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Role of Battery Energy Storage System in Modern Electric Distribution Networks - A Review

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ABSTRACT

The dependence on the conventional energy sources is on the decline due to their limited stocks and the pollution involved. This has resulted in the shift in the focus towards renewable energy harnessing in recent times. But there is a major limitation of these renewable sources that these are all intermittent in nature. The increase in penetration of renewable energy in various applications, due to the major focus of significant government and private initiatives has also led to the development of energy storage systems to enhance their reliability. Battery energy storage systems (BESS) is one such system. It is dedicated equipment or system which is used in renewable energy systems, and in electric power distribution networks to enhance the overall reliability and quality of power supply. In this paper, an effort has been made to compile the role of BESS in the electrical distribution systems without/with renewable energy systems in stand-alone and grid mode.

Key words: BESS, SOC (state of charge), STATCOM (static synchronous compensators), LFC (load frequency control)

1. INTRODUCTION

Energy storage systems such as potential energy in pumped hydro, heat energy as in molten salt, in case of flywheels as kinetic energy, compressed air energy storage (CAES), capacitors (electrical energy), batteries (electrochemical energies) form an important aspect in improving the reliability of renewable energy systems. The cost of pumped hydro is less but due to its dependability on unpredictable factors like environmental and geographical, the inclination has shifted towards energy storage systems like Battery energy storage systems (BESS) so that cleaner and sustainable energy is retained. The sporadic character of renewable energy generation adds a supplementary unpredictability to the grid systems [1].

In light of this, BESS is an essential system that can help in significantly improve this undesirable situation. The path breaking impact of BESS in the electrical power system is such that it makes the grid smarter by providing a backup option [2-3]. The role of BESS in the electrical distribution systems without/with renewable energy systems in stand-alone and grid mode is of utmost importance [4-5]. There can be different batteries that are used in BESS. Table 1 presents the performance parameters of four such types of batteries [6]. The sodium sulfur battery is supposed to be kept at 290~350℃ to facilitate customary working. The worth of lithium ion battery is relatively high in comparison to other batteries. Low energy density of flow battery and phenomenon of discharging by self of Ni-MH is exceedingly sharp [7-8].

Table 1: Comparison of Batteries [3]

Battery type	Capacity (kW)	Energy density (Wh/kg)	Life span(cycles)	Self discharge (%)	Operating temp. (C)
Sodium sulfur	100	100	2,500	0	290 - 350
Lithium ion	200	90-160	600-1,200	6-9	(-30) - 50
Flow batteries	10	30-50	10,000	0	0 - 40
Ni-MH	100	60-80	1,000	30-50	-30 - 55

2. ADVANCEMENTS IN BESS TECHNOLOGY

Using Super capacitor for Renewable Energy Power Generation

Among all type of utilities, renewable energy sources are becoming more significant and environment friendly. For grabbing a big deal of attention wind generators and photovoltaic cells are competent [9]. They suggest valuable compensation for better stability, power quality and constancy of supply. Power source voltage drop results from the rapid increase of load which shall depreciate power quality. Moreover, for reaching the peak power requirement in some intense circumstances the major power source is inadequate to provide required power [10]. So, to increase the specific power and density of power sources, there is a vital need of energy storage systems.

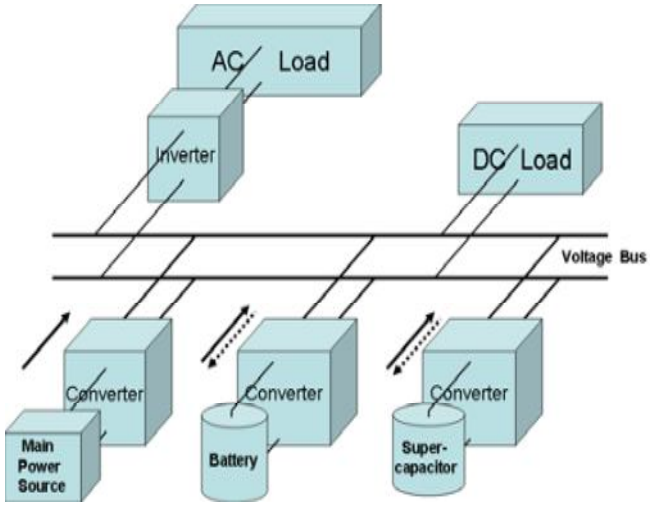

Figure 1: Architecture of super capacitor hybrid system [17]

Super capacitors have larger density of power in the form of static electronic charge as compared to battery which uses electrochemical process for achieving energy storage [11-14]. On combining these two devices, as shown in figure 1, higher power output and better energy performance is found. To reimburse rapid power output changes the super capacitor is useful which is a device for short time energy storage, but to appropriately meet the energy demand, the long lasting device for storage of energy is BESS [15-18]. In terms of flexibility, active hybrids in hybrid energy storage system are more flexible than the passive hybrids in which power source and voltage bus are directly connected [16]. For dynamically controlling the power allocation in devices for energy storage in these systems, dc/dc power converter is used for connecting each and every energy device [17-19]. Unlike pre mediated hybrid sources like fuel cells/ super capacitors, fuel cell/ battery [20-23], there is no justification for the control of active hybrid battery/ super capacitors system for energy storage [24-25].

Using superconducting coil for clean generation

The results verify that fuel cell system which don't have energy storage element cannot be made use of to start the motor. To solve this issue, an energy storage power system and a hybrid fuel cell, whether in a higher range temperature form, along with utilization of superconducting magnetic energy storage system can be suggested. The motor starting problem is solved by the hybrid system and the slow responding fuel cell system is complimented with quick operation of energy storage system. This is advantageous in terms of increasing the efficiency and fuel cell operating life.

3. ESTIMATION OF SOC BALANCING OF BATTERY UNITS

Even though cascade converters are being mostly studied for static synchronous compensators (STATCOMs) and motor drives [26]–[29], their characteristic structure finds it appropriate for energy storage applications based on EDLC (Electric double layer capacitor) and BESS. Battery management system (BMS) plays an essential part in the estimation of the SOC, frequently referred as the "fuel gauge" function. On the basis of certain parameters like voltage, current, and internal impedance which fluctuate with the SOC, the estimation can be made [30-31].

Tolbert *et al.* [32] describes working of a cascade converter by using BESS for a motor drive where voltage balance control is maintained by injecting harmonic currents [33-35].

4. IMPROVING POWER QUALITY USING BESS

Wave energy conversion (WEC) system

For smoothening the output of the power of the WEC there is an application of BESS. Back to back converters and controllers for BESS are integrated and are generally used to assimilate WEC system into power grid [36-38]. Capacitor charging/discharging with in power conditioner brought the instantaneous power flow balancing in back to back converters. Thus, in WEC, active power is retained along with adequate power quality using BESS.

Using BESS in scheduling

For achieving system load shifting from daily peak to lows, BESS is used. MOPF (Multi-period optimal power flow) simulations face longer time consuming constraints. This creates practical limitations to the battery scheduling method. The extent of the system which can be simulated also suffers drawbacks, because of the relationship between the MOPF time intricacy and the size of the system being nonlinear [40-41].

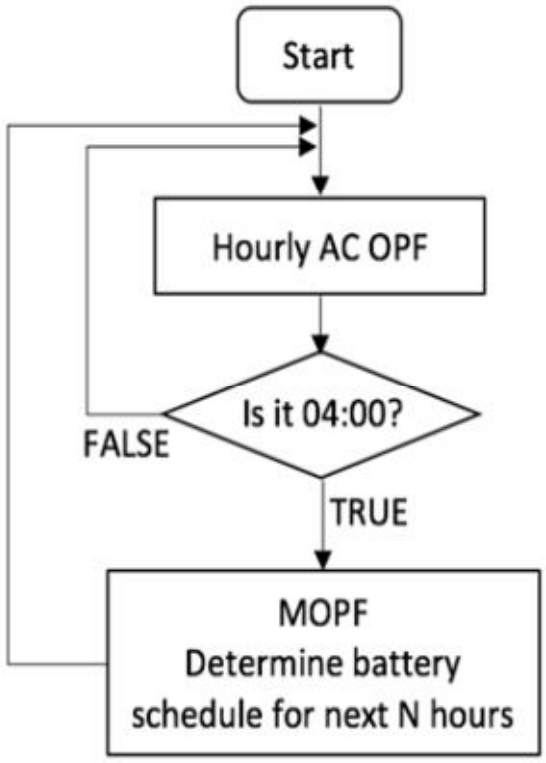

Figure 2: Battery scheduling flowchart [39]

Block diagram of system is projected with STATCOM as shown in figure 2.

Using Double Buck-boost DC/DC converter

The implementation of double BUCK- BOOST DC/DC converters ensure a power bi-directional power transmission control circuit. Proficient systems like fuzzy logic, neural network [42-45] are lately functional to detect and contain the pitfalls of conventional controller. Aditya et al [45] applied BESS to a reheat thermal system which was interconnected to control load frequency. The discharging and charging maneuver of battery and super capacitor is controlled by the systematic circuit, and the high quality DC bus voltage control of PV system is realized [46-47]. An important role is played by energy storage converters in hybrid energy storage systems. The main application of BESS is the operation in uninterruptible power supply systems for systems involving emergency and communication purpose.

BESS for Load frequency control (LFC)

Lim et al [48] has anticipated a vigorous decentralized load frequency controller which is created on the basis of Riccati-Equation approach.

Wind turbine, photovoltaic power generators and other such renewable sources may lead to power system instability situation sometimes due to their output distortions. BESS are hence considered as the counter measure for such issues. The output of PV system as shown in fig .3, depends on the fluctuating weather conditions and the natural surroundings, which affects largely in the power output leading to frequency instability of the grid [49-51].

It is obligatory to develop balance in the charge across each cell in battery pack to boost the effective capacity [52-54], augment life time [55], and avoid thermal run-away [56-58]. Nonetheless, accessible systems are loss and can capably reduce the life span of the cells under assured situations [57-58].

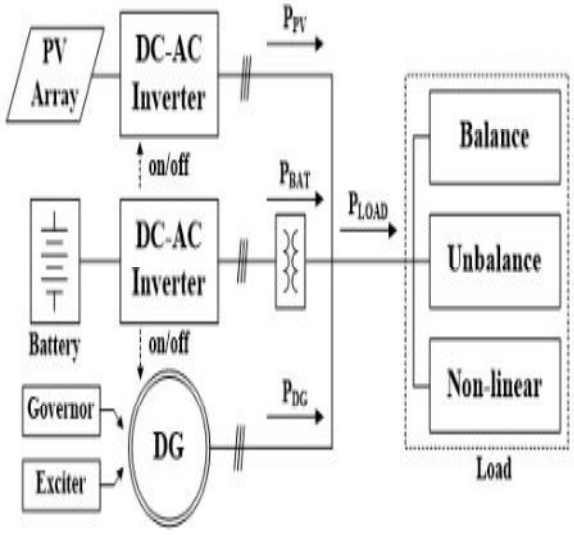

Figure 3: Standalone micro grid configuration [59]

Other applications

Superconducting magnetic energy storage (SCMES) and BESS are applicable in order to help with area and frequency control [59], regulation [60], greater transmission capacity [61], and better power quality [62-65]. It is observed that flywheel energy storage (FES) is appropriate for mitigating problems that deal with dynamic and transient stability [66-67], voltage regulation [68-69], and majorly improvement in power quality [70-71]. BESS has also been worked upon in the application as PVCF [72-76]. Although there is no different way to smoothen the PV output, still area of moving-average-based ramp-rate control is being explored [77-79]. Also, in load forecasting area, MAS (Multi-Agent System) been used which provides with power simulation, utility based micro grid, easy fault detection and an active distribution network system [80-82].

5. HYBRID ENERGY STORAGE SYSTEM

Because of technological advancements internationally and further progress on the WPGS (wind power generating system) [83-86], reduction in cost of generation from it has been observed. Generating electricity from the FC (fuel cell) is advantageous as it provides high efficiency; less polluting, easy installation and the heat and water waste can be reused because it consumes variety of fuels [86-91]. Adequate amount of electricity can be generated using large PV arrays in order to supply isolated load or a utility grid using dc-ac converters [92-94].

Flywheel energy storage system (FESS)

FESS has higher storage energy density, exchange of power within the system as well as greater conversion efficiency with a prolonged non- polluting design [95]. The FESS is able to provide a short-lived storage in order to filter power fluctuations by integrating the remote power systems working on WTGs into the weak grid [96-97].

Other Integrated generation systems

Aqua electrolyzes have been used in order to contain the issue of generating energy from the WTGs [98-106]. In [107-108] a single recurrent neural network (RNN) has been used to assess the energy performance in the long run which integrates wind and photovoltaic systems which consists of double diesel groups and BESS. Ceraolo et al. [109] created a mathematical model of BESS and represented it in [110-112], which led to the rising of the question that whether their control method depends on the mathematical model or not [113- 115]. Various kinds of RNN techniques for the modeling of intricate time-dependent phenomenon have been worked upon [116-118].

6. CONCLUSION

Grid stabilization has turned out to be a frequent concern all over the world with the increase in incursion of natural energy generation systems. The usage of renewable sources in the power grid to provide supply is escalating due to their non polluting, environment friendly nature. The availability of these resources in abundance has triggered its usage with BESS to contain power quality issues and improving reliability. The crux in case of renewable energy sources lies

in the fact that intermittent power output is provided, such that the BESS has to be managed and used, and hence the combination of wind and solar photovoltaic could be driven to the loads as per the hourly forecasting considering the constraints regarding the SOC in order to avoid deep discharge. Hence, this has led to the shift in trends towards hybrid energy storage systems keeping in view the intermittent nature of renewable energy sources to increase the system reliability. BESS plays a vital role in further enhancing the reliability in addition to improvement in power quality of a distribution network without and with renewable energy sources.

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