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Significance of energy storages in future power networks

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Abstract

As a result of the major challenges the world is facing today due to global warming and the ever decreasing conventional sources of energy such as fossil fuels, developing methodologies for harnessing all possible forms of renewable energy has become a heavily researched area within the power and energy research communities. Deploying energy storages increases the possibilities of harnessing several sources of renewable energy in a more meaningful manner. Some of the key areas where energy storages could make things better, when it comes to harnessing renewable energy sources are, Wind energy, Bio energy, Geothermal energy, Solar energy and Wave energy. The paper investigates application examples of energy storages in these areas through a thorough review of reported scientific literature. On the other hand, major energy consuming areas such as transportation, manufacturing, electricity consumers etc. could also benefit by the introduction of energy storages. As an example, in transportation, increasing usage of hybrid electric vehicles, plug-in electric vehicles and emerging new concepts in transportation such as electric highways have raised the significant role of energy storage solutions for transportation to its highest level. It is believed that this way of looking at the energy storages will strategically position them with the significance they deserve within the energy and power engineering research community.

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Keywords: energy storages; power network; renewable energy; energy efficiency; micro grid; transportation

1. Introduction

As a result of the major challenges the world is facing today due to global warming and the ever decreasing conventional sources of energy such as fossil fuels, developing methodologies for harnessing all possible forms of renewable energy has become a heavily researched area within the power and energy research communities. With the

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aging power networks the world over reaching their limits, demand side management, distributed generation, harnessing renewable energy sources and incorporating energy storages have become extremely important for the power industry [1]. Looking at energy storages in renewable energy integration from a grid operator's point of view is done in [2]. Hierarchical management of energy storages in a distribution grid is addressed in [3]. Use of energy storages to enhance the distribution feeder capacity is presented in [4]. The fact that energy storages are making an impact on the future power networks is further confirmed by the study in [5] which analyses different storages and different time-variable operation modes of energy storages in future electricity markets. Interestingly, all these modern aspects of power networks are associated with incorporating some form of energy storages in the network. As such, it is possible to observe a near exponential increase in research in energy storages in power networks. These investigations can be categorized from various points of views. Two of the main categories that are reviewed in this paper are; power network configuration in which energy storage is incorporated and the type of renewable energy source harnessed using the energy storage.

Under the category power network configuration in which energy storage is incorporated; energy storages in Smart Grid initiatives [6 - 9], energy storages in Micro Grid applications [10 – 14] and Hybrid Energy storages [15 – 22], Under the category type of renewable energy sources harnessed using the energy storage; use of energy storages in wind energy harnessing [23 - 30] and photovoltaic energy harnessing [31 - 35] can be highlighted as key applications. However, due to space limitations all of these applications will not be reviewed in this paper.

The paper then focus on energy storages in transportation giving emphasis to automotive sector considering its significance with emerging concepts such as electric highways etc., which has a bigger impact on the future power networks. With battery technologies being the key energy storage solution in future power networks; the paper also summarizes capabilities of some widely used battery technologies towards the end.

2. Energy storages and power network configuration

Looking at the energy storage system from the power network configuration point of view becomes important from various aspects. Some of these key aspects are, sizing of the energy storage, selection of the type of energy storage and control aspects of energy storages.

2.1. Energy storages in Smart Grid Systems

In Smart Grid applications, the use of Plug-in Hybrid Electric Vehicles (PHEV s) and Battery Electric Vehicles (BEV s) as configurable distributed energy storages has been heavily researched [6]. This concept allows the utilities to treat large parking areas of densely populated cities to treat as energy storages. The charging times can be managed depending on the supply demand patterns so that all other associated strategies such a demand side management, peak shaving and voltage regulation issues related to solar power generation can also be successfully addressed [6]. A review of such applications in the United States can be found in [6]. Apart from the use of PHEV and BEV as energy storages, a more mathematical approach to the problem by proposing a cost-based optimization strategy for the optimal placement, sizing and control of energy storages in Smart Grids is proposed in [7]. Such energy storages can support energy management as well as power management at all three major stages of a power network; generation & transmission, distribution, consumer as shown in Table I [7].

Table 1. Energy Storage System Services (Functions).

Stages of a power network	Applications in Energy	Applications in Power
Generation & Transmission	Electric energy time-shift, Electric supply capacity, Transmission congestion relief, Transmission upgrade deferral	Voltage support, Power Oscillation Damping, Black start, Supplemental reserve
Distribution	Distribution upgrade deferral, Power reliability, Intermittent mitigation	Voltage support, Power Quality
Users	Electric energy time shift, Interruption backup	Demand charge management, Power Quality