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PhD student position in Centrale-Supélec Chair on Systems Sciences and Energetic Challenges

Subject: Modelling and optimisation of energy distribution networks with multiple and diverse producers

Period: Spring 2011 - Spring 2014
Status: CDD-FR of 36 months.
Net income: 1,500 /month.
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Keywords: complex systems, graph theory, electric grid

Thesis subject:

The growing penetration of renewable energy production systems within the historical electricity grids is changing the way electricity distribution is addressed. The grid landscape is moving from a directed hierarchical graph from high capacity producers (e.g., nuclear power plants) to consumers towards a bi-directional complex graph where multiple low capacity producers are connected at different levels (e.g., large windmill farms are connected to the transport network while small farms are connected to the distribution network) and where consumers are also producers. Moreover, the inconstant energy production of windmills and solar panels introduces stochastic behaviours in different positions of the grid. This is even more so in distribution networks primarily based on renewable energy production, such as in insular grids.

This new setting radically changes the management of the electric grid. The bi-directional property of the grid causes congestion problems in case of power overload events that may weaken the grid locally or globally. The stochastic behaviour of the energy production units turns the deterministic human-controllable management of the grid into a complex process which reduces the grid reliability and calls for automatised management, especially in case of high penetration of such units. The stochastic contingencies, added to the large dimension of the grid, requires a synergy between local self-organisation of the grid and global load balancing.

The objective of this thesis is to model, analyse and develop optimal solutions for the future heterogeneous electricity grid. Grid modelling will require tools from graph theory and random graph theory as well as Bayesian probability theory to characterise the randomness of the energy sources. The analysis of the reliability, safety and management of the grid will call for further tools from graph theory along with random matrix theory that intervenes in the study of adjacency matrices. Decentralised grid management solutions will require game theoretical considerations, where the network production units will be assimilated as players competing to optimise local and global energy distribution as well as to maintain system reliability. The time varying aspect of the grid may then demand to study dynamic games, while the relative rationality of the actors (consumers and producers may act erratically) may require to extend game theoretical considerations to evolutionary games (e.g., genetic algorithms). Information theory is also another important tool to analyse the performance of flow networks as well as to identify the amount of information to be

exchanged within neighboring nodes so to ensure stability, safety and overall performance. Reliability and failure analysis requires to mix the above studies with probability theory considerations. Alternative approaches may include considerations in statistical mechanics, stochastic geometry or neural networks.

Possible techniques investigated:
Multi-agent modeling, Bayesian modeling, statistical mechanics, Monte Carlo simulations, Markov chains, game theory (also evolutionary games, mean field games), signal processing, neural networks, graph theory, random graph theory, random matrix theory, probability theory.

Educational motives and job opportunities:
This thesis aims at preparing the PhD student to become, from a theoretical viewpoint, an expert in specific mathematical tools for the analysis and optimization of large dimensional dynamic systems and from a practical viewpoint, an expert in the management of complex power systems: safety, reliability and control analysis, productive design, optimization etc. This expertise enables the student to obtain positions as a complex system analyst, designer, operator, manager, regulator or a safety and risk analyst, both for energy systems and for analog complex systems: transportation and telecommunication networks, biological and chemical processes etc.

Possible cooperations outside Centrale-Suplec:
Massachusetts Institute of Technology, ETH Zurich, Tsinghua University (Beijing), Telecom ParisTech, Electricité de France.

Required skills:
We seek a PhD student who fulfills the following areas of expertise:

- strong mathematical background, especially in probability theory,
- advanced knowledge on complex power systems,
- knowledgeable about C and Matlab coding.

Information:
The application date is immediate for an immediate starting date. Applications should be sent to Corinne Ollivier (*corinne.ollivier@ecp.fr*) and Anne Batalie (*anne.batalie@supelec.fr*).