Speeding up a Risk-based Security Assessment Method for Electrical Power Systems

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Background

The electrical power system is under increasing stress due to a variety of reasons (see Figure 1):

- the consumption of electrical energy increases every year, whereas the infrastructure (e.g., the number of transmission lines) remains almost constant due to high building costs;
- a shift from a regulated monopoly to a competitive market;
- higher in-feed from renewable energy sources (RES) such as wind and solar.

To ensure secure grid operation in the future, additional measures are needed to stabilise the electrical power system. One may think of:

- inclusion of “smart components”, such as phase-shifting transformers (PSTs), flexible AC transmission systems (FACTS) and high-voltage DC (HVDC) links;
- development of risk-based security assessment (RBSA) methods in addition to the deterministic (N-1) methods being is use today. Risk-based methods can further help transmission system operators (TSOs) to steer the power system in a risk-averse state and to exploit the available capacity of the power system.

The ♠ Umbrella project

In order to cope with the increasing vulnerability of the electrical power system, in January 2012 the 4-year European research project ”Umbrella” was initiated. To primary goal of the project is to develop a dedicated and innovative toolbox to support secure grid operation by TSOs.

Among a total of 15 participants, Delft University of Technology (TU Delft) has a key position and provides its expertise in mathematical modelling and fast computation of large scale networks (see Figure 1).

It is Work Package 4 of the Umbrella project in which RBSA methods are being developed and the impact of smart components on the system risk is being studied.

The TU Delft contributed to the project by providing a methodology based on probabilistic load flow (PLF) using Monte-Carlo simulation and full AC computations to get the highest level of accuracy.

For information about the Umbrella project, see http://www.e-umbrella.eu.

Figure 1: The Umbrella Project will provide an innovative toolbox for TSOs to ensure secure grid operation in the future.
A brief description of the method developed by TU Delft

The generation and the demand of electrical power are varying because of wind and solar in-feeds and the fluctuating demand from the consumer side. In order to accurately capture the complex stochasticity of the load, a Monte-Carlo (MC) framework is used. In Figure 2 the flowchart is shown that is followed by each MC sample and sample output of the methodology.

At the heart of the methodology is the computation of many AC power flow (PF) problems, see the block “Run AC PF”. Also, the methodology proposes a set of remedial actions to stabilise the power system once it has become unstable, see the block “Remedial actions” in Risk Tool II. For this an AC optimal power flow (OPF) problem is solved.

A more detailed description of the method can be found in [1].

The problem

Both the AC PF and the AC OPF computations are time-consuming for larger networks. Especially within a Monte-Carlo framework, where typically these computations are performed 10,000 to 1,000,000 times, the computation time of the proposed methodology becomes its main drawback.

We are seeking for a student to speed up the method so that it becomes applicable for real-time operation.
The aim of this MSc / BSc project

The aim of this project is to speed-up the proposed RBSA methodology. First ideas one may think of are:

- **Smart initial guesses for AC PF and AC OPF.** It is to be expected that a smart initial guess may (strongly) reduce the required number of iterations till convergence;

- **Reuse of data.** Since the PF computations in the Monte-Carlo simulation are much-alike, reuse of information may be a good way to strongly reduce the amount of computations;

- **Exploit parallelism of the method.** Since Monte-Carlo sampling is embarrassingly parallelisable, one may achieve great speed up by dividing the work over many computing units (Multi-CPU / GPU / ...);

- **(Variance reduction techniques.** Variance reduction techniques may be used to reduce the required number of Monte-Carlo samples for a predefined level of accuracy.)

The student is encouraged and challenged to come up with more key solutions.

Organisation

The project consists of the following steps:

- Literature study and getting acquainted with the method (Matlab / MATPOWER);

- Profiling the code to see which are the most time-consuming parts;

- Proposing and figuring out ways to speed-up the method;

- Implementation of the solutions and performance analysis;

- Writing a report (and defence of the thesis in case of MSc).

References