Integration of Renewable and Conventional Energy Generation

Demosthenis Teneketzis and Hamidreza Tavafoghi
Department of EECS, University of Michigan, Ann Arbor

In recent years, to increase the share of sustainable energy resources in total generated electricity, electricity generation from modern renewable resources has been developed. In 2013, 4.1% of the net generation in the U.S. comes from modern renewable resources. The U.S. is planning to expand the share of solar and wind generation to 20% by 2030.

The intermittent nature of modern renewable resources makes the integration of renewable energy generation into the current designed infrastructure for conventional generation a challenging problem. Electricity generation from modern renewable resources is not predetermined and cannot be treated as conventional generation. The integration of this stochastic energy generation results in many new technical issues in generation reserves, transmission, reliability, forecasting, as well as market structure.

Currently, all the produced electricity from renewable energy resources is guaranteed to be procured in the real-time market at a fixed price, and the procured energy is treated as a negative load on the grid in the real-time market. Renewable energy producers receive subsidy, and do not take any risk associated with the intermittent nature of renewable energy generation.

As the share of renewable energy increases, because of network stability and reliability concerns, regional independent system operators (ISOs) will gradually require renewable energy generators to participate in the day-ahead market and commit to a fixed amount of energy generation. If a renewable energy generator fails to meet its commitment, it must either produce the energy deficiency using a backup generator or pay a penalty. Furthermore, with increasing share of renewable generation, the number of generators of renewable energy will increase, and these generators will behave strategically in the emerging competitive markets.

The above considerations create a new challenging problem for ISOs. Specifically: How do ISOs deal with strategic energy producers that possess both conventional and renewable energy production capabilities and have technologies (for conventional and renewable energy generation) that are their own private information? We propose this general problem on the integration of renewable and conventional energy generation as our position statement.

We began developing an approach to the problem using a simple model for optimal energy procurement. We consider a mechanism/contract design problem for energy procurement, when there is one strategic buyer and one strategic seller. We assume that the buyer has all the bargaining power and therefore is the mechanism designer. The seller has the ability to generate from a conventional and a renewable plant. The renewable energy generation is not deterministic, it depends on a random variable (*e.g.* weather) which is realized at the time of production. We assume that the generation technology for each plant is the seller's private information and the buyer's utility from energy consumption is the buyer's private information. We design a mechanism/contract that maximizes the buyer's expected utility, and guarantees the voluntary participation of the seller. We prove that the solution to the problem is a menu of contracts (a nonlinear pricing scheme) that the buyer offers to the seller and the seller chooses one based on her technologies.

We have identified extensions of this model that include energy procurement with one buyer and many sellers, as well as energy procurement over a finite time horizon.