

Battery Balancing For a Multilevel Inverter



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Abstract: Battery balancing for a H bridge seven level inverter for a distributed generation is presented in this paper. The individual bridge is given input which is straight away attached to the battery. This arrangement of the batteries could be balanced by regulating the switching angle of switches in inverter. The standard setup of the scheme is described, and then mathematical equations are obtained. The outcome of simulation shows that battery balancing is achieved.

Index Terms: Multilevel inverter, Battery balancing.

I. INTRODUCTION

By the increasing plea and endless exhaustion of fossil fuel reserves, renewable energy sources have gained major importance in generation of electricity. Integrating the renewable energy sources with power grid affects the voltage/frequency leading to severe power quality issues as renewable energy homes are discontinuous in nature and produce fluctuating power [1]. To overcome the concerns the power generated can be stored in the battery. The batteries can be cascaded to increase the capacity of storage and reduce the transmission losses., [1], [2], [3]. The battery balancing techniques have been proposed which can be classified as i) Dissipative battery balancing [4], [5] and ii) Non dissipative battery balancing. [6].

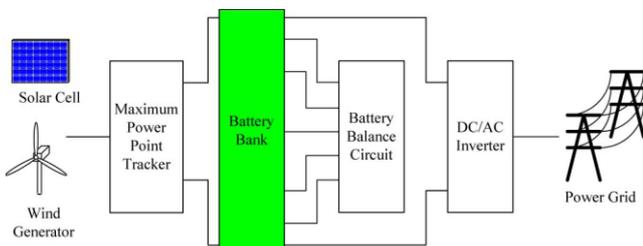


Fig. 1: Renewable energy systems

By adding a resistor in parallel across each cell Dissipative battery balancing can be achieved to make the voltage equal, but is not appropriate for energy storage. DC-DD converter, fly back converter etc are included in the non-dissipative battery balancing approach. [7], [8]. Transfer of the charge from battery with higher charge to battery with lower charge is the basic principle.

The complexity and the cost of the circuit is reduced due to battery balancing circuit and also the efficiency. Battery balancing for single phase multilevel inverter is anticipated to overcome this, which can be controlled such that the battery is balanced and the harmonics are condensed.

II. OBJECTIVE

To minimize the THD and to achieve battery balancing by calculating the ideal switching angles of the switches in the inverter bridge.

III. MATH

A. Cascaded Multilevel Inverter

Amongst all the topologies for multilevel inverter, cascaded multilevel inverter is the superior to all other topologies. To each bridge the input is given by single voltage source in the form of a battery which comprises of the stored energy, produced by the renewable energy sources and is cascaded by supplementary sources through a distinct H-bridge circuit allied by it. Output voltage is yielded is either positive, negative or zero volts and is depending on the switching angle as the individual circuit contains four switching elements. The output that is yielded is $2N+1$ level; where N indicates the integer of batteries or number of full bridge inverter[9].

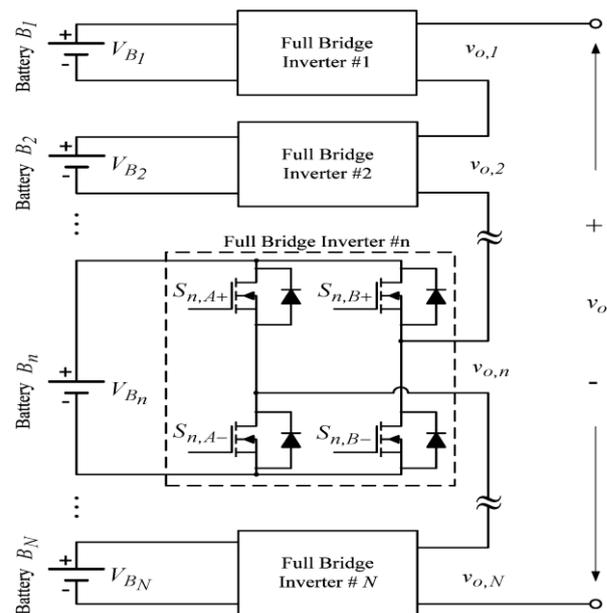


Fig. 2: Battery balancing for $2N + 1$ inverter level.

B. Battery Balancing

Batteries set could be designated as

$$Q = \{Q_1, Q_2, \dots, Q_n, \dots, Q_N\} \quad (1)$$

The output can be made nearly equal to sinusoidal by encoding appropriate M structure regulated by positive and negative polarity regulator [23]. The switching pattern swapping organization could be implemented, if the characteristics of each battery is identical.

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The set of battery 'Q' is sorted and if the characteristics of any two batteries are found to be different, and the sorted battery set 'Bsort' is accomplished.

$$Q_{sort} = \{Q_1^*, Q_2^*, Q_3^* \dots \dots \dots Q_n^* \dots \dots \dots Q_N^*\} \quad (2)$$

Which has $V_{Qn}^* < V_{Qn-1}^*$ 'n' is the natural number (1,2,...N). The battery Q_i^* is with maximum voltage, and battery with subsequent maximum voltage is indicated as Q_i^* then so on. RMS voltage and Fourier series for h^{th} harmonic output wave can be articulated as the following

$$V_{h\ rms}(\alpha_{Q1}^*, \alpha_{Q2}^*, \dots \dots \dots \alpha_{Qn}^*) = \sqrt{\frac{4}{2h\pi} [V_{Q1}^* \text{Cosh}\alpha_1 + V_{Q2}^* \text{Cosh}\alpha_2 + \dots + V_{Qn}^* \text{Cosh}\alpha_n]} \quad (3)$$

h can be odd number (h = 1,3,5,7.)

Conferring with equation (3), the switching angles $\alpha_1, \alpha_2, \dots \dots \alpha_N$ could be calculated so as to curtail the THD and the output is close to reference.

Depending upon value switching angles $\alpha_1, \alpha_2, \dots \dots$ X batteries with maximum voltage are decided.

$$Q_x = \{Q_1^*, Q_2^*, Q_3^* \dots \dots \dots Q_x^*\} \quad (4)$$

Multilevel inverter resultant voltage is being expressed as

$$V_0 = V_{Q1}^* + V_{Q2}^* \dots \dots \dots V_{Qm}^* \quad (5)$$

Discharging capacity of a battery having greater voltage is bigger compared to the battery acquiring subordinate voltage. Thus for a multilevel inverter battery balancing is achieved.

C. Battery Balancing Controller

Regulator is used for accomplishing battery balance along with selective harmonic rejection by applying equation (3) and to adopt appropriate switching angles $\alpha_1, \alpha_2,$ and α_3 . Besides this the regulator also consist of algorithm for a battery assessment, a harmonic decreasing system and also an algorithm for MOSFET state control.

Voltagess across the battery V_{Q1}, V_{Q2} and V_{Q3} are noted at instant $\omega t=0$ and $\omega t=180^\circ$ and are sorted further.

$$Q_{sort} = \{Q_1^*, Q_2^*, Q_3^*\} \quad (6)$$

Fundamental frequency RMS voltage, third order harmonic and fifth order harmonic are symbolized by the following equation according to (3):

$$V_{1\ rms}(\alpha_1, \alpha_2, \alpha_3) = \frac{4}{\sqrt{2\pi}} \left[V_{Q1}^* \text{Cos}(\alpha_1) + V_{Q2}^* \text{Cos}(\alpha_2) + V_{Q3}^* \text{Cos}(\alpha_3) \right] \quad (7)$$

$$V_{3\ rms}(\alpha_1, \alpha_2, \alpha_3) = \frac{4}{3\sqrt{2\pi}} \left[V_{Q1}^* \text{Cos}(3\alpha_1) + V_{Q2}^* \text{Cos}(3\alpha_2) + V_{Q3}^* \text{Cos}(3\alpha_3) \right] \quad (8)$$

$$V_{5\ rms}(\alpha_1, \alpha_2, \alpha_3) = \frac{4}{5\sqrt{2\pi}} \left[V_{Q1}^* \text{Cos}(5\alpha_1) + V_{Q2}^* \text{Cos}(5\alpha_2) + V_{Q3}^* \text{Cos}(5\alpha_3) \right] \quad (9)$$

Newton Raphson method is being used to find angles α_1, α_2 and α_3 to meet equation (7-9). If the switching angles cannot meet equation (7-9) then (7) will be priority.

All switch states are attained rendering to α_1, α_2 and α_3 . Finally, in the multilevel inverter the battery balancing function and the harmonic decrement can be realized.

D. Newton-Raphson method for finding Switching angle

Output voltage waveform using fundamental frequency switching scheme and Fourier series expansion is by means of equations below

$$V_0(\omega t) = 4 \frac{V_{dc}}{n\pi} [\text{Cos}\theta_1 + \text{Cos}\theta_2 + \text{Cos}\theta_3] \quad (10)$$

By solving the following equations, switching angles can be established.

$$\text{Cos}\theta_1 + \text{Cos}\theta_2 + \text{Cos}\theta_3 = m \quad (11)$$

$$\text{Cos}3\theta_1 + \text{Cos}3\theta_2 + \text{Cos}3\theta_3 = 0 \quad (12)$$

$$\text{Cos}5\theta_1 + \text{Cos}5\theta_2 + \text{Cos}5\theta_3 = 0 \quad (13)$$

Where $m = \frac{V_2\pi}{4V_{dc}}$ (modulation index)

The transcendental equations are transformed to polynomial equation using modification of variables and trigonometric identities.

$$X_1 = \text{Cos}\theta_1, X_2 = \text{Cos}\theta_2, X_3 = \text{Cos}\theta_3,$$

$$X_4 = \text{Cos}\theta_4, X_5 = \text{Cos}\theta_5, X_6 = \text{Cos}\theta_6,$$

$$X_7 = \text{Cos}\theta_7 \quad (14)$$

$$\text{Cos}3\theta = 4\text{Cos}^3\theta - 3\text{Cos}\theta \quad (15)$$

$$\text{Cos}5\theta = 5\text{Cos}\theta - 20\text{Cos}^3\theta + 16\text{Cos}^5\theta \quad (16)$$

The set of above non- linear equation can be solved by means of Newton-Raphson method and switching angles can be adjusted to accomplish battery balancing and minimizing the harmonics.

IV. EXPERIMENTAL OUTCOMES

Presentation of H bridge inverter along with battery balancing is tested by the simulation outcomes.

Solar model was simulated the output of which is stored in battery and this is given as input to the individual full bridge inverter.



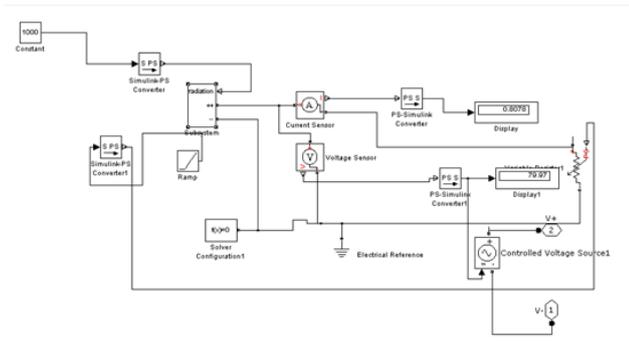


Fig.3: Simulation of solar cell.

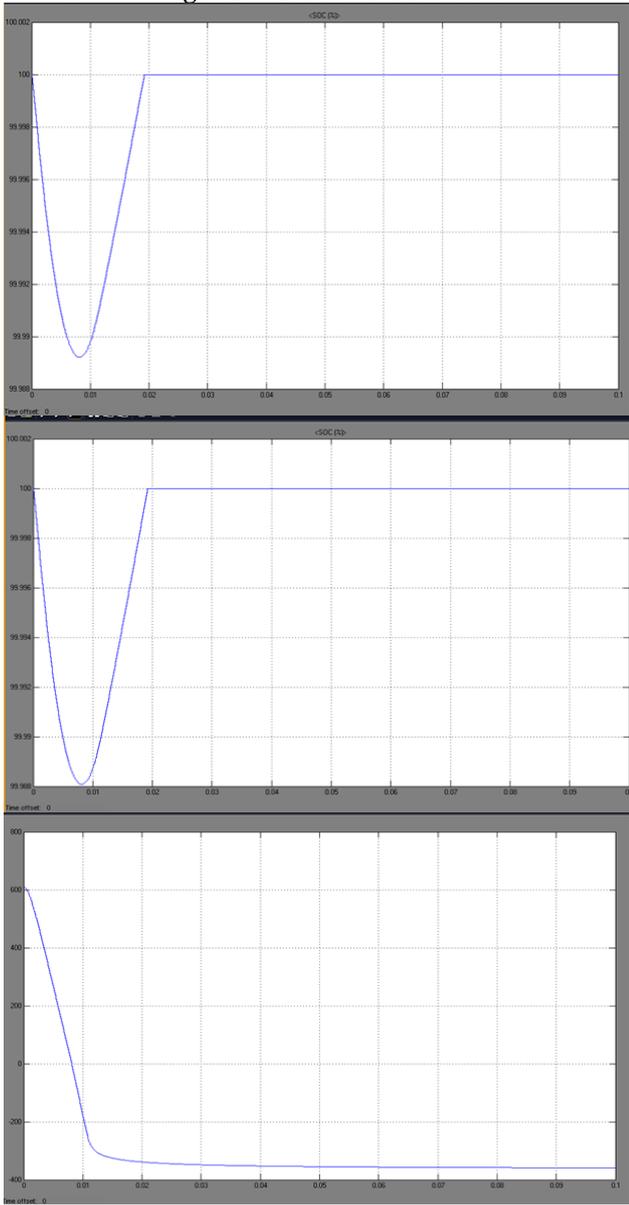


Fig. 4 : Battery discharge current (before balancing)

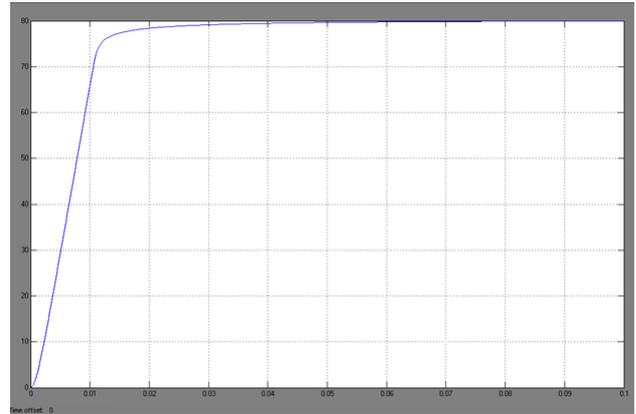
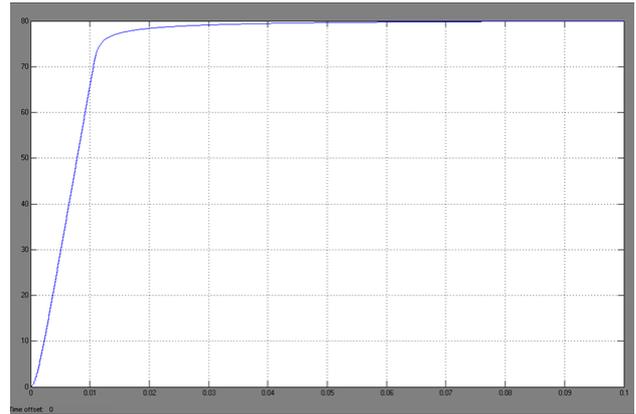
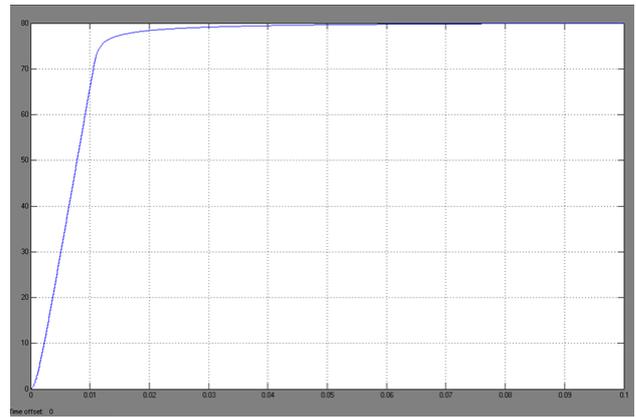


Fig. 5: Battery currents (after balancing)

For battery balancing we have used here three batteries $Q_1 = 44V, Q_2 = 48V, Q_3 = 52V$, We have taken switch condition to the battery. The Switch unit is passed over the first input or third input grounded on the value of the second input. The first and third inputs are termed as *data inputs*. Second input is termed as the *control input*. Here I have taken control input as 48V. First data input 44v and third 54V. If control input is greater than 48, it will shift towards third input. If control input is less than 48 then it will shift toward first input. Further if one of battery is default .then we are just transferring first battery to the third and third to first.

Switching pulses for the switches in the inverter can be simulated by comparing sinusoidal wave with saw tooth wave as in case of PWM technology.

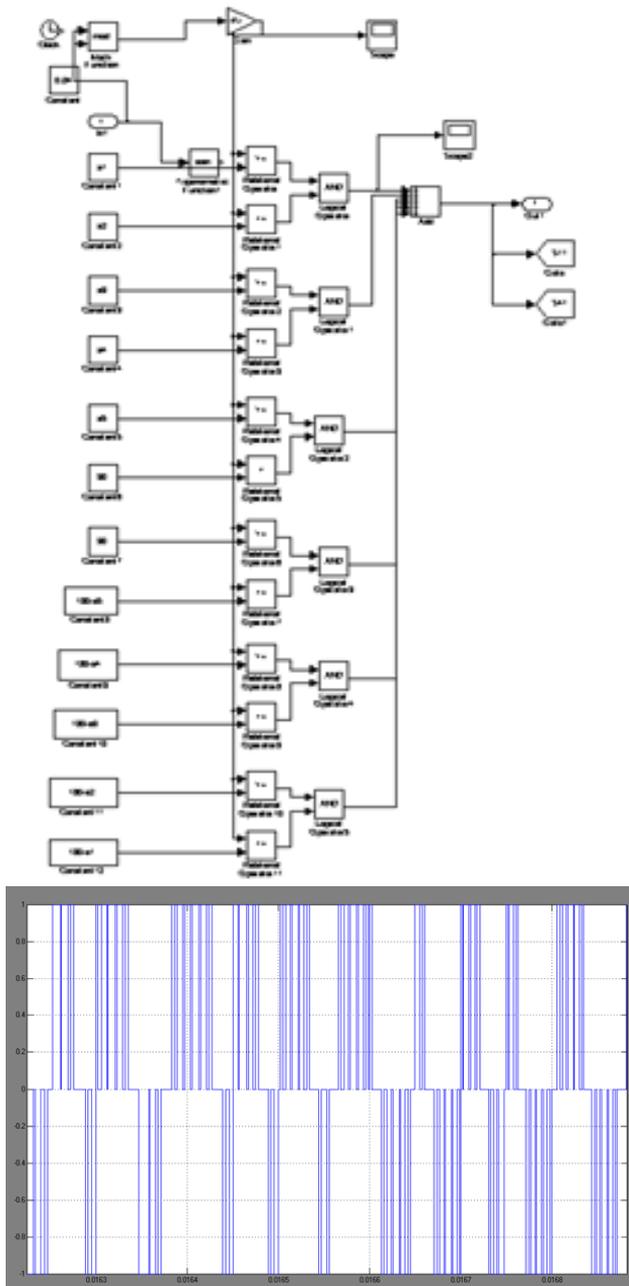


Fig. 6 :Simulation for generating switching pulse and its output

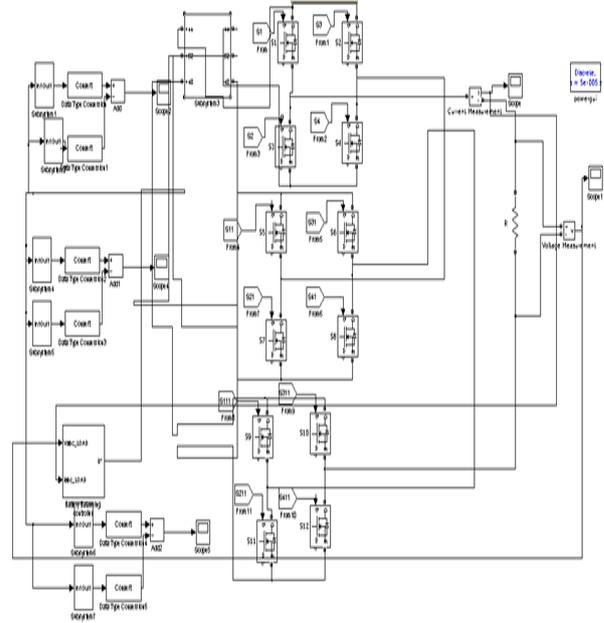


Fig. 7: Simulation of the overall system

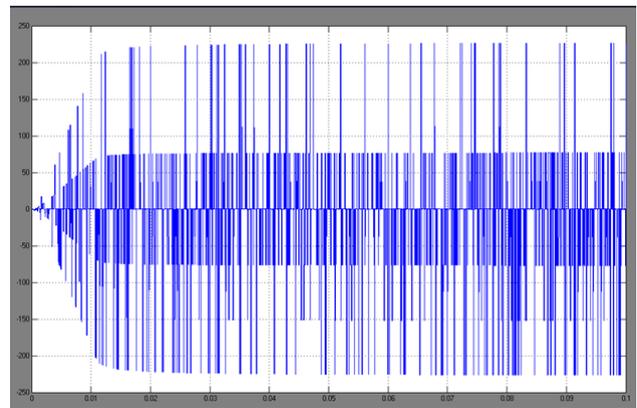


Fig. 8: Output of the system.

V. CONCLUSION

Battery balancing for a multilevel inverter is simulated successfully in this paper. Input to the specific full bridge inverter was given through a battery which was stored by the energy produced by the solar cell. Depending on the battery’s voltage battery balancing function was employed and analogous switching pulses were also generated, thus battery balancing is achieved.

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