Chapter 5
Design Models for Resource Allocation in Cyber–Physical Energy Systems

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ABSTRACT

Today's and tomorrow's smart grid systems are made more efficient, cleaner, and reliable by "smart" control mechanisms and decision models that deliver information to consumers so they can better manage energy resources. The rapidly changing needs and opportunities of today's electric grid market require unprecedented levels of interoperability to integrate diverse information systems to share knowledge and collaborate among sub-devices or sub-systems in the grid. This book chapter focuses on optimal mathematical models for resource allocation. A series of mathematical models is presented in this book chapter for solving large-scale energy allocation problems with partially observable states, utility functions, and constrained action is introduced. The authors' techniques use a Linear Programming (LP) approach to determine resource allocations among a set of fuzzy rules that allocates Distributed Energy Resources (DER's) or power sources/sinks and uses to determine improving resource management.

INTRODUCTION

Dynamic real-time power systems often operate in continuously changing environments such as adverse weather conditions, sudden transformer failures, malfunctioning of a sub-system of a transmission or distribution network. These disruptions along with the complexity of our power network systems, cause the energy demand and loads of a power system to fluctuate, potentially resulting in widespread outages and huge price spikes. Electrical energy is traditionally generated at large power plants and transferred in bulk to substations that in turn distribute power to residential, commercial, and industrial customers. A wide variety of devices are involved and utilized,

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including transformers, sensors, controllers, and, more recently, smart meters at points of consumption. A successful Smart Grid must be highly instrumented, data rich, networked, and integrated and managed as a complete "end to end" system. However, centralized control is clearly impossible, leading to the challenge of distributing control and still providing high performance and efficiency.

Data from the North American Electric Reliability Council (NERC) and analyses from the Electric Power Research Institute (EPRI) indicate that average outages from 1984 to the present time have affected nearly 700,000 customers per event annually as noted by Masood Amin (2004). Smaller outages occur much more frequently and affect tens to hundreds of thousands of customers every few weeks or months, while larger outages occur every two to nine years and affect millions. Although preventing these outages remain challenging, such changes (increases or decreases) in demand by consumers can often be offset by Distributed Energy Resources (DERs) which are renewable resources like solar and wind based power to satisfy the shortages or reduce the outage levels. In our work, we consider the use of such DER based standby mechanisms and formulate to support their issue.

The book chapter is divided into two sections. Section 1 focuses on resource optimization methods by formulating generalized Linear Programming models and section 2 details the applicability of branch and bound method in allocating DER resources. In section 2, we specifically apply an Iterative Binary Integer Linear Programming (IBILP) technique similar to Wolsey (1998) to optimally assign DERs to a region based on criteria such as power levels, demands and preferences.

BACKGROUND

Green Energy solutions that are described as "smart"—from smart meters, smart buildings to smart appliances to the Smart Grid—have intelligent sensors to measure temperature or other variables to receive and transmit data, memory chips to store the information and process it, and manage the power flow to adjust energy loads. In building a Smart Grid self-healing model, there are multiple considerations that are important to include as explained by Amin (2008). Some considerations pertain to the physical infrastructure, such as the generators, busses, relays, and transmission lines should be considered. Other considerations pertain to the cyber infrastructure, such as the communication networks, storage, protocols, and procedures for management of the grid. There was been several studies that pushes for advanced secure infrastructure of the grid as described by Amin and Stringer (2008).

The current electric grid in the U.S. is about 100 years old and while incremental upgrades to it have been made over the last few decades, the advancements in fields such as Software and Internet Technologies, wireless technologies, have been slow to transition into the grid. It is the convergence of a number of factors that provides for a perfect storm today that is expected to make a revolutionary change in the nature of the electrical grid.

The various factors that led to futuristic self-healing grid are as follows:

- Rapid reduction in limited natural resources
- Growth in population
- Rising cost of energy
- Current technology advances make it possible
- Increase in Global warming and climatic conditions
- Changes in the utility business operations worldwide
- Deregulation in various parts of the world
- Better awareness and education among consumers
- Increase in renewable, distributed, and smaller power generation
- Increase in power storage capability

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