Survey on Battery Energy Storage System (BESS) and Advancements in the Micro Grid Energy System

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Abstract: **Recent works have highlighted the growth of the Battery Energy Storage System (BESS) in the electrical system. In the scenario of high penetration of renewable energies in distributed generation, BESS plays a key role in efforts to combine sustainable power with reliable distributed load. Different converter topologies can be used to connect BESS to the network. There is no defined and standardized solution, especially for medium voltage applications. This paper introduced the BESS control strategies and the microarray control system. Reactive power compensation and related techniques based on artificial intelligence (AI) are also discussed.**

Keywords: BESS, Microgrid, Modular Multilevel Converter, Control Strategies.

I. Introduction

Battery-powered energy storage systems have been used in remote areas for several decades, particularly to provide energy or to meet certain service requirements. There has been a revolution in electricity generation. Today, among other things, the production of solar and wind energy is an important part of the electricity production matrix in the world. However, in this high renewable energy scenario, BESS plays a key role in efforts to combine a sustainable energy source with a reliable shipped load and to mitigate the effects of intermittent sources [1]. Therefore, the installation of BESS has increased around the world in recent years. Despite their advantages, the implementation of such systems faces considerable challenges [2].

The nominal voltage of the electrochemical cells is much lower than the connection voltage of the energy storage applications used in the electrical system. For example, the nominal voltage of a lithium battery cell is between 3 and 4 V / cell [2], while BESSs are typically connected to the medium voltage (MV) grid, for example 11 kV or 13.8 kV . The connection of these systems in MV networks can contribute with various services such as peak shaving, time shifting and reserve rotation [3, 4]. Therefore, it is common to connect multiple cells in series to form a battery bank that can deliver a recommended minimum voltage across the DC link. In many applications, this voltage is typically 600V, which is converted into AC current for grid connection via an inverter. Furthermore, a controllable intermediate circuit voltage can be obtained by inserting a direct current / direct current stage between the battery bank and the intermediate circuit. In these conditions it is possible to increase the degree of freedom of control of the state of charge (SOC) of the battery. DC / DC converters also allow you to use fewer batteries in series, as converters can increase the voltages for grid connection [5]. Note that the DC / DC converter must be bidirectional to ensure energy flow during charging and discharging of the batteries [6, 7].

In this sense, the general structure of a BESS connected to the MV network is shown in figure 1. This system consists of the battery, the DC / DC stage and the DC / AC stage. Converter topologies in each phase are less classified as transformer or transformer topologies. If low voltage switches are used in the DC / AC stage for two or three level topologies, a step-up transformer is required to connect the BESS to the MV network [8]. A disadvantage of these topologies is the high current on the low voltage side of the transformer, which can reduce its efficiency. Therefore, the trends in transformer less DC / AC converter technologies are applied in BESS, e.g. B. two levels with serial switches and modular multi-level converter (MMC).

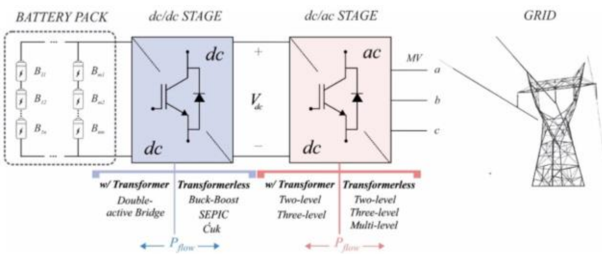

Fig. 1 Conventional structure of BESS connected to the medium voltage (MV) power grid

In view of the above, this document offers a review of the main topologies of the converters involved in BESS and a comprehensive overview of the conversion technologies for this application. The aim is therefore to summarize the most important works in the literature and to show the advantages and disadvantages regarding power losses, the number of semiconductor components, and the harmonic distortions of the output current, the number of control circuit's relevant and necessary sensors. Some issues, such as control strategies and drive design, are discussed to analyze the inherent complexity of any topology. Several articles dealing with these issues are reviewed. Finally, a case study is carried out to compare and analyze the topologies of converters for BESS, taking into account some aspects such as efficiency, power quality and the number of components.

II. LITERATURE REVIEW

Markus Mühlbauer et al. [9] this paper provides a method for the systematic analysis of multiple energy flow control strategies in a heterogeneous multiple battery storage system. Due to the difficulty of comparing different PFCS in different scenarios and system configurations, a total of five static and dynamic PFCS are examined in two separate application-oriented scenarios and are evaluated by two target indicators, namely performance and efficiency. A simulation model based on a heterogeneous multiple BESS is set up with a hierarchical control scheme, the model components are validated and a real test bench verifies the functionality of the PFCS. Simulations in MATLAB / Simulink are performed to analyze the performance and efficiency of the applied PFCS in an application scenario related to energy and load.

J. Kumar et al. [10] This document covers all aspects of DCMG control, whether it is DC bus voltage, power, or power. In this article, different MG structures with their comparative analysis have been provided. Various control schemes: Basic control schemes such as centralized, decentralized and distributed control and multilevel control schemes such as hierarchical control were discussed. Energy management in grid connected mode, island mode and transition mode was presented. Several energy management strategies were presented, as energy management plays a very important role in optimizing the size and evaluation of the energy storage system and its maximum utilization.

X. Li et al. [11] in it, an energy management strategy is presented, with which the performance of 100 megawatt battery energy storage stations (BESS) must be monitored and thus the ability of the large BESS to autonomously distribute the electricity in real time. Based on the multi-agent particle swarm optimization strategy, the real-time performance of the power conversion system (PCS) was calculated. Meanwhile, the layer structure of the main agent, sub-area agent and PCS agent is under development for BESS.

Q. Wu et al. [12] this article aims to remove the influence of capacity on SoC balance and maintain good power quality. The proposed control strategy does not require any central communication or control and the scalability of the system is greatly improved. The effectiveness of the proposed approach was confirmed by simulations and experimental results.

III. BESS CONTROL STRATEGIES

Various control strategies can be applied to BESS. However, most of them are based on the same principles as cascade power control with current control as shown in Fig. When the DC / DC step converter is not in use, the actual power reference for the DC / AC step control is calculated from the SOC of the battery during charging and from the demands on network services during discharge, as shown in figure 2 These services are explained in the following sections.

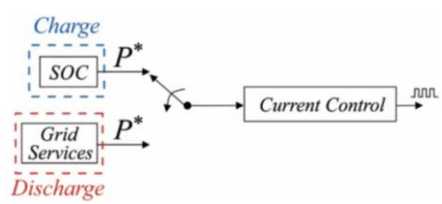

Fig. 2 BESS control strategies

As for the current control of the DC / AC stepper converter, it can be placed in different reference systems such as natural ABC coordinate, stationary reference system (αβ) and synchronous reference system (dq). An example of a control strategy based on the stationary repository is shown in figure 3. The active power reference generated by the SOC or for certain network service requirements and the reactive power reference, the current references (i_α^*, i_β^*) for DC / AC stepper converter control are calculated using instantaneous power theory:

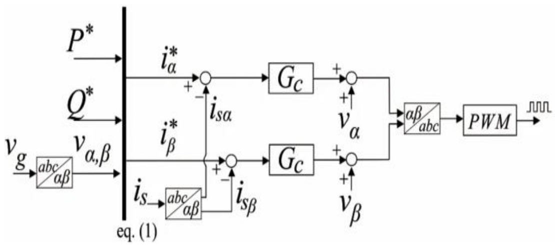

Fig. 3 Current control example of BESS

$$\begin{bmatrix} i_\alpha^* \\ i_\beta^* \end{bmatrix} = \frac{1}{v_\alpha^2 + v_\beta^2} \begin{bmatrix} v_\alpha \; v_\beta \\ v_\beta - v_\alpha \end{bmatrix} \begin{bmatrix} P^* \\ Q^* \end{bmatrix}$$

Where vg is the line voltage and vα, β are the components of the line voltage in the stationary reference system. The current references are compared with the converter currents (isα, β) and the Gc commands reduce the error between these currents. Finally, PWM technology calculates the pulses of the converter.

MMC topology-based BESS can solve some problems concerning the converter structure. The use of hash cells involves low frequency currents in the cells and requires interfaces between the battery bank and the cell input, such as the DC stage, which adds complexity. Another issue is SOC balancing, especially in unbalanced operation which deals with unbalanced SOC on the converter arms. Therefore, it is necessary to check the SOC between the mean SOC of each arm and between the SOC difference in the upper and lower arm of each phase.

The MMC control offers two different external reference loops for supply or power absorption, similar to the 2 L and 3 L topologies. In case of battery charge, a SOC reference is provided for the main power control, as shown in figure 4 Circulation flow control is also used to check average and individual SOC. Finally, these signals are used to modulate each cell.

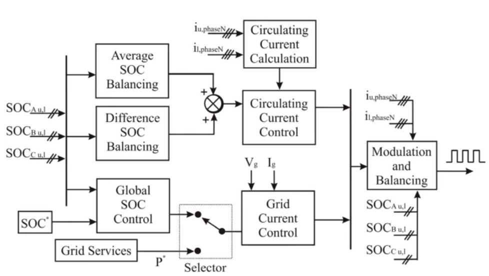

Fig. 4 Overall system control block diagram for MMC-BESS

IV. Reactive power compensation

Reactive power compensation is defined as reactive power management to improve the performance of AC systems. In general, the problem of reactive power compensation is related to the load and voltage support. In load support, the goal is to increase the system power factor value, compensate for the actual power drawn from the AC supply, improve voltage regulation and eliminate harmonic components of the generated current and fluctuating non-linear industrial loads. Voltage backup is usually needed to reduce voltage fluctuations in a specific connection on a transmission line. Reactive power compensation in transmission systems also improves the stability of the AC system by increasing the maximum effective power that can be transmitted.

V. Microgrid control system

Control system structure of microgrid

The micro-network control system consists of two control levels: the central level and the local level. The micro-network is managed via local controllers in the DG and BESS units, as well as via a central MMS controller. MMS is a central monitoring control which includes several key functions, such as: B. economic management functions, frequency control, voltage control, etc. For dispatch able DG units, the MMS can exchange information with local controllers (LCs) and determine power output set points. For RES DG units, in some extreme situations eg. The wind power is greater than the required load and the ESS reaches its maximum limit. MMS can reduce RES. The hierarchical control structure is shown in Fig. 5.

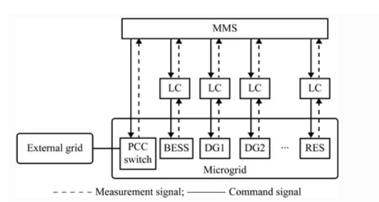

Fig. 5 The hierarchical control structure of microgrid

Control Based On Communication

As the name suggests, this control method is based on a continuous exchange of information between the different resources of the micro-network. With this approach, the control of the micro grid can be centralized or fully distributed with high accuracy due to the shorter communication delay during information exchange. However, if there is a loss of security and reliability of the communication link, it affects the stability of the system. To solve the problem of stability and reliability problems, a hierarchical control scheme with a combination of static and communication methods is proposed. The underlying implementation of centralized control of the HACDC micro grid is shown in Fig. 6.

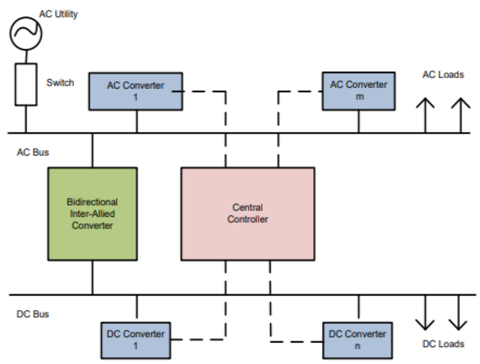

Fig. 6 General Structure of Centralized control of HACDC microgrid

In this configuration, the AC and DC subnets are connected to a central controller using a bidirectional inter-allied converter. Through communication-based centralized control, all local control data for distributed energy resources is transferred in real time to the central control of the micro-network. Therefore, this approach is a one-time mistake, but it responds better than static checking. A communication-based control strategy is applied to each source in the microgrid using power regulators. Current modules with a phase locked loop (PLL) are available to synchronize phase and frequency including the reference signal. A simple and efficient approach has been described, called master-slave control, whereby it can be used in both grid connection and island mode. With this control method, one drive works as a master and another as a slave for the existence of data transmission between the master and slave controllers. Although this method is not very complicated from a technical point of view, a failure of the main controller will affect the overall operation of the system and will also decrease its reliability. To avoid communication links and provide good scalability, an alternative control method called peer-to-peer control has been proposed. In this scheme, the presence of power fluctuations and a decrease in energy consumption occurs with an increase in the number of renewable energy sources. In general, the master-slave approach is used in isolated mode of operation, while the peer-to-peer method is applicable in network-connected operation mode. There is therefore a problem of stability in the movements. To solve this problem, a hierarchical method is developed, suitable for demanding micro-networks. In order to overcome the occasional failure with centralized control, an alternative form of control based on communication without centralized control is being developed, called distributed control. In this control mechanism, a control action is designed on the local transducers in the microarray. Operational information from each source is communicated to neighbors and complete information is collected at the IAC.

VI. Energy Management Strategies

The presence of more than two distribution energy resources (DER) in the system as well as the presence of an energy management system (EMS) are necessary for the distribution of electricity to the DERs, energy production costs and emissions. According to the International Electro technical Commission (IEC) 61970 standard, EMS is defined as "a computer system that includes a software platform that provides basic support services and a range of applications that provide the functions necessary for operation efficient energy transmission. Provide to ensure proper operation. Security of energy supply at minimal cost. "The different categories of energy management strategies are illustrated in Fig. 1.7

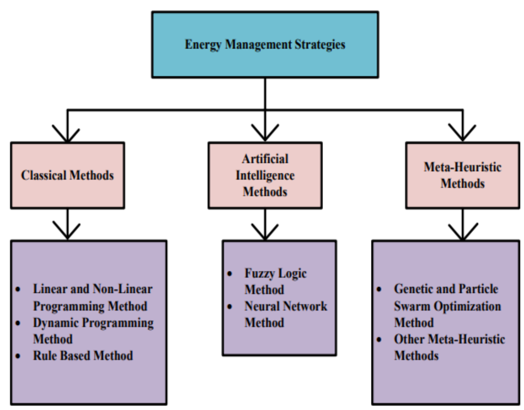

Fig. 7 Energy Management Strategies

To predict hourly production in a high-frequency AC micro-grid, an intelligent energy management system called Fuzzy ARTMAP Neural Network has been proposed that uses adaptive resonance theory. Based on the rules that have been developed, [13] proposed an energy management strategy called the rules-based method for an independent wind photovoltaic fuel cell system. In [14], an expert and prediction system was proposed using a linear programming method with mixed integers for optimal energy management. A real-time EMS using particle swarm optimization (PSO) technology was developed by [15] to minimize operating costs. In order to balance the performance between the sources, the performance monitoring and management strategy of [16] was implemented in the PSCAD / EMTDC simulation software. For efficient energy management of HACDC microgrids, a two-step method called the crow search method was proposed in [17] in order to increase the search capacity.

VII. Conclusion

This paper introduced the BESS control strategies and the microarray control system. And he also described energy management strategies. Another important aspect in determining the feasibility of the project are the BESS services, which can be used to obtain an efficient system that will maximize the return on investment. Recent studies show that BESS can further contribute to the expansion of renewables in the power system and reduce the effects of intermittent generation of these sources, as well as the appropriate compensation system for display control and lead to further improvement in grid performance.

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