Stability Analysis of Modern Power Systems

Key words:nonlinear/hybrid systems, power system stability, control

Context:
As for any dynamic system, stability is an important matter for power grids. However, several types of stability have been defined in power systems literature: transient, voltage and small-signal stability. Despite the fact that each of them is well defined, the check for stability is usually done by numerical simulations and analytical results are very difficult to provide on realistic (i.e., large-scale) grid situations. This is the case for transient and voltage stability. This is a limitation, for example, for the synthesis of nonlinear control laws and to prove their stability in several grid conditions.

The difficulties mentioned above are due to several facts. First, power systems are nonlinear systems. They contain physical nonlinear dynamics but most of the nonlinearities come from saturations and dead-bands which are systematically integrated in each regulator in order to protect the material. Next, transient stability is defined with respect to a critical event of the system – usually a short-circuit - which is eliminated in a given laps of time. This kind of event produces modification of the topology of the grid.

Research subject, general work plan:
Several approaches are envisaged:
- Quantification of transient stability and stability margins (region of attraction) via sum of squares type Lyapunov functions (via LMI) [1].
- Optimal tuning of the regulators parameters to maximize the aforementioned margins. - Study via equivalence transformations (feedback linearization)
- analysis as a switched system
- Model-free control (i.e., using a very simplified model) [2]

The results will be applied to concrete grid cases, in particular the regulation of the High-Voltage Direct Current (HVDC) lines.

Framework: This work is proposed in a general framework of collaboration with RTE – the French Transmission System Operator – and it is thus connected to real needs of the interconnected power systems. Realistic tests and validations of the theoretic developments mentioned above are possible on grid models and scenarios provided by RTE. The Control of Power Grids chair (http://chairerte.ecnantes.fr/) which exists between Ecole Centrale Nantes and RTE R&D guarantees the direction and the financial founding of this work. The work will be carried out in Nantes-France.

Skills required:
Mathematical background on (Lyapunov) stability of nonlinear systems and (optimal) control
Optimization (LMI)
Motivation for benchmarking (algorithms use/implementation/modification) and to discover the power systems domain (modelling, dynamic behaviour, …)

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References:
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[2] https://hal-polytechnique.archives-ouvertes.fr/hal-00828135v2