b33=b2;
elseif(b2>b1 && b2>b3 && b1>b3)
     b11=b2;
     b22=b1;
     b33=b3;
elseif(b2>b1 && b2>b3 && b3>b1)
     b11=b2;
     b22=b3;
     b33=b1;
elseif(b3>b2 && b3>b1 && b1>b2)
     b11=b3;
     b22=b1;
     b33=b2;
elseif(b3>b2 && b3>b1 && b2>b1)
     b11=b3;
     b22=b2;
     b33=b1;
else
     b11=b1;
     b22=b2;
     b33=b3;
end
```

Fig. 8. Program for sorting the input battery voltages

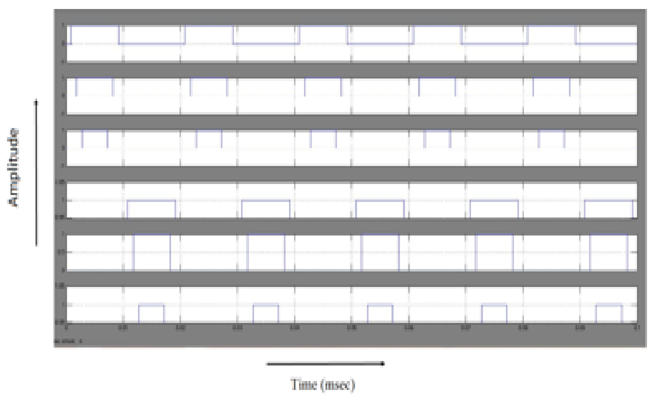

Fig. 9. System generated switching pulses

The THD obtained by without using the battery management algorithm is 25.70% which is shown in fig.11. By using battery management algorithm in the multilevel inverter the obtained THD is 13.94% which is shown in Fig. 12.

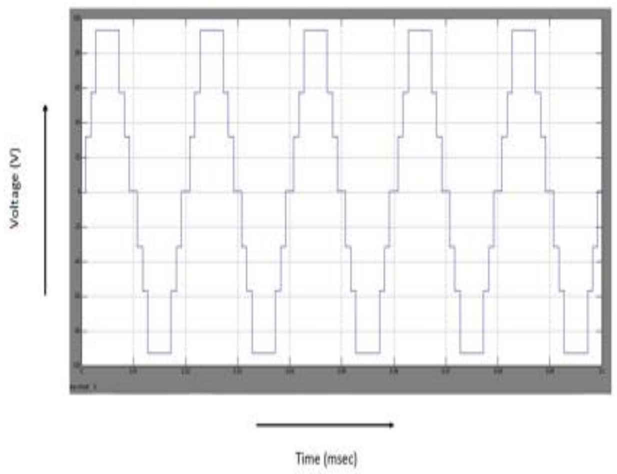

Fig. 10. Output voltage waveform of seven level inverter

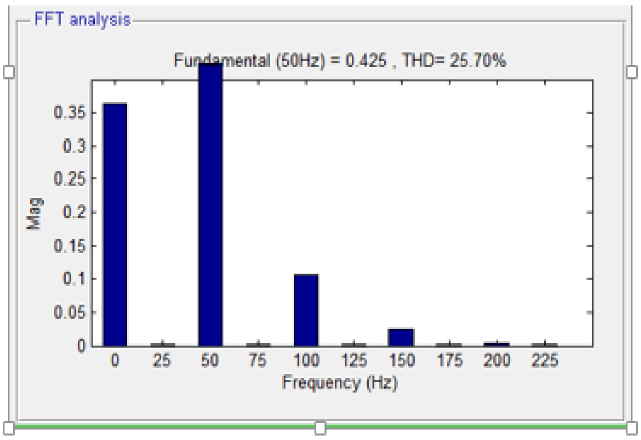

Fig. 11. THD analysis of multilevel inverter without battery management

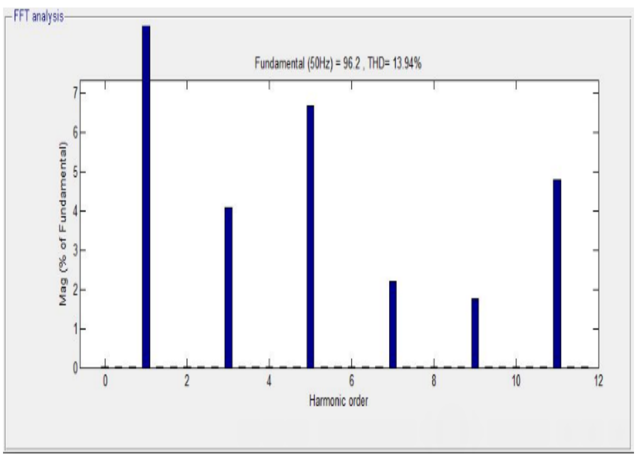

Fig. 12. THD analysis of output waveform with battery management

VI. CONCLUSION AND FUTURE SCOPE

In this paper, a single-phase multilevel inverter with battery management algorithm 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-management function. A prototype was designed and implemented to verify the feasibility and excellent performance. Experiments show that the battery-management 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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