A New Topology for Regulation of Active Power by Battery Storage System with Cascaded Multilevel Inverter using Three Phase System

G. Balasundaram*, S. Arumugam, J. Gowrishankar and C. Dinakaran

1Department of EEE, St. Peter’s University, Avadi, Chennai - 600054, Tamil Nadu, India; balusni.sundaram23@gmail.com
2Department of EEE, GRT Institute of Engineering and Technology, Tiruttani - 631209, Tamil Nadu, India; grtietprincipal@gmail.com
3Department of EEE, Sastra University, Thanjavur - 613401, Tamil Nadu, India; gowrishankarva@gmail.com
4Department of EEE, S. V. C. E. T, Chittoor - 627855, Andhra Pradesh, India; dina4karan@gmail.com

Abstract

The battery plays a major role for energy storage in non conventional energy systems. This paper proposed an AC-DC-AC converter using Pulse Width Modulation Technique for Multilevel inverter. Normally the voltage drop increases when the load increases. Because the load voltages are consume more than the source voltages. To overcome this problem, the battery energy depot system is linked to the converter for controlling the active power. The performance of the proposed topology is a present active power regulates in battery energy depot scheme has been verified by simulation MATLAB/ SIMULINK environment.

Keywords: Cascade Multilevel Converter, Energy Storage System, PWM Technique, Phase Shifting Transformer, Smart Grid

1. Introduction

Energy depot system is an equipment that stores electricity when the demand is low. Electrical energy depot at the same time when generates power from generating stations specifically non conventional energy sources such as wind and solar power exceeds utilization and when increased discretionary load is turned on but utilization is still deficient to consume it1,2. Electrical energy cannot be stored directly, but it can be stored in the mode of electromagnetic, electrochemical, kinetic or a potential energy is again transformed back to electricity when needed3,4. Amongst the power applications utilizing energy storage, The Battery Energy depot Schemes have been increasingly used in the last two decades. Currently, batteries are one of the most adequate energy storage technologies are accessible, particularly lead-acid batteries shows an well-established and developed automation5,6. These batteries can be created for bulk energy storage or for accelerated charge/discharge operations. Advances battery technology offers increased storage denseness, most dragging effectiveness, higher authenticities and diminished cost3,7.

Battery Energy depot schemes have newly appeared as one of the greater auspicious near-term depot technologies for power utilization, Beneficence an immense range of power system applications such as area governance, area coordination, spinning reverse, and improvement of power factor. Many of the energy depot systems are in operation for the purpose of the load leveling, preserving, and load frequency control8.

*Author for correspondence
This scheme can be unified with Flexible AC Transmission Systems power controller to enhance the power system function and control. The essential to diminishing the adverse emanation against the conventional power plants, direction to a progression of the power systems almost diffused generation based on non-conventional energy sources\(^8\). Wind plant and solar photovoltaic installations are the most important in renewable with significant worldwide installed capacities and higher annual growth rate. The defect of this renewable energy sources is the huge variation on daily and seasonal basis. This experience makes their combines with high percentage into the grid a renowned challenge, since the preservation of supply is a more antecedence\(^10\).

Factors affecting the selection of batteries: Inmost discharge (70% - 80% of deep discharge), depressed charging /depressed discharging current, great duration charge (slow) and Long discharge (long duty cycle), Intermittent and changing charge/ Varying discharge, self discharge is small, life time period is more, maintenance requirement is less, High energy storage capacity, Less cost, state of charge is low, Deep of discharge is maximum\(^12\). The batteries lifetime dependencies on depth of discharge (DOD) as shown in Figure 1.

Flying capacitor and Diode clamped have one voltage source and the count of output voltage levels are equal to the switches used in the circuit. The predominant disadvantage in the diode clamped inverter is crucial to control the actual power flow of the respective converter. Because of the DC levels overcharge without precise control of diodes. The major disadvantage of flying capacitors multilevel inverter is the balancing of voltage levels in bulky power capacitors it needs additional recharging circuitry, in real power transmission, switching frequency and switching losses are more. This system efficiency is not satisfactory, performance of modulation index is poor and difficult to package with the bulky power capacitors\(^11\).

In this scenario, cascaded H Bridge multilevel converter (DC-AC) is proposed to replace Diode Clamped and flying capacitors inverter in moderate and large voltage level applications such as electrical machines and generation of power in solar Photovoltaic (PV) system.

2. Battery Energy Storage System

The objective of the proposed scheme is design of modular battery energy storage system, taking into account the interaction between the electrochemical system and the power electronics. The power can be controlling through the cascaded multilevel inverter arrangement which we have designed converter cell configurations are 200 V, 10 kW, 3.6 kWh. Traditional Battery energy storage system is existing and proposed modern energy storage as shown in Figure 2.

The energy depot scheme delivers compelling improvements in voltage quality ,power quality and security to the loads. Power conversion is required by the reason of batteries or DC sources so it is merge these batteries to the AC system. In this system the advantageous of the converter to have a four quadrant operation of a converter. So the System can be achieved by bidirectional current flow. The features of the converter provide a interspersed battery charging scheme in the main control function, it contribute effective filtering to maintain the harmonic profile and steady modular control system as shown in Figure 3.

In the Energy depot scheme is based on different depot has been analyzed. In power applications scheme the Electric Double Capacitors (EDLC) and DC source or Batteries have materialize as Energy depot scheme. The Energy Efficiency of a EDLC has 95% is high, the high Power density is 300-500W/Kg and it exceeding up to a 500000 long cycle life. The Batteries Energy density scheme has 50-130 Wh/kg for Lithium batteries and 30-80 Wh/Kg for Nickel Metal Hybrid Batteries. When EDLC is compare with all Batteries the EDLC has 3-5Wh/ Kg lower energy density scheme.
3. Battery Energy Storage System for Active Power Control

The Energy depot scheme is based on a Multilevel Cascaded H Bridge Converter. The following system is based on Life Efficiency of the scheme, Battery cost and Maintenance, startup method in the scheme, balancing the cell, merge between the cascaded Converter and the DC voltage, in individual H bridge Converter the Active

Figure 2. (a). Traditional Battery Energy Storage Systems, (b) Modern Battery Energy Storage Systems.

Figure 3. Single line diagram of Real Power Control of a Battery Storage System.

Figure 4. Block Diagram for Active-Power Control of the Battery Energy Storage System.
power control is analyzed, fault tolerance and the battery units have the balancing State of charge.

The battery depot scheme is used to control the real power as shown in figure 4. Therefore the active power control is depends on two categories.

- In modular multilevel cascaded H-bridge converter cells are used to control the Active power is expressed in dashed lines as shown in the Figure 4.
- The thick lines represents real power control of respective converter cells.

The first one based on the synchronous dq reference frames has the responsibility of the total active-power control.

\[
\begin{bmatrix}
  V_d \\
  V_q
\end{bmatrix} = \begin{bmatrix}
  V_d \\
  V_q
\end{bmatrix} - (\begin{bmatrix}
  0 & -wL & \\
  wL & 0
\end{bmatrix}) \begin{bmatrix}
  i_d \\
  i_q
\end{bmatrix} - \begin{bmatrix}
  K \\
  0
\end{bmatrix} \frac{di_d}{dt} - \begin{bmatrix}
  K \\
  0
\end{bmatrix} \frac{di_q}{dt}
\]

Here, \( V_{dq} \) and \( i_{dq} \) are the d-axis and q-axis components of \( V \) and \( I \), while \( \dot{I}_d \) and \( \dot{I}_q \) are the d-axis current command and the q-axis current command are given by

\[\begin{align*}
I_d^* &= \frac{P^*}{V_{sd}} \\
I_q^* &= \frac{q^*}{V_{sd}} = 0
\end{align*}\]

Where \( P \) - Total Real power
\( q \) - Total Reactive power (\( q^* = 0 \)) ensures that Unity power factor operation.

4. Design of Restrained Battery Energy Storage System

![Figure 5. Power Circuit using Coupled Buffer Inductors.](image-url)
The term Modular Multilevel Cascaded H bridge Converter is expressed as the combination of Cascaded H bridge Converter and Modular Multilevel Converter is called as a Modular Multilevel Cascaded H Bridge Converter (MMCHC) as shown in figure 5.

In Figure 6 shows the Three phase input supply of 200v and 50Hz is drawn to the Source inductance of 48µH with circuit breaker and a starting resistor of 10Ω with AC Inductor (L_{ac}) of 1.2mH is connected Cell1, Cell2 and Cell3 through Rectifier. The Filter DC capacitor is 16, 4mF is flows to the circuit Breaker (CB2) with starting Resistor of 20Ω and fed through the Batteries 72V, 5.5 Ah x 9. The VDC voltage across the capacitor is 72V. In Rectifier the carrier frequency is 800Hz.

5. Simulation Model of Battery Energy Storage System

The battery energy storage system can be obtained by arranging the each individual converter cells in a cascading manner to get the response of multilevel output voltage respectively control on the real power which is stored in battery storage system. This battery energy storage system has been implemented in smart grid arrangement for intermittent of Energy sources as shown in Figure 7.

The simulation model of this battery energy storage system with control of active power in the sense of multilevel converter configuration has been shown in the above simulation model.
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Figure 7. Simulation Model for Active-Power Control of Individual Converter Cells with Grid Connected System.

Figure 8. Simulation Results of Three Phase Waveforms (a) Input Current and (b) Input Voltage.
The waveforms show the input three phase current ($I_{dc}$) and voltage ($V_{ac}$) waveforms from the measurement State of Charge (SOC) as shown in Figure 8.

The Figure 9 is the simulation results of controlled multilevel output voltage waveform and corresponding output current waveform. The high voltage and current are stored power from the battery energy storage system, which is controlling the power on basis of multilevel inverter arrangement at outcome of the dc stored power from battery energy storage system. The total harmonic distortion respectively output voltage and current as shown in Figure 10.

5.1 Simulation Model of Single Converter Cell Model
In the above simulation model we will have a arrangement of rectification i.e., converting from AC to DC after that converter will have to arrangement of NiMH battery storage system i.e., here the converted power has been stored in this battery storage system arrangement.

The simulation model above Figure 11 having a breaker arrangement will helpful to avoiding the hazards from the faults to the smart grid at the utilization side. Capacitors are connected for the purpose of charging and discharging of the voltage in the battery energy storage system. In the battery storage system we will have a voltage and current measurement arrangement to know the charging and discharging of DC voltage and current.

5.2 Simulation Model of Cascading of Three Individual Converter Cell

Design of three converter cells is cascading arrangement model as shown in Figure 12. Nine converter cells are cascading arrangement by cascading of three blocks. In each block consist of three converter cell cascading arrangement to get the concept of multilevel inverter for control of real power.
Figure 13 shows the waveform of DC voltage which is from battery energy storage system.

Figure 14 shows the waveform of DC current which is from battery energy storage system and $I_{dc1}$, $I_{dc2}$ and $I_{dc3}$ waveforms respectively.

Figure 13. Simulation Results of Output DC Voltage Waveform ($V_{dc}$).

Figure 14. Simulation Results of Three Phase Waveforms (a) Input Current and (b) Input Voltage.
6. Total Harmonic Distortion

The total harmonic distortion of the output dc voltage ($V_{dc}$) and output dc current ($I_{dc}$) has shown in Figure 15.

DC voltage which is input to the inverter, THD of $V_{dc}$ is 79.29% and it will be reduced to 28.77% of THD of $V_{load}$ which is output of inverter as given in Table 1. The harmonic content reduces nearly 50%. Because multilevel of voltage at the output side on reduction of harmonics due to implementation of cascaded multilevel inverter in a Battery Energy depot System with controlling of real power.

Table 1. Analysis of Total Harmonic Distortion (THD) in an active power control in a Battery Storage System using with cascaded multilevel inverter

| S.No | Voltage & Current | Fundamental Frequency in (Hz), at | Total harmonic distortion in (%), at |
|------|------------------|----------------------------------|-----------------------------------|
|      |                  | 60 Hz              | 50Hz              | 60Hz | 50Hz   |
| 1    | Vscr(input)      | 9168               | 9307               | 0.0  | 19.70  |
| 2    | Iscr(input)      | 3996               | 3602               | 0.16 | 38.34  |
| 3    | V load(out)      | 9.443e-006         | 1.063e-005         | 28.77| 31.43  |
| 4    | I load(out)      | 4.966e-006         | 5.082e-006         | 10.40| 44.59  |
| 5    | Vdc              | 4.871e-007         | 5.603e-007         | 79.29| 86.63  |

7. Conclusion

This paper gives a detailed of battery energy depot systems having a real power control which is from battery energy depot system along with a cascaded multilevel converter topology is implemented. Electrical energy depot system using batteries is progressing to emerge technologically, increasingly being approved as a applicable, potentially
subversive resources which could essentially modify the way of electricity is generated and utilized. As the economy of energy depot systems decreases and their accuracy rises with enhanced technologies. An improved technology battery energy storage system for smart grid is designed and implemented for a multilevel cascade H-bridge converter with PWM technique, with the specifications of energy depot system is 200V, 10kW, and 3.6kWh. It is observed that the active power is controlled and harmonic content can be reduced by battery energy storage system with high effective multilevel inverter configuration. Three phase output is adjusted according to the load requirements. The active power can be controlled by adjusting of currents and voltages by applying pulse width modulation technique.

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