OPTIMAL DISPATCH CONTROL USING EVOLUTIONARY ALGORITHM

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Abstract

Under a deregulated environment, ancillary services (AS) are defined as the set of products separated from the energy production, which are related to security and reliability of a power system. Ancillary services require unloaded generating capacity previously scheduled to be used by the independent system operator (ISO) in real-time. Therefore, the corresponding generating capacity must not be traded in the energy market. The system operator is the entity responsible for the secure operation of the power system and in this way, the management of all the AS is considered a specific function of the system operator. Ancillary services are activated both by automatic control and human operator. The objective of ISO is to allocate reactive power generation, while satisfying numbers of constraints. Self-Organizing Migration Algorithm is applied for optimization of this non-continuous, nonlinear function which may have a large number of local minima and maxima.

1 Introduction

Modern electric power systems are large-scale systems with a complex structure comprised of interconnected networks. The Union for the Coordination of Transmission of Electricity (UCTE) coordinates the operation and development of the electricity transmission grid in 24 countries, including Czech Republic as depicted in Figure 1.

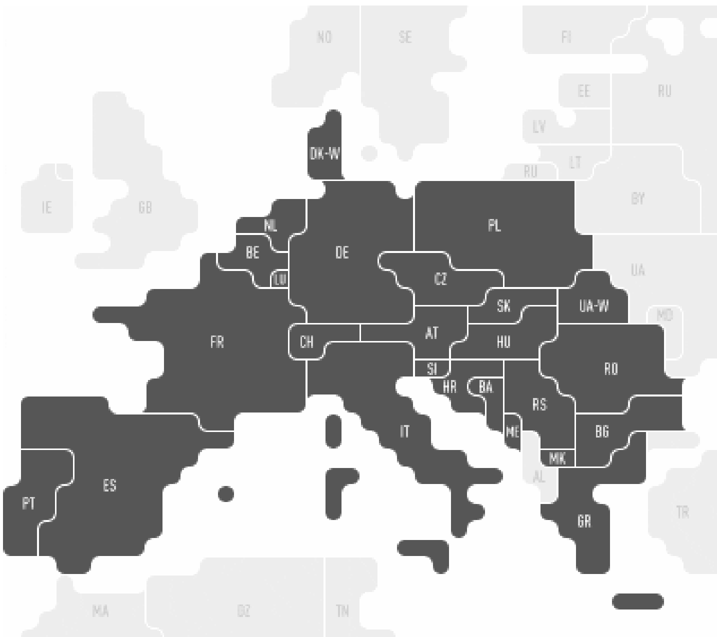

Figure 1: Synchronously linked grid of UCTE

Recently, dispatch control has received an increasing interest from electric utilities because of its significant influence on secure and economic operation of power systems. Due to the lack of reliability of transmission elements AS are needed to assure the necessary equilibrium between generation and demand. The ISO is an operating regional coordination centre, handling transmission access, security, ancillary services, emergency operation, voltage/loss optimization.

An expert system that has reliability requirement as the inputs and volume and composition of ancillary services as output has been developed in [1]. The optimization method proposed in this paper is intended to aid the TSO in calculating the necessary ancillary services for system security and reliability. An optimization problem is formulated that enables the ISO to make least-cost decisions for purchasing ancillary services.

2 Ancillary services

Power systems are subjected to sudden and unpredictable changes due to changes of generation and fluctuations of loads. Supply of electricity is one critical infrastructures influencing function of a modern society. Other infrastructures such as traffic, transportation or production strongly depend on its performance.

Therefore continuous regulation is essential in maintaining system frequency. If generation exceeds load then frequency rises. If load exceeds generation frequency falls. If generation exceeds load within one balancing area, then power will flow over the trans-mission line ties to adjacent areas. Continuous Regulation is also important in controlling inter-area power flows. If generation exceeds load within one balancing area, then power will flow over the trans-mission line ties to adjacent areas. Normal system operations are infrequently punctuated by unexpected generator outages and transmission line failures. To be able to respond to contingencies without affecting overall reliability system operators have a coordinated set of operating reserves. If there is a generator outage the frequency has to return to its preset value of 50Hz within 15 minutes. These reserves dedicated for the balance control are called ancillary services.

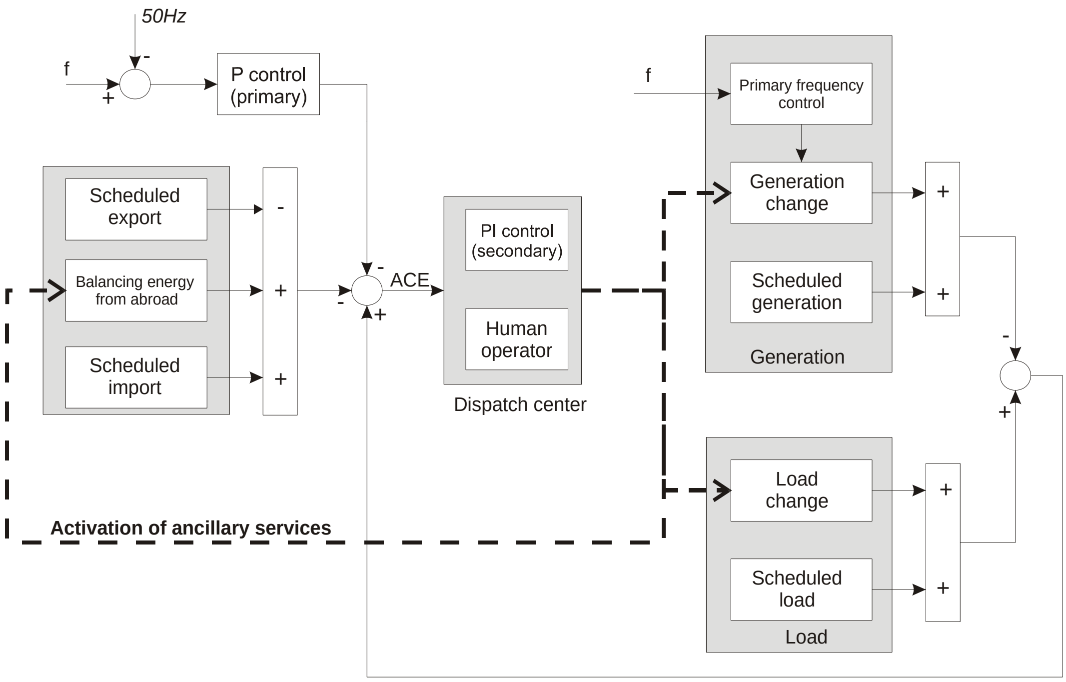

Figure 2: Power balance control

The Czech ISO operator ČEPS uses following ancillary services:

Primary Frequency Control is an automatic response to frequency changes reacting immediately at the generation units. The high-speed nature of the control allows it to be the first to react to any change in the frequency.

Secondary Frequency Control is a process a regulated unit output change as required by the secondary frequency regulator. Dispatch centre at ISO is responsible for utilization of regulation reserves RZSR. The reserve must be available within 10 minutes with minimum rate of 2MW/min.

Tertiary control consists of a change of the operating point of the generation unit's output based on re-quest sent to the power plant by the dispatch centre at ISO. The whole regulation reserve for tertiary control must be provided within 30 minutes at the minimum rate 2MW/min. The tertiary control is used to free up the exhausted secondary reserve so it can effectively balance the frequency fluctuations. The reserve denoted RZTR- is used to decrease the output and RZTR+ to increase the output.

Quick-start reserve RZQS is a reserve that contains units capable of providing the reserves within 10 minutes. The main purpose of this reserve is the correction of power imbalances occurring as a consequence of a failure at a power plant or a significant load increase.

Dispatch reserve RZDZ is provided by units that are capable of reaching nominal or agreed value within 90 minutes. These reserves are activated upon request from ISO dispatch centre. The provider must guarantee minimum 24 hours duration of provision of dispatch reserve.

Emergency assistance HV from abroad is based on mutual agreement with neighbouring ISOs.

Balancing energy EregZ can be purchased from abroad. The inquiry to the source TSO must be submitted by the provider 2 hours before the scheduled supply of EregZ. It is possible to activate or terminate the supply of EregZ on a change of business interval, currently on the hour. This energy is not guaranteed and may not be obtained when it is needed.

3 Regulation reserves

The volume of the contracted power reserves in the form of ancillary services has to be selected to ensure secure operation of the power grid. The expert system that has a reliability requirements and the composition of ancillary services as the output has been developed in [1]. This expert system helps the Czech ISO plan ancillary services purchase under the changing market condition. It uses historical records of ACE and activation of ancillary services, technical and economical characteristics of generation companies at market and returns recommended optimal set of ancillary services, expected costs and reliability indices that describes behaviour of the power grid controlled with such a set of AS.

4 Problem formulation

Dispatch is the real-time control of all generation and transmission resources that are currently online and available to meet load and to maintain reliability within the control area. The Area Control Error (ACE) is a difference between the scheduled and actual foreign power exchange corrected with the effect of the primary control, which acts independently of the central controller, to avoid counter-regulation. The ACE should be kept at the zero level. The problem for TSO is how to use all the possible resources efficiently and in a coordinated way to ensure system security.

The dispatch control has the following information:

- 6h-prediction of ACE
- capacity of reserves in the form of ancillary services
- prices of AS at different generating blocks

The sampling period is set to 5 minutes. Thus the 6h-prediction is represented as row vector with 72 columns. The task of the predictive dispatch control is to minimize ACE and minimize operating costs. The overall costs are given as sum of costs for ACE and costs for ancillary services:

$$Costs = Costs_{ACE} + Costs_{AS} \tag{1}$$

The costs of AS are given as

$$Costs_{AS} = \sum_{i=1}^{360} P_i^{TR} TR_i + \sum_{i=1}^{360} P_i^{QS} QS_i + \sum_{i=1}^{360} P_i^{DZ} DZ_i + \sum_{i=1}^{360} P_i^{HV} HV_i + \sum_{i=1}^{360} P_i^{EREG} EREG_i \tag{2}$$

where TR, QS, DZ, HV and EREG represents vectors of activated ancillary services per minute on 6h prediction horizon and $P_i^{TR}, P_i^{QS}, P_i^{DZ}, P_i^{HV}, P_i^{EREG}$ are prices of ancillary services per minute. The secondary control reserve is not included in the plan for ACE balancing and is used to balance the uncertainty of the prediction vector. The outputs of the optimization process are the time-vectors of particular ancillary services.

5 Optimization via Evolutionary algorithm

Evolutionary algorithms (EAs) are a less analytic approach to optimal solution search in discontinuous space, which have also had success in combinatorially immense problems. EAs mimic the natural mixing and occasional mutation of genes in heterozygous reproduction. Through many rounds of reproduction, in which more favourable solutions are the dominant reproducers, natural selection is mimicked, and optimal solutions are approached.

The Self-Organizing Migrating Algorithm - SOMA [2] is based on the competitive-cooperative behaviour of intelligent creatures solving a common problem. Such behaviour of intelligent creatures can be observed anywhere in the world.

6 Simulation results

To test the optimization properties of the SOMA algorithm 2 history dataset were used. The characteristics of the ancillary services as stated in Section 2 and the capacity of the AS at each generating block at each sampling interval that is available for particular AS were used as system and operating constraints for optimization. If two generating units have the same price they are replaced by a dummy source with the capacity of both sources.

The SOMA algorithm then searches for solution that minimizes the cost function (1). The following parameter values to guide its search: population size of 100 and 100 migrations. The optimization time depends not on the number of parameters but on the computation time of the validity function. Depending on the step of the SOMA algorithm 100 - 500 computations of the validity function are needed for one generation.

The first dataset is for the longer outage of a small generating unit. Figure 3 shows the results of optimization where dP_o represents the error between the production and consumption in the open loop, i.e. without any control and dP_c represents the error between the production and consumption with ancillary services being applied.

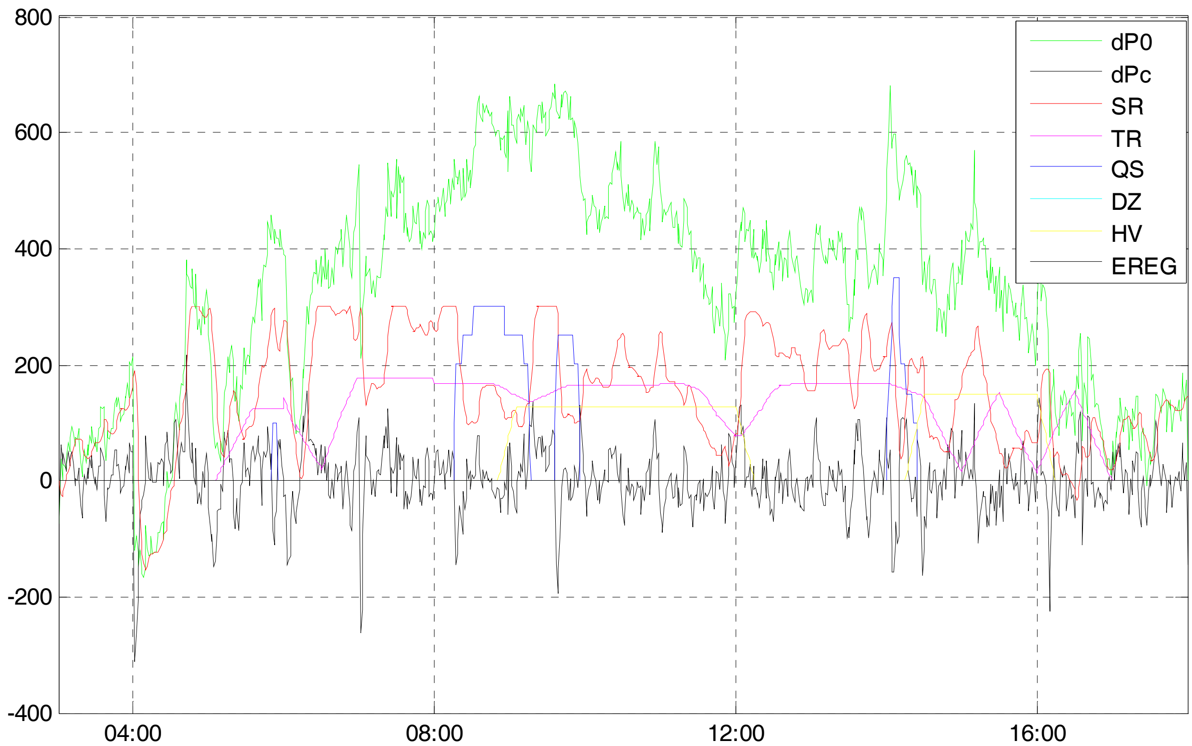

Figure 3: Optimized ancillary services for dataset 1

The second dataset is an outage of a large generating block. The optimal control sequence suggests activation of Quick-start reserve and the whole positive tertiary control reserve when generator outage is identified in the prediction dataset. The capacity of Quick-start for one day is limited and thus it is necessary to save some reserves for another generator outage. The emergency assistance from abroad HV is also used to balance the lack of power in the system. The activation of the ancillary services during the outage is depicted in Figure 4.

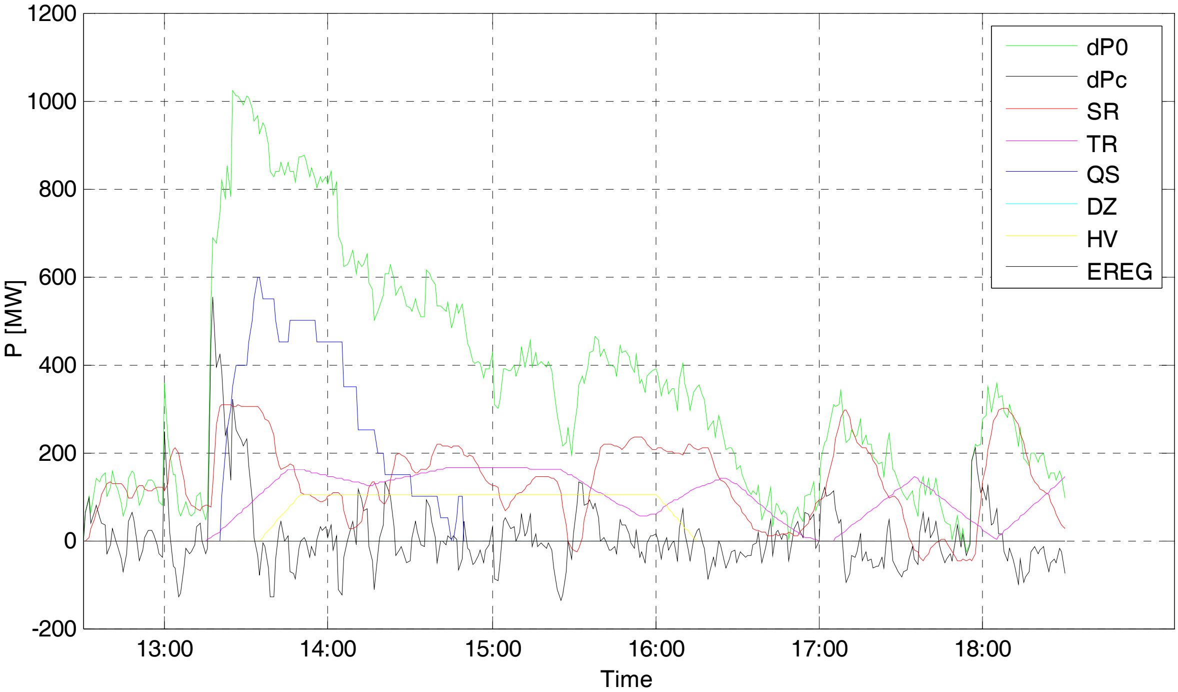

Figure 4: Optimized ancillary services for dataset 1

Conclusion

The research concerning the tool that could help the operation centre at ISO to select proper ancillary services with optimal costs is still in development. However, the optimization of ancillary services via evolutionary algorithms shows possible solution how to find the optimum of the dispatch control problem with operational and system constraints.

References

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