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Energy storage systems for renewable energy power sector integration and mitigation of intermittency

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ABSTRACT

Currently, the electric power sector is looking forward towards increasing the bent for availability, reliability and security of energy supply to consumers. This pursuit has vehemently increased the intention for integrating renewable energy (RE) into the electricity sector as a strategy to curb the problem of energy deficiency especially in isolated off-grid settlements. However, the variability in the sources of RE supply coupled with conditional changes in the level of energy consumption with respect to time has brought to focus the necessity for energy storage systems (ESSs). Despite the stochastic nature of RE produced from solar and wind energy and to some extent hydro, interest in their exploitation is still growing high due to their sustainability regarding environmental receptiveness. Thus, this paper extensively reviews the state of the art of three different kinds of energy storage technologies (pumped hydroelectricity storage, batteries and fuel cells) suitable for the integration and management of intermittency in RE. Within the context of the review, advantages and disadvantages of the various technologies are also presented. Additionally, it also pin-points on the different areas of applications of ESSs for RE integration and offers review summary on factors to be considered for selecting appropriate energy storage technology for either commercial or domestic applications. Finally, the paper concluded that ESSs selection is based on performance characteristics and fuel source used whereas no single ESS can meet all the possible requirements to be called a supreme ESS.

Contents

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1. Introduction

Generally, the importance of energy storage systems (ESSs) is to increase in future as more attention is concentrated on renewable energy development. High interest in RE exploitation is due to accelerated depletion of energy resources from fossil background. In traditional electrical power generation, energy produced has to be consumed immediately otherwise it will be wasted and result into economic failure. Moreover, intermittent RE such as wind and solar, though little of hydro which can be affected by fluctuations in the intensity of rainfall, cannot be stockpiled in the absence of energy storage systems (ESSs) and must also be used when available or else they will lose energy potentials as well [1]. To overcome this problem there is an inescapable need for electrical energy storage systems (EESSs) which are to be charged at a time of less energy demand and discharged during the period of high demand from customers. Therefore, EESSs refers to a method of transforming electrical energy from electrical power network into a form that can be stored for converting back to electrical energy when needed [2–4] to serve any intended purpose. Harvesting electrical energy using modern technologies to foster development is a very essential and challenging undertaking to power engineers especially to the experts in energy conversions.

Though renewable energy sources (RES) are inexhaustible in quantity but they are characterized with fluctuating power output as commonly observed in wind, tidal wave and solar power systems. Fig. 1 shows a grid electricity demand for summer and winter day as superimposed with total wind power generation for the summer day. The wind power generation system exhibits a significant and drastic variation in output power which is fundamentally not connected to the demand for electrical power [5]. This exhibits the fact that wind power output can change randomly with respect to the degree of availability of sustainable wind source. In recent past, ESSs have become a progressive area of study attracting more keen interest for RE intermittency mitigation and management of RE integration. Apart from intermittency function of energy storage systems (ESSs), conventional electricity industry also needs ESSs [6–10] to accomplish some important power systems functions. RE intermittency have some effects on the energy delivery systems especially when there are changes in load demand. This variation can produce some power quality problems such as voltage transients. One of the ways out being anticipated to improve the reliability and performance is to incorporate energy storage devices into the power system networks [11]. Exception to this basic disadvantage of RE is geothermal and to some extent biomass power which has high tendency to conveniently replace fossil energy grid systems where it is available. This intermittent effect has been one of the major factors responsible for the low competitive nature of RE technologies compare to conventional energy conversion systems for electricity [12].

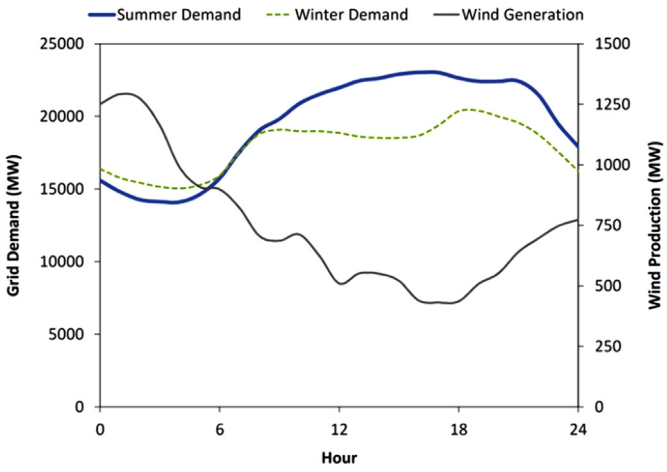

Fig. 1. Ontario grid demand for a summer and winter day overlaid with total wind generation for the summer day [5].

Energy storage systems allow for meeting customers' load demand services for extended period of time even when small renewable power generation system is used. Currently, there exist accelerated global efforts towards RE development resulting from interest in a portfolio for sustainable energy supply and ensure healthy environmental integrity. The total contribution from RE is also expected to increase in the nearest future due to continuous rise in demand for energy and emerging policies. Many energy experts have indeed argued in favor of the development of autonomous RE systems as a reasonable option to grid extension especially in remote and isolated communities. RE option can be used as a strategy to reduce dependency on fossil fuels consumption, not only for large-scale energy but also for small-scale autonomous energy systems [12,13]. The uses of autonomous RE systems have become unavoidable judging from economic constraints of fossil fuels centralized power systems. Changeability in the price of oil, fast depleting nature of crude oil resources and regional political alterations especially in oil rich countries had greatly maneuvered the availability and the sustainability of oil for energy consumption.

Many contemporary studies on RE revealed that the development of RE in off-grid approach has a potential impact on lower high cost of grid expansion and energy deficiency scenarios prevailing in developing countries. In this kind of situations, new challenges on how to stabilize and store energy output to be consumed when needed other than the time they are being generated validates the quest for the development of technologies for ESSs. Economically workable ESSs are required for energy conversion and storage which can also be converted back to electricity when needed for any application [6]. In power systems, ESSs have some important applications in operations like grid stabilization, stable power quality and reliability management, load shifting and grid operational support [1]. The reality of these functions had encouraged the