ABSTRACT

Climate change has become an important issue that all human beings have to address in order to maintain sustainable development in our world, integrating more renewable energy into our current infrastructures is one of them. This kind of energy resource with almost 0-emission of CO_2 (Carbon Dioxide) can be integrated into our energy portfolios in order to reduce the amount of CO_2 emission from our energy infrastructures.

Climate change may cause species extinctions, more extreme weather events and negative impacts on agricultural product yields. These are the important motivations of RPS (Renewable Portfolio Standard) also called renewable electricity standard (RES). RPS is a regulation that requires the energy production from the renewable energy sources, such as wind, solar, biomass, and geothermal to be increased. RPS also requires that the electricity supply companies produce a specified fraction of their electricity from renewable energy sources. [72]

We use five mid-west states (with rich wind energy [94]) in U.S.A. as an example to present quantitative results about the impacts of RPS [72] policy on the development of fossil/renewable power generation/transmission system development. In order to satisfy growing power demand in this area, generation/transmission capacities need to be expanded so that each state in this area can realize their RPS policy goals. Therefore, we need to understand the impacts of RPS on the generation/transmission capacity expansions. We design a strategy-level energy planing modeling tool in order to analyze the investment that we have to do for the capacity expansions if we want to realize RPS goals in all states of this area. We show these models using linear network flow optimization models.

In classical linear network flow (LNF) problems, a network consists of multiple source and sink nodes, where each node is a sink node or a source node, but not both. Usually, there is only one kind of commodity flow and the goal is to find flow schedules and routes such that all sink nodes' flow demands are satisfied and the total flow transmission cost is minimized. We develop a capacity expansion multicommodity network flow (CEMNF) problem, in which the total existing commodity supply is less than the total commodity demand. There are more than one kind of commodities and each node is a commodity flow generator, as well as a consumer. It is allowed to do expansions for commodity flow generation capacities at each node and also to do expansions for commodity flow transmission capacities of each arc so that more flows can be transmitted among nodes. The goal of CEMNF problem is to find the flow routes and capacity expansion plans such that all flow demands are satisfied and the total cost of flow routing and planning is minimized.

High-performance distributed computing algorithms designed to solve classical linear network flow (LNF) problems have been proposed. Solving the general CEMNF problems by high-performance distributed computing algorithms is an open research question. The LNF problems can be formulated as linear programming models and parallel algorithms have been proposed to solve them efficiently on distributed computing platforms. But, the constraints of the CEMNF problems do not allow them to solve using the same methodology for LNF problems. In this dissertation, we develop a transformation method to transform CEMNF problems into LNF problems in polynomial time and space complexity to solve them efficiently on distributed computing platforms. The results show that we can solve CEMNF problems with high performance by transforming CEMNF problems into LNF problems. Both of CEMNF and LNF problems can be formulated as linear programming models. We apply the transformation algorithm and the ϵ-relaxation [19] algorithm to policy-driven (RPS [72]) energy infrastructure planning problems and present the results. We study the uncertainty of CEMNF model parameter estimates and perform statistics analysis of the uncertainty impacts on the CEMNF models' optimal solutions.