As energy demands increase and energy resources change, the traditional energy system has been upgraded and reconstructed for human society development and sustainability. Considerable studies have been conducted in energy expansion planning and electricity generation operations by mainly considering the integration of traditional fossil fuel generation with renewable generation. Because the energy market is full of uncertainty, we realize that these uncertainties have continuously challenged market design and operations, even a national energy policy. In fact, only a few considerations were given to the optimization of energy expansion and generation taking into account the variability and uncertainty of energy supply and demand in energy markets. This usually causes an energy system unreliable to cope with unexpected changes, such as a surge in fuel price, a sudden drop of demand, or a large renewable supply fluctuation. Thus, for an overall energy system, optimizing a long-term expansion planning and market operation in a stochastic environment are crucial to improve the system’s reliability and robustness.

As little consideration was paid to imposing risk measure on the power management system, this dissertation discusses applying risk-constrained stochastic programming to improve the efficiency, reliability and economics of energy expansion and electric power generation, respectively. Considering the supply-demand uncertainties affecting the energy system stability, three different optimization strategies are proposed to enhance the overall reliability and sustainability of an energy system. The first strategy is to optimize the regional energy expansion planning which focuses on capacity expansion of natural gas system, power generation system and renewable energy system, in addition to transmission network. With strong support of NG and electric facilities, the second strategy provides an optimal day-ahead scheduling for electric power generation system incorporating with non-generation resources, i.e. demand response and energy storage. Because of risk aversion, this generation scheduling enables a power system qualified with higher reliability and promotes non-generation resources in smart grid. To take advantage of power generation sources, the third strategy strengthens the change of the traditional energy reserve requirements but ensuring the same level of system's reliability. In this way we maximize the use of existing resources to accommodate internal or/and external changes in a power system.

All problems are formulated by stochastic mixed integer programming, particularly considering the uncertainties from fuel price, renewable energy output and electricity demand over time. Taking the benefit of model's structure, a modified Benders' Decomposition is applied to solve the latter two problems using an enhanced solution scheme. Compared to the classic Benders' Decomposition, this proposed solution scheme is able to increase convergence speed and thus reduce 25% of computation times on the same cases.

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The public is welcome to attend.