Chapter 4
Application of Spatial and Temporal Predictive Analysis for Energy Network Optimization

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ABSTRACT

Energy supply is characterized by its diversity. It involves a complex network system composed of energy generation, energy transformation, energy transportation, and energy consumption, and presents a complex task for conducting agile energy dispatching when extreme events have caused local energy shortages that need to be restored timely. One of the useful methodologies to solve such a problem is soft computing that conducts collaboration, association, and complementariness of the different techniques that integrate it and that cooperate from their basics. Their main objective is to take advantage of inherent tolerance of the imprecision and uncertainty to obtain tractability, robustness, and low solution-cost. In this chapter, the spatial and temporal predictive analysis techniques and their application in energy network optimization are briefly introduced. The application scope covers the energy demand prediction, the identification of the strategy to meet the peak demand requirement, and the environment impact optimization. The demonstration application is presented to demonstrate the application capability and capacity of temporal and spatial analysis to provide prediction of temperature change trend, demand forecast, and the potential environmental impact of traditional power plant operation.

1. INTRODUCTION

Nowadays energy supply is characterized by its diversity, including traditional energy such as fossil fuels, nuclear power, as well as renewable energy such as solar, hydroelectric, geothermal, biomass, and wind energy. It involves a complex network system composed of energy generation, energy transformation, energy transportation, and energy consumption. The network does provide the great flexibility for energy transformation and transportation; meanwhile, it presents a complex task for conducting agile energy dispatching when extreme events have caused local energy shortages that need to be restored timely. The design and optimization of energy network needs to investigate
the environment impact of current power plants in order to replace the fuel combustion method with renewable energy facility and integrate the consideration of the energy restoration during the emergency situation of regional shortage.

The energy network optimization actually involve a lot of factors such as climate change trend, regional energy demand forecast and regional environment impact assessment of traditional power plant operation with fuel combustion. The modeling and optimization to reversely determine the dynamic emission rate and search for the optimal energy restoration is always a high nonlinear multi-objective MINLP (Mixed Integer Nonlinear Programming) problem, which is difficult to solve with current deterministic MINLP solvers. Thus, the solving algorithm of multi-objective genetic algorithm (MGA) will be a good choice. MGA can directly obtain Pareto frontier of the raised two objectives from all possible patterns under different optimal scenarios. Furthermore, since the entire local area might be investigated, the whole region needs to be partitioned into a large number of grid cells and energy condition and its impact of each cell will be calculated. Thus, the optimization will involve lots of simulations, causing the simulation duty during the optimization is very heavy. All these operations are full of uncertain situations.

Facing these challenges, decision makers often encounters various uncertainties that inevitably influence the performance of a being designated energy dispatch plan. The uncertainties can upset the optimality and even the feasibility of the dispatch plan. Thus, quantitative analysis on the impact of uncertainties is of great significance for the study of energy network optimization. Technically, a viable approach is to conduct a full evaluation of the effects of uncertainties based on all their possibilities. This will provide decision makers a complete roadmap of the space of uncertainty parameters. Through this way, the objective function and the optimization parameters are represented as functions of uncertainty parameters (i.e., parametric programming); meanwhile, the regions in the space of the uncertainties characterized by these functions can be obtained. Therefore it is very useful for the stakeholders to apply spatial and temporal predictive analysis techniques during the optimization of energy network operation.

2. TECHNIQUES OF SPATIAL AND TEMPORAL PREDICTIVE ANALYSIS

With the help of information technology, the spatial and temporal data are more than ever before. The environment monitoring for weather forecasting are typical spatial and temporal data. They have brought bring new challenges and opportunities to the research area of data analysis and intelligence solution. More predictive patterns should be identified from the integration of space and time dimensions in order to solve real-world problems. In real world, massive data volume are always available with uncertainty, complex relationship, and system dynamics. Spatial and temporal analysis has become one section of data mining (Fayyad, Piatetsky-Shapiro, & Smyth, 1996). It has become interdisciplinary research field of computer science (Clifton, 2010; Hastie, Tibshirani, & Friedman, 2009) which apply computation to identify and predict patterns from available large data sets. The applied methodologies or techniques include artificial intelligence, statistics, predictive analysis, information technologies, machine learning, and database systems. It aims to extract information from a data set and transform it into an understandable structure for further use. Besides data analysis, spatial and temporal analysis system also needs to integrate database, data management, data pre-processing, modeling and interpretation, complexity assessment, post-processing, visualization, and real time updating (Clifton, 2010; Hastie, Tibshirani, & Friedman, 2009).
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