Enhancing the Smart Grid with Energy Storage

Background

Traditional sources of power generation are increasingly mixed with a growing fraction of emerging energy sources such as wind and solar. Wind and solar have the characteristic of being intermittently available in the case of cloud cover or as weather patterns move through an area. As of July 2011, 89% of base-load power generation in the U.S. came from coal, gas, oil, and nuclear plants (EIA, 2011). As non-traditional sources of energy integrate into the base-load, there is a critical interplay to improve load-following to allow full utilization of the intermittent sources on a smart grid. The contribution of this study is to investigate the application of smart grid forecasting, grid abnormal situation management, and integration with cryogenic carbon capture to fully utilize intermittent power sources.

Although grid improvements been successful in creating a reliable power supply in many parts of the world, the changing nature of the base load will expose the "lack of systematic stability analysis and controller design" (Feng, 2006). This lack of systematic design has led to notable black-outs or capacity shortages in recent years and has highlighted the importance of grid-wide analysis. Integrating the energy storage into the smart grid has the capacity to utilize and shed excess load from the most energy intensive portion of a typical daily cycle. While coal, nuclear, or gas plants are incapable of changing loads at the rate required by the intermittent sources, the certain energy storage technologies offer a viable storage and utilization mechanism. When power supply is abundant or oversupplied, the energy storage capability allows full utilization of power that may be otherwise grounded.

Coal fired furnaces and or nuclear powered boilers are constrained by certain physical limits, such as rate of temperature change on tubes, allowing only restricted power cycling. Furthermore, energy from renewable resources has become increasingly popular. The National Renewable Energy Laboratory indicates that the US Department of Energy has a vision wherein wind energy contributions to total electricity production in the future is projected to increase. It is their aim that over the next 2 decades, wind will comprise 20% of US electricity production (Thresher, Robinson, and Veers, 2008). However, coal-fired or nuclear power plant cycling to accommodate renewable resources can actually increase wear and tear costs on the equipment such as steam headers. The longer the boilers sit idle, the greater the damage done to the boiler as it is ramped up after the idle time. This will decrease boiler life and increase maintenance costs that will offset the benefits of renewable energy (Lew, Brinkman, Lefton, Piwko, 2011). It may seem as though these two factors cannot be optimized simultaneously.

Summary of Research Objectives

Your group will test whether energy storage will enhance the ability of the smart grid to respond to disturbances while fully utilizing new intermittent available capacity (wind). This study will demonstrate the potential to cycle the energy storage with steady nuclear power-generation. The objective is to meet both heating and electric supply with intermittent wind energy and a small modular nuclear reactor (max 100 MW_e). The nuclear reactor produces waste heat at a rate of 3 times the rate of electricity generation. The nuclear reactor responds slowly (τ=3 hours) to changes in electrical demand. To compensate for this, a vanadium redox flow battery system with a max capacity of 200 MW_e-hr is available to store excess capacity. The vanadium redox flow battery system has 70% efficiency in capturing oversupply of electricity. The simulation horizon is a period of 24 hours and over which heat and electricity demands must be met by adjusting the nuclear load. It is desirable for the control system to minimize heating oversupply and minimize electricity demand difference while keeping both positive (avoid undersupply).

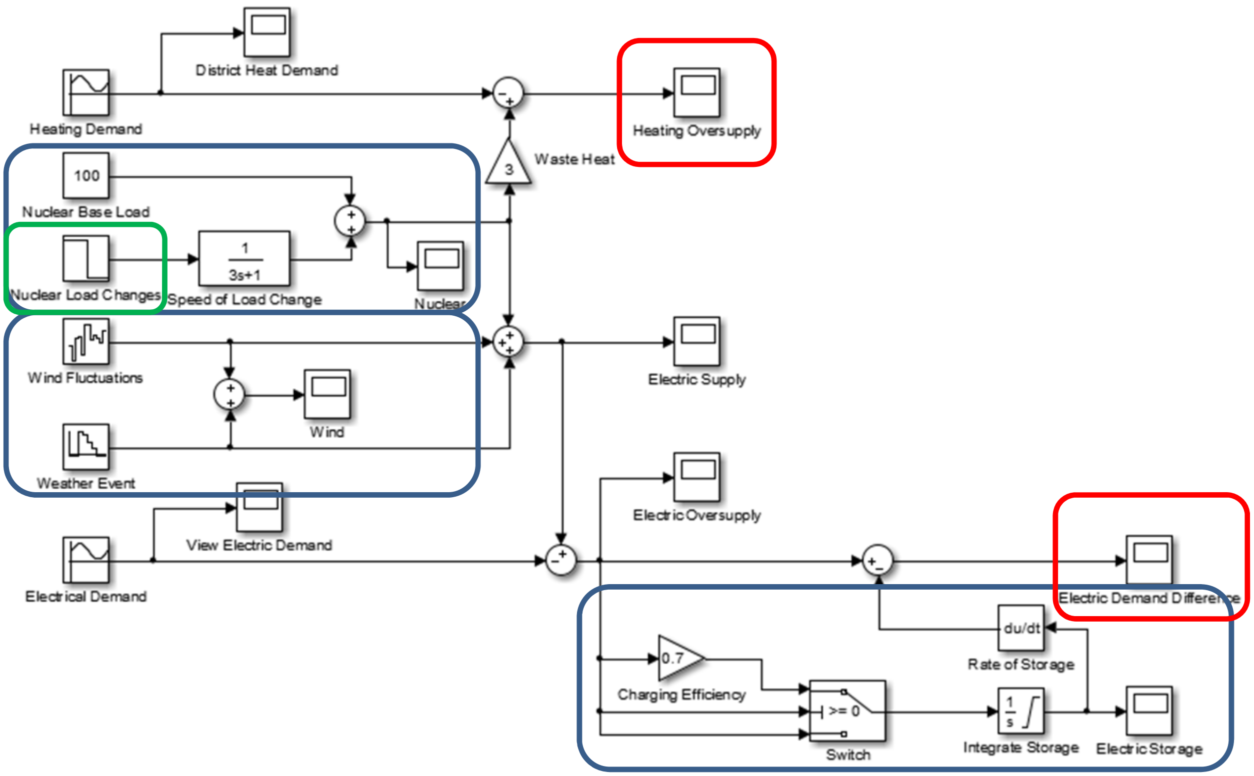

Figure 1. Manipulate Nuclear Load Changes for the Nuclear, Wind, and Battery System to Maintain Heating and Electrical Production while Minimizing Overproduction.

With energy storage, the intermittent nature of the wind supply fluctuations can be captured by a sufficiently large storage device. With these developments, there is full utilization of wind energy with uninterrupted nuclear generation. It is the combination of renewable, base-load systems, and energy storage that can lead to a robust and sustainable smart grid.

References

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