CONCEPT OF VIRTUAL POWER PLANT PARTICIPATION IN THE SLOVAKIAN ELECTRICITY MARKET

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POVZETEK

Članek obravnava možnost vključitve virtualne elektrarne v trg z električno energijo na Slovaškem. Na začetku dela je razložen koncept delovanja virtualne elektrarne, pri čemer so opisani tudi razlogi za njeno uporabo. Drugi del je posvečen kratkemu opisu trga z električno energijo ter opisu in principu uporabe različnih obratovalnih pogojev med obratovanjem virtualne elektrane na trgu.

ABSTRACT

The proposed paper deals with a Virtual Power Plant (VPP) concept in the Slovakian electricity environment. The first part of paper explains the concept of VPP and also the reasons why is worth dealing with this concept. The second part of the paper briefly describes the market environment in the Slovakian power system, as well as methodology within individual constraints related to the operation of individual sources are considered.

1. INTRODUCTION

Distribution grids are facing tremendous challenges due to several factors. Among them, the most important is the increasing penetration of Distributed Energy Resources (DERs), especially those based on renewable energies [1]. Following, the way in which the power system has evolved from conventional structures into structures with more dispersed energy generation, some basic problems can be pointed out. In conventional power system the energy generation takes place in central units. Energy is transported through transmission systems to distribution systems, where is distributed to consumers, additionally. The energy flow is one-directional and the system structure corresponds to a “top-down” structure. Disadvantages of this structure are that the produced energy needs to be transported through long distances from generation to consumption points, which is connected with high costs and energy losses. Dispersed generation, based on renewable energy resources (RES), was introduced as a solution to reduce the impact of that problem [2].

The Regulatory office for network industries in Slovakia had established the law (no. 309 Z.z) [3] in which was stated that Distribution System operator (DSO) must buy electricity coming from RES for a very lucrative price comparing to other conventional sources. These RES which had an installed output power up to 4 MW did not have to take a responsibility for causing power imbalance in the power system. This fact led to speculative behaviour of potential power plant owners, especially the photovoltaic (PV) power plant ones. They started to build PV power plants up to the 4 MW (3,999 MW or so) and penetration of non-controllable sources to the power system had been rapidly increasing. The law (no. 309 Z.z), after this “photovoltaic boom”, changed the situation and the value of maximal installed power was sharply decreased to 1MW and later even to 100kW. But by that time (July, 2011) the installed power in PV power plants connected to distribution networks had increased to approximately 480 MW. The Slovak Transmission operator (SEPS) established the installed capacity for photovoltaic power plants to 120MW. This is four times smaller capacity than the real power installed!

Aforementioned rapid penetration brought along several problems to be solved. Due to the stochastic character of RES and a high number of installed DERs new problems are arising, like change of power flow direction, overloading of lines and other system elements, or overvoltages, balancing of power system and frequency control. In order to balance the generation and consumption of energy new solutions were introduced, like network security management systems (NSM), energy storage systems (ESS) or virtual power plants (VPP). In this paper the concept of VPP is briefly proposed as well as the methodology of participation of such a VPP in a different electricity markets.

2. VPP CONCEPT

A virtual power plant, sometimes referred to as virtual utility [4], contains a mixture of different generators. VPP combines different types of renewable generators and storage devices to be able to pose on electricity market as a single power plant with defined hourly output [5]. A well-chosen mix of all these types can offset the inherent unreliability of different generators to provide a virtual plant which can be treated as a conventional one. From the point of view of any other market agent the VPP is a unique entity, although in reality it represents multiple DERs and conventional power plants on the energy market [6]. The internal VPP dispatch is strictly the problem of the owner(s) of the VPP. The VPP is operated with connection to the grid. The primary objective of optimal dispatch can vary. For example, an economic optimization can either aim to minimization the cost of producing energy or maximizing the profit of the VPP. In this paper the second alternative is considered. In our case, optimal dispatch problem within VPP is to find the optimal combination of power generation units that maximize the total profit of VPP, while satisfying all operational constrains.

In our case the VPP consists of four types of power plants such as a non-controllable RES, a run-of-river power plant, a biomass power plant and a pumped hydro power plant as well. That mixture of sources was chosen to have the ability for modeling not only the generation but also consumption. Participation of the VPP in spot market, secondary and tertiary ancillary service market is considered. All of the sources are described by their costs functions. Generally the cost function has following form (1)

$$Costs = a_i \cdot P^2 + b_i \cdot P + c_i + SU_i^t\left(u_i^t\right) + SD_i \tag{1}$$

In (1) a (€/MW^2), b (€/MW), c (€) are coefficients known from dispatch of thermal power plants, SU^t (€) are start-up costs (dependent from unit status u_i), SD (€) are shut-down costs. It is not necessary that every source have all coefficients non-zero, for example *SD* costs of run-of-river power plant are zero. Index i marks i-th unit, index t marks t-th time window.

3. THE MARKET ENVIRONMENT IN SLOVAKIA

Market structures differ according to their participants, the amount of information that participants share with the independent system operator (ISO), and the role of ISO in facilitating or controlling the individual markets [7]. Slovakian electricity markets are deregulated with competitive bidding in auction markets for energy and reserves and some degree of non-discriminatory pricing and access to transmission. In particular, paper briefly describes following markets implemented in Slovakia: spot market (day-ahead), ancillary service market (primary, secondary and tertiary) and intraday market.

Spot market

The Spot market is the basic market and it trades with physical delivery of electricity. In this type of trade an auction mechanism is employed which works on hourly basis. Traders send their orders of demands and supplies for each hour to the Market Organizer (MO) exchange system, while it is open. The market closure for day D is at 10:00 a.m. in day D-1. After this market closure (market clearing) the matching algorithm matches these demands and supplies and for each hour a market clearing price is calculated.

Ancillary service markets

Ancillary services are necessary for ensuring the certain quality of electricity and for ensuring the reliability of the power system. Fig. 1 shows the types of ancillary services existing in the Slovakian market environment. The daily market with ancillary services for day D is closed at 1:00 p.m in day D-1.

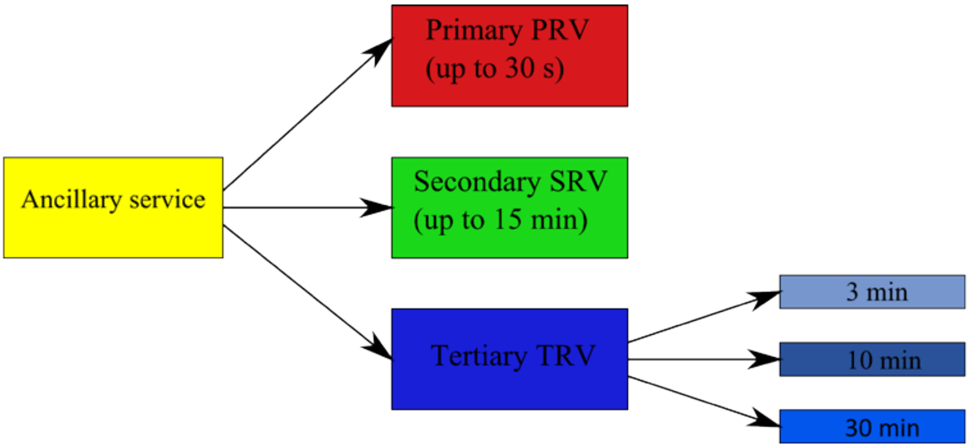

Fig. 1: Ancillary services provided in Slovakia

Intraday market

An intraday market allows to employ flexible changes in daily diagrams offered in the spot market for traders. Each change in the daily diagram must help in decreasing of overall power imbalance in the power system and thus decrease the needed costs. The Slovakian intraday market has been implemented since 2009 and it consits of six time windows, which each lasts for four hours. The receiving of daily diagrams starts a six hours before and ends an one hour before the realization of each time window. The daily diagrams are not accepted when they are delivered after the window closure or the volume of power traded exceeds the 20 % of power agreed in the primary daily diagram offered in the spot market.

4. PROBLEM FORMULATION AND CONSTRAINTS

The whole algorithm would consist of two stages. As we can forecast the output power of non-controllable renewable sources with certain accuracy, therefore the first stage of algorithm will be the simulation of the forecast for output power of non-controllable sources and also an estimation of the error in forecasting. After that is possible to calculate a real expected output power and therefore a reserve of adequate accumulation capacity of controllable sources to accommodate these fluctuations. The self-scheduling of controllable renewable sources (biomass, run-of -river and pumping hydro storage power plant) is based on aforementioned forecast, prices on different markets (power energy market, secondary ancillary service market and tertiary ancillary service market) at each hour, and operational constraints (logical constraints, ramp-rate limits, minimum up-down time, energy constraints...). This will be the second stage of the algorithm, which is supposed to create a daily schedule of the VPP participation in mentioned markets during each hour throughout the whole day, while all constraints are fullfiled. In other words, described problem needs to be optimized. Therefore is necessary to create an objective function, which would take into account all of the aspects mentioned above and also constraints. The related problem how to bid to achieve participation in all markets is beyond the scope of this paper.

4.1 Objective function

Objective function of VPP concept could be constructed as (2) shows,

$$\max OP = TR - TC \tag{2}$$

where *OP* is an overall profit, *TR* are total revenues from sold energy and *TC* are total costs of produced energy. The *OP* includes profits from participating in all markets as mentioned above.

A VPP owner receives the reserve price per unit for reserved power even for the time period when the reserve is allocated and not used. If the reserve is used, the VPP owner can receive the energy price for that reserve. Fig. 2 shows the probabilities of using each type of ancillary services during the year 2011 [8], which could be used to weight the opportunities of participating in different markets.

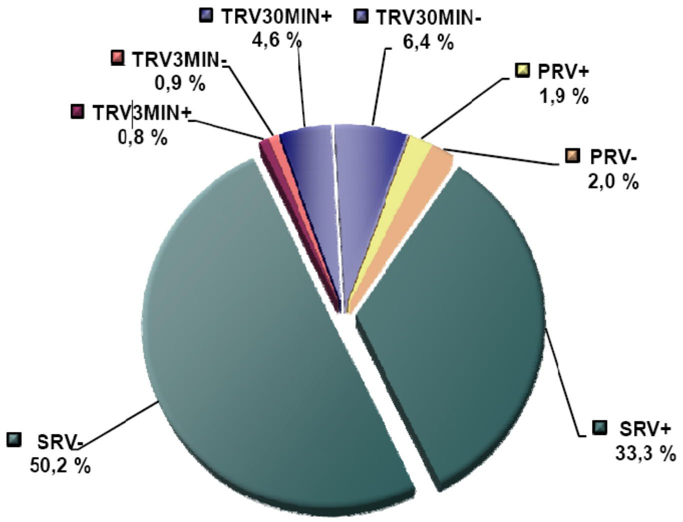

Fig. 2: Probabilities of calling up an each ancillary service

4.2 Constraints

The amount of hourly expected power which must be generated by each power plant in each hour to response in the energy and the secondary and the tertiary reserve markets and also to cover the deviation caused by stochastic behaviour of non-controllable sources is dealt as a constrains, firstly. After that the next set of constraints is related to energy balance when producing electricity, as well as the available hourly amount of energy and the limits of imported energy (volume) to the power plant. Market constraints reflect the conditions for joint participation of the VPP in these markets. Sources with accumulation ability must be able to response to the worst condition from their point of view. This means to provide electrical energy for the day-ahead market and for ancillary service markets simultaneously, as well as for covering deviation caused by non-controllable sources. These conditions are included in an accumulation ability constraint.

5. CONCLUSION

The paper deals with the VPP participation in the market environment in Slovakia. An appropriate methodology dealing with the operational properties of each power plant is described briefly. Also the conditions of the Slovakian market are considered in form of the corresponding constraints. The proposed problem is complex and nonlinear - therefore it needs to be optimized by a powerful algorithm. So, the following task will be the implementation of described methodology and testing it using different operational conditions.

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