Automation of year-round AC power flow calculations of the European electricity grid

MSc. graduation project proposal in cooperation with TenneT

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Background

TenneT is a European system operator, who is responsible for safe and reliable transport of high-voltage electric power in the Netherlands and large parts of Germany (fig. 1 shows the grid map of TenneT). One of the key challenges to ensure safety and reliability is to keep the voltages within safe limits across the transmission network. The rapid increase in addition of Renewable Energy Sources (RES) into electricity networks causes voltage fluctuations to occur more frequently. TenneT uses year-round power flow simulations to plan the essential infrastructure to best prepare the transmission system for the future to ensure safety and reliability.

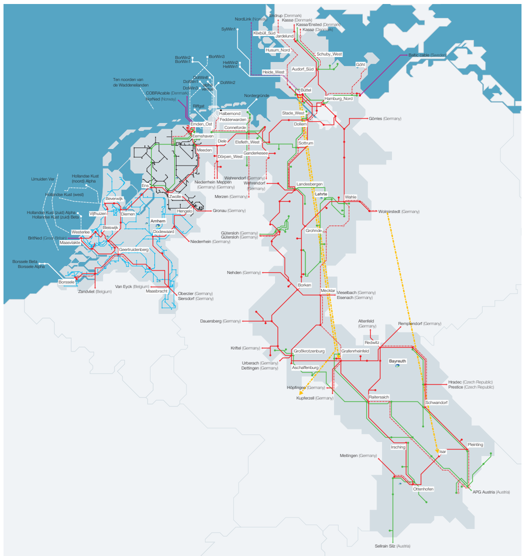

Figure 1: Grid map of TenneT

In year-round simulations, modifications to the network are made by adding certain electricity cables to the electricity grid. The new network is then tested for 5, 10, or 30 years ahead with varying hourly load and generation data. A consequence of this is that the power flow problem often fails to converge to a solution. In TenneT, convergence problems are currently being solved by manually making adjustments to the power flow problem; for example, by changing the topology of the grid or by adjusting the input data. This is a trial and error approach and takes on a lot of time. Therefore, MSc. student Shravan Chipli has developed an algorithm, in co-creation with TenneT, which can automatically fix convergence problems during year-round AC power flow simulations [1]. The goal of the current proposal is to continue the development of the algorithm, such that it can be widely used by system operators.

Goal of the project

The automation algorithm is based on the theory in [3], where optimal changes to the load and generation input data are made, when they are outside the solvable region. This is achieved by navigating to the closest solvable operating point in the parameter space by computing zero eigenvalues of the Jacobian matrix.
At this point, the algorithm helps overcoming convergence issues but has limited practical applicability for system operators, because the changes that are made are not yet subject to all the necessary constraints required to operate the grid safely. At this moment, only a limited amount of constraints is applied, such as the maximum allowance of power injection at a small set of predefined buses. A negative consequence of this is that is slows down convergence or even cause divergence, the problem that we tried to solve in the first place.

During this project, we will continue to improve the automating algorithm by posing this challenge as a non-linear constrained optimization problem. In this optimization problem, we can pose constraints on the voltages to keep them within safe operating limits. It involves solving the optimal power flow problem in which we determine the best control action to change the operation of shunts and transformers. Moreover, additional constraints can be added to the automating algorithm such as power limits. For example, imposing a reactive power limit on a generator. Furthermore, we will dive into the theory of bifurcation and eigenvalues to study the boundary between the solvable and unsolvable region in more detail. This will help us improving the convergence of the automating algorithm such that is helps TenneT to gain faster AC calculations.

Project constraints

The objective of this project is to continue the development of the automation algorithm to be used to solve optimization problems. The student will work in PandaPower, a software library in Python used to solve power flow computations, where it will continue on the algorithm that is made by S. Chipli [1]. The graduation project is in cooperation with TenneT and the student will use real-world grid models such as the Dutch grid model and the sub-European grid model. As prerequisites, we would recommend to have programming experience in Python (or any other high-profile language) or a strong interest to learn so. Furthermore, knowledge of non-linear optimization is a pre.

References

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