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Evaluation of energy storage technologies for integration with renewable electricity: Quantifying expert opinions

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A B S T R A C T

Solving climate change and the associated need for increasing renewable energy supply make energy storage a critical technological component of the future energy landscape. Research to build more reliable and cost-effective energy storage technologies is now on the rise. As a result, many new technologies and applications are evolving and competing. This paper presents a method to evaluate and select energy storage technologies for investor-owned or public utilities. For this purpose, energy storage applications which could benefit wind power in the Pacific Northwest region of the United States are identified through internal interviews and surveys with experts at the federal wholesale power marketing agency in Portland, Oregon. The study employs a technology evaluation process integrating fuzzy Delphi method, analytic hierarchy process and fuzzy consistent matrix. The result shows that compressed air storage is the most promising technology for sustainable growth of renewable energy in the region.

1. Introduction

Energy storage is rapidly gaining more interest from industry leaders, policymakers and academic researchers. In the past, energy storage was considered as a tool to contain surplus energy

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during non-peak or low market price periods so that it could be used later in peak periods or as a resource during periods when high market prices prevailed. In Europe, for instance, Switzerland with its extensive network of hydro run-of-river and pumped hydro reservoirs has allowed to import cheap base load nuclear power from neighboring France and Germany to pump water uphill and store it in vast reservoirs. The energy could then be sold back to these countries during peak-priced periods, or sold to Italy, Europe's largest electricity-importing nation. Energy storage is recently in vogue because of concerns about climate change and peak oil. As a result, energy efficiency, conservation, and renewable resources receive much attention in debates on energy policy and investment. The intermittency of renewable resources, such as solar and wind facilities, threatens the reliable operation of electricity supplies of public utilities, investor-owned utilities and balancing authorities (US Department of Energy, 2007). Therefore, they are struggling to identify solutions for this problem so as to allow for a significant increase of renewable power in the electricity grid system.

In addition to new policy drivers like climate change, innovation acts as a driver of more interest in energy storage as well. While the example of Switzerland pumping water up shows a proven practice that is quite large – both in terms of the overall development cost and the megawatt capacity production – this is no option for a small utility in the middle of a desert. New advances in storage are creating options with smaller outputs using a variety of practices and approaches, ranging from batteries of all types to flywheels and compressed air stored in underground caverns.

The recent high rate of diffusion of renewable energy, such as solar and wind power plants, causes problems in reliable and sustainable energy supply in US due to its intermittency. Energy storage is considered as a prominent solution for the problem as it provides an inventory for the unexpected surplus or deficit from renewable generation.

With the addition of more intermittent renewables in the western United States, many studies and pilot/demonstration projects of potential solutions for managing high levels of renewable intermittency are being conducted (WEIL Update, 2010). Pacific Gas and Electric Company (PG&E) in California, for instance, is developing a renewable integration model to assess the required flexible integration resources and forecast uncertainty of intermittent renewables. A research project by Idaho Power, an investor owned utility (IOU) in Idaho, is to develop a weather forecasting model of wind speed, direction and ambient temperature of their area, which will help determine additional power that can be carried by transmission lines during favorable weather conditions.[1]

Other relevant research is undertaken by the Electric Power Research Institute (EPRI), which is analyzing the need for balancing resources for increasing variable generation. This comes in part from rapid growth of renewables expected for California. The California Independent System Operator (CAISO) identifies the impact of renewable portfolio requirements in California as follows: 20% of all electricity must come from renewables in 2012 and 33% in 2020. CAISO acknowledges that the role of innovative resource options, such as demand response and energy storage, will be important as the state's energy providers work toward these targets.

In this study, we evaluate multiple energy storage technologies to select a best option for the application to intermittency of renewable power in Northwest US region. For this purpose, a challenge posed by wind energy and a potential solution in the form of energy storage by the Bonneville Power Administration is studied. Northwest US is reported to be very focused on the adoption of renewable energy (Cowan et al., 2010; Daim et al., 2010; Daim and Cowan, 2010) and specifically wind energy (Daim et al., 2012).

Bonneville Power Administration (BPA), which markets electricity to public utility customers in Washington, Oregon, Montana, Wyoming, Utah, Nevada and some parts of California, has more than 3000 MW of wind power interconnected to its grid. The federal agency expects an additional 3000 MW of wind to be added by the end of 2013. The BPA is engaging multiple solutions for the integration

[1] Transmission lines typically have a maximum capacity that is in part calculated from the potential for high temperature excursions and other extreme weather events – which means that the lines may be able to safely "squeeze in" more capacity under cooler ambient temperatures and when the air is calm.