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Optimal Spatial Allocation of Ancillary Services for Power Systems

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1 Introduction

A stable, reliable and economically efficient electrical energy supply plays a crucial role in every modern society. During the last 20 years electrical power systems have been experiencing some major changes. They have been restructured from the vertically integrated industry[1] to the open market systems. From control point of view, the systems have shifted from centralized to decentralized operation. With the process of the deregulation of power systems and emergence of energy markets, new challenges that originate both from the physical and economical layer have been introduced. For instance, in the vertically integrated industry, ancillary services[2] (AS) were an integral part of electrical energy supply. Nowadays, AS became a separate commodity and as such are traded on AS markets. Having the sufficient amount of AS in the system and having them located at the right place is indispensable for power system's reliability and operation. Determining the spatial distribution of AS has proven to be a challenging task, see e.g. [1] or [2] and the references therein; and is not taken into account in current practices. The work presented here formalizes the problem of spatial allocation of ancillary services for power systems in terms of optimization problem. In our future work the algorithms for market-based optimal allocation of ancillary services will be devised with the aim that the solution they produce is as close as possible to the solution of the here presented mathematical problems ("golden standard").

2 Assumptions

Here, AS are treated as commodities with a spatial dimension, or more precisely, the spatial needs and distribution of AS are modeled and analyzed taking into account the limited capacity of the transmission network. To find the "golden standard", there are several assumptions made. Firstly, we are concerned with one type of AS only: AS for real power balancing (i.e. reserve procurement). Next, it is assumed that there is one unique entity which optimizes both markets, energy and AS market, simultaneously in one iteration. Also, it is assumed that market participants[3] share sensitive information (confidentiality data), i.e. that their bids are known and correspond to their (marginal) production/consumption costs.

3 Formulation of the problem

Based on the above listed assumptions, we present a mathematical formulation of the optimal market-based allocation of both energy and AS reserves while taking into account constraints on both the local (i.e. market participant) and the global (i.e. overall power system) level. The energy and AS market are strongly coupled. Firstly, the coupling exists as the participants, with their limited amount of production capacity, participates in both energy and AS market at the same time. Secondly, the activation of AS might cause the transmission system to become congested if the location of AS is not taken into account a priori, i.e. during the market clearing process. The activation of AS to counteract unforeseen imbalances results in changes of the transmission network power flows. These power flows always have to satisfy the physical constraints of the network. To account for these power flow deviations, we formulate energy and AS market goals in terms of a robust optimization problem.

Acknowledgment

References

[1] Study of the interactions and dependencies of Balancing Markets, Intraday Trade and Automatically Activated Reserves, 2009, Available online at: ec.europa.eu/energy/gas_electricity/studies/doc/electricity/2009_balancing_markets.pdf

[2] F. L. Alvarado, "Understanding Locational Reserves and Reliability Needs in Electricity Markets," Proceedings of the 39th Annual Hawaii International Conference on System Sciences (HICSS'06), IEEE, 2006.

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[1]In the vertically integrated industry one utility (the central operator) operated the system, i.e. dispatched power with nominally full knowledge of the operational costs and constraints of the system

[2]Ancillary services are a set of services (commodities) that supports the operation of power systems and are essential to maintain stability and reliability of the electrical energy supply. Some AS are frequency regulation, voltage control, reserve procurement or black start capability.

[3]A *market participant*, or *balance responsible party (BRP)*, is the only entity that is allowed and capable of trading on energy markets.