Energy Informatics – Computer Science for Power and Energy Systems of the Future

Martin Leucker and Martin Sachenbacher

Technische Universität München, Department of Informatics
Boltzmannstraße 3, 85748 Garching, Germany
{leucker,sachenba}@in.tum.de

Summary Energy informatics is emerging as a new field in which aspects of computer science and engineering sciences are converging. This process is driven by factors in both disciplines: From the point of view of engineering science, a growing demand in energy, rapidly dwindling natural resources, and climate change mean that power generation and distribution systems need to become dramatically more efficient and environmentally friendly. On the other hand, from the point of view of computer science, a phase transition has occurred in the scale of problems that can be solved by automated reasoning from formal models, leading to a revolution in a range of disciplines including planning and scheduling, verification, diagnosis, and hybrid systems.

The goal of energy informatics is thus to apply informatics technologies to the energy domain, and to further develop and refine these techniques in order to model and reason about technical and economical aspects of sustainable energy production, efficient energy distribution, storage, and consumption.

Power and Energy Systems of the Future Due to dwindling fossil or nuclear energy resources and the pressing need for emission reduction, the shift towards so-called renewable energy production will intensify in the future. These power plants will typically be small-scale, privately owned and distributed across large areas. Therefore, the traditional roles of producers and consumers tend to merge into "prosumers", who both buy and sell back energy to the grid. At the same time, the expansion of weather-dependent renewable energies, such as wind and solar power, leads to an increasingly fluctuating energy supply.

Thus, energy companies face the challenge to provide a stable power grid based on a large number of producers with an at most stochastically predictable energy supply. Today, there are no reliable models regarding energy production of the future's power grid. Informatics has developed a vast array of modeling techniques together with a rich tool framework to analyze such models. Within the last decades, formal methods like model checking have proved their advantages in reasoning about the qualitative and quantitative properties of system models. It can be expected that such modeling and analysis techniques rooted in informatics provide a basis also for developing energy-efficient end-use equipment such as intelligent household appliances, reducing energy consumption in smart buildings, and controlling the future's energy grid.

To give a concrete example, a typical energy informatics problem emerges in the development of new energy storage technologies to compensate for the fluctuating renewable energy supply. Among other techniques, electrical vehicles offer a potential solution, because if the cars are not in use, their batteries can be used as energy buffers to stabilize the grid and shift peak demands. However, to be useful both for the vehicle owners and utility companies, this decentralized buffering and trading of electrical energy must happen in a fully automated way, while minimizing the risk and discomfort for the car owner. This problem might be posed as follows: given a model of physical battery behavior and a stochastic model of human car usage (which predicts when the car will be driven), compute a control strategy that maximizes the effectiveness of energy buffering, but at the same time keeps the mobility risk of the user (chance that the car cannot be driven because it is insufficiently charged) below a certain threshold (say 1%).

The challenges for computer science Solving such problems requires to develop models that take into account discrete logics and continuous dynamics of technical components, but also human behavior, together with efficient reasoning algorithms that quickly estimate the system's state and find optimal and user-acceptable control strategies. While many of the appropriate languages and modeling formalisms, as well as real-time reasoning algorithms for planning and monitoring have been developed in informatics in the last years, these elements are currently spread amongst several disciplines and communities, like hybrid systems and control, AI-based planning and scheduling, embedded systems design and verification, and constraint solving and optimization and are not tailored so far for the application within the energy domain.

The previous discussion identifies *models*, *control*, and *markets* as three major challenges for computer science within the field of energy informatics:

Models Modelling, simulation, and analysis frameworks suitable for energy grids and their components, including prosumer behavior;

Control Control algorithms for autonomous steering of distributed power generation, incorporating self-healing capabilities, security aspects, etc.;

Markets Semi- and fully-automatic trading platforms for energy markets that allow large numbers of prosumers to optimally participate in the power grid.

The authors The authors are young researchers at the department of computer science at TU Munich. They are currently involved in the e-energy project E-Tour Allgäu, which is funded as part of the German initiative *information and communication technology for electrical mobility*. Within this project, they are responsible for the ICT aspects arising in the shift towards electric cars. Also, they are co-organizers of on upcoming Dagstuhl seminar on *Runtime Verification, Diagnosis, Planning and Control for Autonomous Systems.*