ENBARK: ENergy-Based analysis and control of the grid: dealing with uncertainty and mARKets

with Plus Project in Amsterdam*

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Energy based analysis and control of the grid: Dealing with uncertainty and markets in an urban environment

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Analysing and controlling the physical grid and market mechanisms as well

Any control strategy for future smart grids cannot disregard economical considerations that allow producers and consumers to fairly share utilities and costs associated with the generation and consumption of energy. So far, the analysis and control of the physical grid and the market mechanisms are analysed separately. ENBARK provides new analysis and control methods in an integrated manner, so that the two responsibilities are coupled – based on energy functions. For the physical grid, energy is the quantity that all its components (synchronous machines, transmission lines, etc.) have in common, whereas for the market mechanism ENBARK defines a concept of energy based on economic quantities.

* Dynamic pricing

ENBARK has established a unifying energy-based approach in the design of dynamic pricing algorithms for higher order model of the power network based on the primal-dual gradient method. The proposed controllers allow for optimal power dispatch in the presence of constraints on the power generation, power demand, and the capacity of the transmission lines. The latest developments include the extension to markets where the independent system operator and the generators engage in a competition game.

* Stability analysis framework

ENBARK has developed a modular stability analysis framework by exploiting suitable (incremental, differential) energy functions. This framework is able to capture many of the existing control algorithms in the grid, and moreover suggest new ones with mathematically provable stability and performance. ENBARK+ Amsterdam proposed new control techniques for DC grids with load uncertainties. The current status of the investigation is summarised in [4].

Read more

1 T. Stegink, C. De Persis, A. van der Schaft (2017): *A unifying energy-based approach to stability of power grids with market dynamics*, *IEEE Transactions on Automatic Control*

2 C. De Persis, N. Monshizadeh (2018): *Bregman storage functions for microgrid control*, *IEEE Transactions on Automatic Control*

3 T. Stegink, A. Cherukuri, C. De Persis, A. van der Schaft, J. Cortes (2018): *Hybrid interconnection of iterative bidding and power network dynamics for frequency regulation and optimal dispatch*, *IEEE Transactions on Control of Network Systems* (in press)

4 K. Kosaraju, M. Cucuzzella, J. Scherpen, R. Pasumarthy (2018): *Differentiation and Passivity for Control of Brayton-Moser Systems*, *IEEE Transactions on Automatic Control*, submitted

The research programme Uncertainty Reduction in Smart Energy Systems (**URSES**) aims to make a quick transition to a reliable, affordable and sustainable energy system possible. It is a joint initiative of several departments of NWO, Shell, AMS and the TKI Urban Energy.

Insights & recommendations

[1] A unifying energy-based approach has been provided to the modelling and stability analysis of power systems coupled with market dynamics. A model of the power network with a third-order model for the synchronous generators involving voltage dynamics has been controlled via a distributed dynamic pricing algorithm to maximize the social welfare. The feedback system has been naturally formulated in port-Hamiltonian form whose properties are exploited to prove stability of the set of optimal points.

[2] A theoretical framework has been provided that sheds new light on the problem of microgrid analysis and control. By means of the so-called Bregman storage functions, several microgrid controllers have been captured in our framework. The twist with respect to existing results is that our approach allows for a large signal analysis of the coupled microgrid. This obviates the need for simplifying linearisation techniques, and for the restrictive decoupling assumption in which the frequency dynamics is fully separated from the voltage one.

[3] A real-time electricity market involving an independent system operator (ISO) and a group of strategic generators has been considered. The ISO operates a market where generators bid prices at which they are willing to provide power. The ISO makes power generation assignments with the goal of solving the economic dispatch problem and regulating the network frequency. It is guaranteed that the proposed algorithm asymptotically converges to an equilibrium corresponding to an efficient Nash equilibrium and zero frequency deviation. The technical analysis builds on the characterization of the robustness properties of the continuous-time version of the bidding update process interconnected with the power network dynamics via the identification of a novel LISS-Lyapunov function. Simulations on the IEEE 14-bus system illustrate the results.

[4] For a class of Resistive-Inductive-Capacitive (RLC) circuits and switched RLC (s-RLC) circuits modelled in the Brayton Moser framework, two simple control methodologies called ‘output shaping’ and ‘input shaping’ are proposed for regulating the voltage in RLC and s-RLC circuits. Moreover, robustness with respect to load uncertainty is ensured by the input shaping methodology. The applicability of the proposed methodologies is illustrated by designing voltage controllers for DC-DC converters and DC networks.

NWO Netherlands Organisation for Scientific Research

AMS AMSTERDAM INSTITUTE FOR ADVANCED METROPOLITAN SOLUTIONS

TKI URBAN ENERGY Topsector Energie