The Determining Factors of Selecting Energy Storage Systems for the Renewable Energy Sources in the Energy-Efficient Building

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Abstract— Electrical energy storage (ESS) is a most important element in micro-grid to balancing the supply and demand of energy, optimising our use of intermittent energy source such as wind or solar energy. In ESSs we can support the incorporation of micro-grids because of their capacity to improve the system reliability and to facilitate the integration of high penetration levels of Renewable Energy Sources (RESs). ESSs can also provide additional benefits for distribution sources, such as an efficient expansion alternative through peak load shaving and methods of mitigating power quality issues. This paper will present the benefits of ESS in RES and most important factors of selecting ESS for the RES in the Energy Efficient Building (EEB).

Index Terms— Energy storage system (ESS), renewable energy sources (RES), energy efficient building (EEB).

I. INTRODUCTION

Residential buildings consume (41%) of energy more than other broad sectors. (70%) of energy, usage in residential building is in the form of electricity, which causes environmental concerns. Most of losses in residential buildings (47%) of energy, lost in transmission-line and distribution (T&D) from the power generation to end-user [1].

The global request on energy is increasing continuously, and there is need for energy to be cleaner than energy, which produced from traditional generation technologies [2].The cleaned energy, which depend on natural sources like sun and wind. Both of them have high generation capacity, which have massive potential to reduce dependence on traditional sources like fossil fuel and greenhouse gas emissions in the generation of electrical energy.

In recent years, there are many researches have achieved improvements on EEB, and focused on improvement of building materials and structures to save energy consumption [3].

In addition, there was investigation in increasing efficiency of High Voltage Alternative Current (HVAC) systems by natural ventilation with the information of outdoor environment [2], [3]. The potential energy savings by utilizing RES and distributed storage devices [4], [5]. Micro-grid technology provides a desirable infrastructure for improving the efficiency of energy consumption in buildings [7-10].

The key to improve operation efficiency of building energy consumption is to coordinate and optimize the operation of various energy sources and loads. However, many challenges and difficulties mentioned in [11].

II. THE BENEFITS OF ESS IN EEB

Efficient and effective implementation of ESSs can provide numerous environmental, economic and technical benefits to energy supply systems [12]. These include:

A. Stoing of Renewable Power

Renewable power generation technologies provide a source of clean power but with highly erratic and very intermittent [13]. ESS technologies enable smoothing of the intermittent power input associated with renewable energy sources, allowing surplus energy from renewable sources to be stored to use later at during periods of peak system demand [14].

B. Reducing the Risk of Power Blackouts

ESS employed for power fluctuation smoothing caused by sudden interruptions to supply or a sudden load change. In addition, ESS technologies used to provide power for long term back up in the event of a large power outage or failure, such as the loss of a large conventional power-generating unit or transmission line allows system security to be improved [15].

C. Supply & Demand Matching

When the power supply is greater than the system demand, ESS technologies used to store surplus electricity, which released when power consumption exceeds the available supply [16]. This enables conventional base-load generating plants which may not be designed to run at part-load or vary their output in response to system demand vacillation, to be set to run more-or-less continually at a level which provides the greatest efficiency and cost benefit [17].

III. Composition and Classification of ESSs

ESSs allow power to be taken from a source (such as the power grid), stored and then released back into the system when it is required. The method used for ESS will differ depending on the technology being used; however, most ESSs will include the following four main components [18];

- Storage Medium.
- Charging System.
- Discharging System.
- Control: To govern the operation of the storage system.

According to [16], the ESSs, which classified into three groups based upon their response characteristics and applications as follows;

1- Short-term ESS (seconds to minutes) – used for power quality applications;
2- Long-term ESS (minutes to hours) – used for grid congestion management and frequency response;
3- Real long-term ESS (hours to days) – used for supply and demand matching over long periods.

In addition to classification based on response characteristics, ESSs classified based upon the form in which the energy is stored, such as mechanical storage, electrochemical storage, electrical storage and thermal storage [19].

IV. Overview Of Electrical ESS Technologies

There are many of ESS technologies. Such as:

- Flow battery ESS
- Superconducting magnetic ESS
- Capacitors (Super-capacitors, electrolytic double layer capacitor, Ultra-capacitor etc.)
- Batteries (Lead-Acid, Nickel Cadmium, Sodium Sulphur, Lithium Ion etc.) [20].

V. Applications Of ESS within Power Systems

ESS technologies such as those described above can provide great benefit to micro- grid, enabling increased renewable source integration and increased supply security and stability to be achieved [20].

A. Integration of Renewable Energy Sources (RES)

One of the main uses for ESSs is to increase the integration with natural sources such as wind and solar [20]. The intermittent nature of inputs from renewable power sources can cause voltage and frequency vacillation occurring within the grid, so affects negatively on system stability [20]. As such, voltage and frequency vacillation can occur very quickly and frequently, it is necessary to employ ESS technologies with high cycling lifetimes and short response times. Supercapacitors, batteries (excluding conventional lead acid) and SMES are therefore particularly suited for this purpose [20]. A widely accepted way for mitigation of the power vacillation associated with wind turbines is incorporating an ESS within the DC link of the back-to-back converters of the machine. This storage system will have a controller, which interacts with the control system of the wind turbine to optimize the overall net power flow to the grid [21].

B. Load Shifting

Load shifting provide delivery of renewable energy to be delayed from periods of non-peak demand to those of peak demand. ESSs can store the excess energy during low demand periods and then release it into the grid at times of peak demand. This helps to smooth excess grid demand and increase the value of renewable energy sources. The ESS technologies that suitable for this purpose must be able to response and react in the region of several minutes and hours, therefore technologies such as CAES, Pumped Hydro and Flow batteries considered most suitable [22].

C. (T&D) Upgrade Deferral

T&D referral allows the annual carrying charges for capital investment to be avoided, thus reducing the overall cost to ratepayers, improving asset utilisation and releasing capital for other infrastructure projects [23].

D. Grid Black Start

In the event of a total grid power loss, it may be mandatory to restore power using a process known as black start [24]. ESS can be used for this purpose. For example, in power generating facilities, batteries used to provide a source of power to start a diesel generator or similar device, which used to generate electrical power to supply auxiliary systems for a major generating unit, which can then supply power back to the grid [22].

E. Energy Arbitrage

Energy Arbitrage refers to the process of charging ESS when demand on energy and therefore cost is low, before then discharging the ESS back into the grid during periods of high demand and cost, thus making a profit. Typically, Pumped Hydro Storage (PHS) is used for this purpose because it built for large-scale ES (+100MW) and used for discharge over a relatively long period (up to several days). Compressed Air ES (CAES) is another technology, which implemented for this purpose, again due to the large capacities and relatively long discharge times [20].

F. Voltage/VAR Support

Voltage/VAR support is an ancillary function provided by system operators in order to provide in the maintaining of grid system robustness. Voltage/VAR contribute requires the supply or consumption of reactive power (VAR's) in order to maintain grid voltage within a specified range [23]. (BESS) is a technology, which used for this purpose. An example of BESS usage for Voltage support is the experimental storage system produced by A123 Corporation in California, having a capacity of 8MW/32MWh using Lithium-Ion Technology [25].

VI. The Determining Factors Of Selecting Selection Of Ess In The Eeb.

To select EES for EEB there are many factors, in this section will be determining these factors of selecting ESS in EEB [13], [26]:

- Energy Density (Wh/kg)
- Power Density (W/kg)
- Cycle Efficiency (%)
- Self-Charge/Discharge Characteristics
- Life cycles (number of cycles)
- Chronological lifecycle
- Large-capacity

Low-cost and long service life of the storage energy technology is certainly the most optimal, but so far, there is not a type of ES technology can satisfy these conditions simultaneously. Therefore, it is necessary for all storage technology choice suitable application field, namely the right selection of ES. Under normal condition, when the selection of ESS, the economy, security and stability, and the capacity of the ESS should be considered.

The conducting independent research on the island micro-grid ESS selection found that pumped storage and compressed air ESS not available for large-scale 10 MW and below sized island independent micro-grid, and the cost of Lead-acid as the only batteries for large-capacity we can approve is widely used in the island independent micro-grid ESS [27].

The advantages and disadvantages of magnetic flywheel ESS UPS, super capacitor ESS UPS and battery UPS, and the two general methods presented in the selection of storage devices in [28]: the discharge current method and estimation method. The discharge current method selects the corresponding battery according to the maximum discharge current (I) of the battery. The estimation way is based on the capacity of the storage battery to choose the storage battery [28].

According to [29] pointed out that, in the system regulation, often using compressed air energy storage, compressed air ESS has the advantages of low cost, long service life and high safety factor. However, due to the restriction of terrain and air stored needs to compress under suitable underground lava cave or mine.

Pumped storage is similar with the compressed air, but limited to the terrain and the longer construction cycle. In frequency regulation, high power load, smooth transmission and distribution grid voltage support and power compensation, can use the flywheel, super- capacitor and superconducting magnetic energy storage.

These three ESS technologies with high efficiency and long life cycle, fast response, clean and relatively simple maintain features, but the energy ratio is low, belongs to the low-power type of expensive storage.

These three ESS technologies can be used to short-time and high-power fast discharge. Battery storage can provide active and reactive support to the system. So it is very important for the control of complex power system [27]. The life of Lead-acid battery is shortened at high temperatures, it has a lower energy and power efficiency , and there are certain environmental pollution, but the low cost, reliability, and mature technology features make lead-acid batteries widely used in UPS, power quality and frequency control [29].

Nickel cadmium battery is similar to lead- acid battery, but it has the serious heavy metal contamination. The efficiency of Li-ion is higher and has the high-energy ratio and power ratio, which is friendly to the environments, but the cost, is high, so it is difficult to apply in power system in the near future. Emerging chemical ESS battery such as fluid flow and sodium sulfur battery is currently the most suitable for large- scale increase of electric power chemical ESS technology.

Vanadium Redox Flow Battery have long cycle life (more than 12,000), high energy conversion efficiency, siting and design flexibility, safety and environmental protection features, but has the low energy ratio and power ratio. Therefore, it is suitable for the selection of renewable energy storage, peak shaving and emergency power supply. Sodium sulfur batteries have high-energy storage efficiency (about 89%) and high-density energy characteristics, about three to four times the size of lead-acid battery, used for power quality and load regulation of peak load shifting; it is the typical type of the energy and ESS type [29].

In outback with a high penetration of renewable energy, power grid weaker, it is better to choose a mature storage technology; for make full use of renewable energy and delay the investment of the construction of the strong power grid, we should choose the most advanced ESS technology [29].

According to [31] combined the characteristics of the operating conditions with the wind and PV power generation, analyses the wind and PV storage system that how to scientifically select the type of lead-acid batteries. Battery life of lead-acid batteries and early failure problem is the main obstacle hinder the promotion of the PV and wind power system. After observation found that gel battery has better deep discharge recovery features, low current discharge performance and the charge rate is higher than from 20% to 30%. Gel battery at high ambient temperatures have a longer service life; virtually can annul internal electrolyte stratification. From the economic analysis of the full life cycle, the advantage of gel batteries in PV and wind turbines system is more obvious.

VII. CONCLUSION

The key element of this work is reviewing the available ESS techniques applicable to electrical power systems. There is obviously a cost associated with storing energy, but we have seen that, in many cases, storage is already cost effective. Also this paper presented the recent technologies in EES and a comparison between them, the rational allocation of the load control system, and complemented by high-performance power electronic devices, flexible transmission, distributed power supply, demand response, efficient control of the new clean energy development model systems and other advanced technologies. However, the dependent on the accuracy of the renewable energy prediction and the improvement of the control level, cannot achieve the comprehensive and efficient use of the energy. With the combination of distributed generation and ESS technology, the system can greatly improve the energy utilization; improve the stability, robustness, and efficiency of the system. Therefore, it is necessary to speed up the development of ESS technology. In summary, the determining factors of selecting EES for the RES in EEB depends on seven factors as we abovementioned. Correct selection of intermittent ESS is critical and complex to large or small -scale use of renewable energy. In practical application, we must be based on the actual application requirements, the correct choice of ESS type, in conjunction with the use of different ESS technologies, give full play to the advantages of various ESS technologies to complement each other. Thereby it will be developing the ESS flexible, technical, and economic.

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