Smart Grid Management under Uncertainty with Decomposition and Coordination Optimization Methods

Scientific training period proposal

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Organism, supervision and material conditions

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Material conditions: a financial gratification is offered
Dates: to be discussed

Proposal

Research domain

Mathematics, optimization, stochastic control, energy, risk.

Context

Optimizing is finding the best compromise between needs and resources. Optimization issues abound in the management of energies, of transport, of natural resources, of the environment, etc. The complexity of systems – related, for instance, to their large size (multiple components), to dynamical aspects (stocks variations) and to the presence of uncertainties (users demand, meteorological conditions) – leads to difficult optimization problems. Electrical network management under constraints (capacity, operational) is a practical instance. The notion of smart grids with interconnected sources and sinks of energy submitted to highly variable demand (accumulators, transport, etc.), intermittent production (solar, wind, etc.), variable costs (nuclear, hydroelectricity, thermal, etc.) makes such problems a lot more complicated.

The dynamic programming (DP) equation is an important theoretical tool to identify optimal strategies in stochastic control problems [3, 9, 7, 4]. However, increasing the dimension of the state leads to the so-called "curse of dimensionality". This is an obstacle to successfully solve large size stochastic control problems. In this proposal, we intend to deal with the state dimension issues by introducing decomposition and coordination techniques [5, 6]. These techniques are adapted to the case where a system is naturally made of relatively "small" units – each with its state and control local variables – with specific interactions (coupling constraints, criterion). For instance, energy production units (nuclear plants, thermal plants, hydroelectricity, solar, wind, etc.) are coupled via costs (criterion) and the coupling constraint that production must equal demand. The theory is mainly established in the deterministic case, but some progress has been made in the stochastic case. The project aims at examining which issues in smart grid management are relevant for decomposition and coordination methods, either deterministic or stochastic.

In the stochastic case, a method based on price decomposition, namely Dual Approximate Dynamic Programming (DADP), has been proposed in [2, 1] for specialized energy system. Others approaches, such

as decomposition by prediction, may be also suited for smart grids. A goal of the project is to examine these alternative approaches.

What is more, environmental issues on the one hand, and safety questions (blackouts) on the other will compel us to introduce certain types of constraints (in probability) and risk (risk measures) in the optimization framework [8]. This will require to develop specific mathematical approaches and algorithms.

Project

The student will work on small instances of networks, to try and test decomposition and coordination methods in the stochastic case. When the instance is small enough to display a numerically tractable exact solution by dynamic programming, the student will compare the performance and the system trajectories in the optimal and suboptimal cases.

References

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