Formal Methods in Energy Informatics

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Abstract. The European electricity market is rapidly evolving towards a decentralized structure, not only because of climatical and political circumstances. With the foreseeable depletion of fossile energy sources this trend is expected to catch momentum also on other continents. The increase of production based on renewable energy implies drastically higher fluctuations in available electricity. The resulting mathematical problem, stochastic electricity balancing, has many facets where quantitative formal methods provide a promising foundation to develop IT-supported strategies to counteract this problem.

The European electricity supply systems are rapidly evolving towards a situation in which not only the consumer behavior, but also the producer behavior must be considered as a stochastic process. This is a direct consequence of small and medium scale renewable energy plants deployed massively, together with the fact that sun intensity and wind speed are uncontrollable. This asks for novel methods to control and manage electricity networks in a decentralized way. The core objective is to continuously match production and consumption of electricity across networks. If both do not match, this impacts the frequency of the supplied power, and this frequency skew in fact serves as a limited buffer for misbalanced production and consumption.

Traditionally, the balance is maintained by the electricity producers on the basis of periodic (weekly, daily, hourly, 15 min) predictions of the anticipated consumption. The real-time match of production and consumption is obtained by dedicated power plants and control loops, which continuously supervise and stabilize the frequency at 50Hz (in Europe). These mechanisms can buffer about 10% of the peak electricity consumption.

This traditional approach however is based on the assumption that the production is a deterministc and a controllable process. Both assumptions are invalid in the future. The resulting challenge, the stochastic energy balancing problem [1], is the problem of decision making to keep the consumption and production of electricity within very tight bounds, where both consumption and production exhibit stochastic behavior. This problem induces a set of principal requirements for future modeling and analysis techniques and supporting tools needed to study, predict and guarantee behavioral properties of electrical energy networks. Quanitative formal methods can play a distinguished role in attacks to solve the problem. They need to combine elements from concurrency theory,

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stochastic process theory, differential equations or inclusions, with methods from computer aided verification. The aim is to arrive at IT-supported approaches to counter the stochastic energy balancing problem. The current focus of major European electricity producer aims at making the consumption more controllable, to be able to buffer the uncontrollable fluctuations in production at the consumer side. These cooperative strategies of producers, consumers and infrastructure providers need advanced software engineering, modeling and analysis techniques for behavioral properties of electricity networks.

Reference

1. Hermanns, H., Wiechmann, H.: Future Design Challenges for Electric Energy Supply. In: Proceedings of the 14th IEEE International Conference on Emerging Technologies & Factory Automation, pp. 1310–1317 (2009)