Reduction of Transmission-Grid Constraints

for Computationally Efficient N-1 Secure Dispatch

Richard Weinhold, TU Berlin, riw@wip.tu-berlin.de
Robert Mieth, TU Berlin, rom@wip.tu-berlin.de

Overview

The current challenges of the European electricity market are mainly challenges of grid utilization and stability. Therefore, it becomes more and more necessary to explicitly incorporate feasible representations of the physical transmission grid into economic analyses.

In common energy-economic models, grid representation is done using the dc load flow (DCLF) approach as a linearization of the otherwise prohibitively complex physical load flow equations. This allows for a both adequately precise and computational sensible market optimization with grid restrictions.

With the same argument the N-1 criterion is usually approximated by enforcing either an absolute or relative error margin on the transmission lines at all times. However, this approximation is not suitable for analysis of market-strategies closely related to the physical state of the line, such as optimal redispatch and flow based market coupling. With increasing shares of renewables and the need for highly efficient grid utilization, such strategies are a crucial part of the current market development.

This paper presents a methodology for a true N-1 representation by reducing the grid matrix to the minimal set of constraining lines. This allows the calculation of a security constrained dispatch while being computational efficient. The methodology is realized by an implementation in Python as of a newly developed open source market model that specifically incorporates grid and market interdependencies.

Methods

To take the N-1 criterion into account, the model has to consider not only the load on each line, but also potential additional load if an outage occurs (Critical Branch Critical Outage - CBCO). This results in $L(L-1)$ constraints, where L is the total number of lines. As the DCLF constraints, i.e. the load flow problem, can be represented in the form of Ax $\leq$ b it can be thought of as a polyhedron where $xa \in \mathbb{R}^N$ are the net injections at all nodes $n \in N$ and A the corresponding power transmission distribution factor (PTDF) matrix with dimensionality $L(L-1) \cdot N$.

Calculating the polyhedron of the load flow constraints corresponds to identifying the critical lines that actually define the feasible region of the load flow problem. There are various algorithms to obtain the polyhedron of a load flow problem which relate to convex-hull algorithms. However, the high dimensionality of the matrix A disallows the straightforward use of off-the-shelf convex-hull implementations.

This paper presents and discusses various methods to obtain the resulting polyhedron of the load flow problem.

Results

As part of an open source power market model, the discussed methods are applied to an example power grid with 163 nodes and 303 lines. The method presented in this study reduces the number of N-1 load flow constraints by over 90% while still allowing to calculate security constraint optimal dispatch.

Conclusions

The N-1 criterion, one of the most important constraints for the secure operation of transmission grids. The methodology presented in this paper allows to reduce the computational complexity of a security constrained dispatch significantly and will allow much more models to include the N-1 criterion. More importantly, it allows to perform studies on larger scale networks and the market mechanisms that will be integral to the development of the European electricity market.