Thesis Abstract

In this work Reactive Power Planning (RPP) is studied. It is the method which aims at locating reactive compensators of optimal size at an optimal location in order to achieve or optimize a certain objective. In this work, the reactive compensators are placed in such a way that they keep the voltages in a grid longer stable and within an acceptable range of values while power flows through the grid. Usually, this power flow disturbs the voltages. RPP was applied in this work in order to allow a larger power flow from one grid area to another grid area. The first area is called the Source-area and it contains generators which can produce power at a cheap price. The second area is called the Sink-area and it is willing to import this cheap power so that it has to produce less power by itself. The two areas are connected to each other with a tie-line, which has a certain capacity (called Net Transfer Capacity or NTC). The capacity is restricted by stability requirements: exceeding the capacity would make voltages unstable in either of the two grid areas. Installing reactive power compensators allows to increase the capacity of the line, keeping the voltages longer stable when the power flow over the tie-line increases. Reactive Power Planning therefore has an economic benefit, and different methods to optimize it will be investigated in this work. The methods of this work are divided into three parts. In the **first part** the relationship is studied between reactive power compensation on the one hand and keeping the grid voltages longer stable and increasing the NTC of the tie-line on the other hand. The grid which is used to illustrate this is the Swedish grid, connected to the grids of Denmark and Finland. We observe that not only increasing the loads can lead to voltage instability in the grid, but that also voltage problems can arise within the Swedish grid from the exchange of power, flowing through the Swedish grid, between its neighbouring countries. It was shown that reactive power compensation is a technique which can potentially increase the NTC-value of the tie-lines between Sweden and Denmark and between Sweden and Finland. Depending on where the reactive power compensators are installed, the NTC increases with different values. In the next two parts however, we focus on the economic analysis of the reactive power compensation. In these two parts an OPF is designed, leading to the optimal placement and choice of the optimal ratings of the reactive power compensators, so that they increase the NTC so that the benefit of the decreased cost of power generation in the Sink area is maximized with respect to the cost of the reactive compensators. The difference between these two parts is in the algorithms that are applied for solving the OPF. In the **second part** a heuristic method based on a Genetic Algorithm (GA), NSGA-II, is used to optimize this benefit. The reason why first a heuristic method is used is that the NTC of the tie-line cannot be expressed as an analytical, closed-form, function of the reactive power ratings. Therefore, an heuristic optimization method is chosen to solve the OPF and the algorithm NSGA-II is used because of its good convergence properties and ease of implementation. However, the algorithm is also able to perform multi-objective optimization and this ability was used to optimize both the economic benefit and the voltage stability index of the Sink-area. It is seen that there is a trade-off between voltage stability and economic benefit and it is up to the grid operators to make choices regarding this trade-off. In the **third part** of this work a deterministic method is used to maximize the economic benefit of the Sink-area with respect to the cost of the reactive compensators. As much as possible mathematical expressions will be used. As the NTC cannot be expressed as a closed-form expression, some approximations need to be made. Two methods were proposed to approximate the NTC: approximation by piecewise linear functions and by polynomials obtained with statistical regression. This deterministic method leads to a Voltage Stability Constrained OPF (VSC OPF). It is programmed in GAMS and formulated as a Mixed-Integer Non-Linear Programming problem (MINLP).