Hybrid Systems: A Review of Current and Future Feasibility

Hybrid energy systems already in place demonstrate that controls, transmission, and storage are obstacles that can be overcome. Societal needs for sustainable power sources can be satisfied using hybrids of photovoltaics and wind, wind/solar and compressed air energy storage, and in the future, the inclusion of burgeoning technologies such as marine hydrokinetics and small modular nuclear reactors.

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I. Introduction

Consumers want more clean and sustainable power, but power sources must meet the minimum threshold of sufficiency, reliability, and predictability to be a significant contributor to our electrical power needs. Renewable power sources such as wind, solar, and marine hydrokinetic often do not meet these minimum thresholds for consumer-level power. The hybrid solution is the integration of two or more systems, magnifying each system's strength while mitigating the other's weaknesses. Ensuring that energy needs are satisfied in a sustainable way will continue to be a policy issue in the coming years. Political will to decrease reliance on carbon emitting energy sources has increased the drive for research into alternative generation sources. This article addresses current technology for hybrid renewable energy systems and technology, the future potential for technological advances and grid integration, and offers a brief overview of relevant energy legislation that

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will be considered by U.S. state legislatures in the 2014 legislative session.

The combinations addressed in this article are solar photovoltaics (PV) and wind; solar PV and wind-battery; solar PV and wind-storage; gas and renewables, geothermal and solar PV; marine hydrokinetics and nuclear combinations. While we focus on hybrid renewable energy systems, we still recognize that current hybrid facilities primarily exist with coal and/or hydro power combinations. The following is a review of the current hybrid systems and their components, as well as an introduction to up-and-coming technologies that stand to increase the options for available hybrid energy systems.

II. Current Hybrid Renewable Energy Systems

As recently as 2009, hybrid systems were not competitive with traditional electricity generation (Nema et al., 2009). Multiple studies suggest that cost effectiveness for wind-solar PV combinations requires a balance of 70 percent solar PV and 30 percent wind (Nema et al., 2009; Deshmukh and Deshmukh, 2008). The most commonly studied hybrid renewable energy system (HRES) is solar PV–wind–diesel–batteries (Bernal-Agustín and Dufo-López, 2009), while the most cost-effective solutions currently available are hybrid solar PV in conjunction with diesel and/or battery (Deshmukh and Deshmukh, 2008). While batteries are currently common and cost-effective, work on energy storage in depleted natural gas wells suggests that batteries will have competition in further generations of hybrid systems (Mason and Archer, 2012). Other research indicates a trend away from stand-alone hybrid systems that then are connected via remote operators, where individual power sources would be connected via operation (Zhou et al., 2010). Deshmukh and Deshmukh (2008) note that while wind and solar PV combinations are not currently sufficient to be stand-alone systems, the combination of the two systems together reduces the load on the baseload or backup system.

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One of the biggest issues surrounding hybrid systems is managing the intermittency of renewable sources. Diesel generators, natural gas, and energy storage are the most common options (Mason and Archer, 2012; Shaahid and Elhadidy, 2003; Mcgowan and Manwell, 1999; Samrat et al., 2014; IPCC, 2011). Sustainable options include nuclear, combined heat and power renewables, some hydro, and gas operating at a minimum level (Shively and Ferrare, 2004). For peak loading in a hybrid system, diesel is secondary to battery storage due a lower operational flexibility (Deshmukh and Deshmukh, 2008). Compressed air energy storage (CAES) could lead to the workability of wind-PV hybrid stand-alone systems (IPCC, 2011). Due to the potential energy of compressed air, CAES plants have faster startup times than natural gas plants, and could then be used as a peak load for the system (Mason and Archer, 2012; Denholm and Sioshansi, 2009). CAES uses the chamber of a depleted natural gas well or saline aquifer to store the energy generated from spinning turbines. While previous reports from NREL indicated that natural gas combined-cycle is currently the most cost effective method to stabilize wind energy supply, Mason and Archer (2012) analyze long-term costs, including climate, and claim that compressed air energy storage (CAES) is a better long-term intermittency solution than natural. Natural gas and wind hybrids limit the transmission options of the generated electricity due to the necessity of a

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