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OPTIMAL OPERATION OF POWER DISTRIBUTION NETWORKS WITH RENEWABLE GENERATION AND STORAGE DEVICES

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Overview

The operation of electricity distribution networks is going to change as a consequence of the large penetration of distributed generation, i.e. power plants (wind, photovoltaic, micro-CHP,…) directly connected to distribution networks. Distribution networks will host both dispatchable power plants (e.g. thermal), for which the production schedule is determined one day ahead by the plant's owner on the basis of load and price forecast, and non-dispatchable power plants (wind, photovoltaic), for which in advance only production forecasts are available, on the basis of weather forecast (wind speed, solar irradiance). As power generated by non-dispatchable plants is partially unpredictable, imbalance between load and generation is very likely to occur. A new operator, the Distribution System Operator (DSO), will be in charge of operating the distribution network, in order to compensate generation-load imbalances, while guaranteeing technical feasibility, i.e. constraints on currents in lines (security) and voltages at nodes (power quality). Internal (i.e. owned by DSO) regulation resources will be electricity storage devices and on-load tap changers. DSO's external regulation resources (i.e. owned by third parties) will be exchanges of active and reactive power with the high voltage transmission network and dispatch of active and reactive power of generation plants. Costs associated to the use of internal regulation resources reflect device deterioration; costs associated to the use of external regulation resources have to be defined by the Regulator, so as to allow a technically efficient operation of the network.

Method

We develop a nonlinear programming model for operating a medium-voltage AC network with distributed generation and storage devices where initial set points are assigned in each period of a given time horizon on the basis of load, price and weather forecasts. A set point in a time period is defined by modules and phases of voltages in all nodes, active and reactive powers, on load tap changer transformation ratio and loads. When the realized values of loads, prices and renewable generation differ from forecasts, new set points are determined so as to minimize distributor's redispatching costs while satisfying security requirements and ensuring service quality (nodal balance of active and reactive power, current transits on lines and transformers for security). Storage devices are modeled by means of constraints that relate adjacent time periods. The optimal set points are computed by an *ad-hoc* algorithm that exploits the problem structure in order to minimize the computational time.

Results

A computational time compatible with the on-line operation of the network is required by the developed model to provide the optimal set points. The choice of alternative objective functions, e.g. minimization of active power losses, are also provided by the model.

Conclusions

The proposed model allows the on-line operation of medium-voltage AC network with distributed generation and storage devices. It can be used as a simulation tools by DSO for finding efficient network configuration (e.g. determine effective positions of storage units) and for analyzing the impact of alternative sets of regulation resources. It can also be used as a simulation tools by Regulators for analyzing the impact of different rules and costs associated to external regulation resources.

References

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