PERFORMANCE INDICATORS FOR ANALYSIS OF THE ACTIVITY ON THE WHOLESALE ELECTRICITY MARKET

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Abstract. *The Romanian wholesale electricity market is a complex system which involves many participants, many types of transactions and many constraints. An electricity market simulator that embeds specific business rules was developed in order to help market participants to find the best mix of transactions from the financial point of view. This paper proposes several performance indicators for analyzing the activity on this electricity market simulator. The analysis can be focused on an individual point of view, providing each participant a feedback that can be used for further improvements and adjustments of individual behavior on market. It can also take into consideration the overall activity of the electricity market simulator, providing a feedback that can be used for checking the validity of the emulated market mechanisms and for improving the simulation parameters.*

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1. Introduction

The structure of electricity markets, built around the time parameter, is based on the need to almost perfectly balance the consumption with the generation, for each moment of the electricity system functioning. A brief description of how markets function for different time periods is presented in the following for: long term contracts- Bilateral Wholesale Markets (BWM), mid-term contracts – Day Ahead Market (DAM), Intra-Day Market (IDM), and short-term transactions– Balancing Market (BM). BWM has as defining characteristics [1]: low prices, the hourly values being fixed all day; there are several types of quantitative profiles, called "products"; the quantities contracted on this market provide the basis of the load curve; the contracts are made for medium to long term, from a few months to a few years. DAM is described by these characteristics [2]: the price is higher than on BWM, following the principle of marginal price; hourly prices are different per day, hour and season; Firm energy transactions take place daily for the next delivery day. BM includes the component of ancillary services, as well as the component that deals with imbalances. On the ancillary services market (ASM), electricity producers make offers for secondary, as well as for fast and slow tertiary frequency adjustment [3]. The producer will be paid for the reserved available power and, in case of activation, will receive additional payment for the period during which it was activated. The imbalances component ensures the last-minute adjustment of system imbalances, having as

characteristics [4]: the price is very high; for each participant on BM, it is mandatory to offer all available, remaining quantities of the dispatchable units (after trading on the other markets); preparatory activities may start a few days before the delivery day, but bids may be placed up to one hour before the delivery time. Thus, electricity markets do not exclude, but complement each other, the common purpose being to achieve an optimal balance at system level.

In this article we present aspects regarding the development of a software tool designed for simulating the participation of a various involved parties on the wholesale electricity market. Producers, suppliers, traders or consumer of electricity may participate in different types of markets and the proposed simulator aims to identify how decisions regarding the price or quantities offered can influence profit optimization. Simulator's functions can be used through its various components. First of all, there is a general settings module where the user has to make some basic configurations, such as: select the type of business that is simulated; indicate the total available power, this being the installed power for a producer or the power required for trading or buying for a supplier or trader; state a technological minimum below which the production cannot be lowered; specify the simulation period. Following, depending on the type of user, various transactions can be simulated on BWM, DAM and BM through dedicated interfaces. In the end, some analytical support is provided by the means of an estimated monthly cash flow report and a set of simulation efficiency indicators, the latter being the main subject of this article.

2. Literature review

One of the most important characteristics of the electricity market is its complexity, mainly due to the large number of participants. Therefore, simulation tools can be very valuable for electricity markets in order to model, predict and analyze participants' behavior.

An agent-based approach for electricity market simulation was proposed in [5]. This study aimed to examine the influence of a transmission line limit on the dynamics of a wholesale electricity market, applied on DAM and IDM. Another agent-based simulation model is proposed by [6]. The paper stresses that agent-based simulation is particularly suitable for modelling wholesale electricity markets with market participants making individual decisions on interrelated markets. The proposed model can simulate wholesale electricity markets with regard to time and point of delivery of electrical energy.

Also, work in [7], presents a simulator for electricity market together with a methodological approach that combines different strategies to build actions proposals. This solution uses learning algorithms and is intended for managing the efficiency/effectiveness balance of the system and for competitor players' profiles definition.

Studies presented in [8] are centered on analyzing the Greek electricity market, trying to determine the impact of integrating renewable energy sources on the electricity market operation. A software tool is applied in order to simulate current and future day-ahead market clearing algorithm of the Greek wholesale electricity market.

Aspect regarding decision making in the context of electricity market were presented by [9]. In this case, the approach is based on artificial intelligence and data mining algorithms and provides a simulation tool that processes data from real electricity markets. The main goal was to create realistic scenarios that consider the modelling of electricity market players' behavior and characteristics, but also to gain insight of the interactions between involved parties.

3. Simulation efficiency indicators

The main objective of the simulator is to allow the user (regardless of its type: consumer, generator, prosumer, storage unit, etc.) to optimize their participation in the different markets of electricity and ancillary services, which are in operation at present. Efficiency analyzes can

be performed *individually*, for any of the participants who make simulations or *globally*, for all the simulations performed in order to optimize the package of offers for participating in the different markets.

3.1. Global indicators for electricity market simulator

The structure of electricity markets (including the system services market) is a complex one and consequently determining the optimal solution is a difficult problem.

From a mathematical point of view, the solution of the problem consists in determining the maximum point of the function presented in (1).

$$V_{total}(E) = I_{BWM}(E_{BWM}) + I_{DAM}(E_{DAM}) + I_{IDM}(E_{IDM}) + I_{ASM}(E_{ASM}); \quad (1)$$

With the following constraints:

$$E = E_{BWM} + E_{DAM} + E_{IDM} + E_{ASM}; \quad (2)$$

$$E \leq E_{max}, \text{ calculated for the analyzed period}; \quad (3)$$

$$P_{max} \geq P_{BWM} + P_{DAM} + P_{IDM} + P_{ASM}, \text{ for each time interval}; \quad (4)$$

Where:

E – the electricity available for trading for the analyzed period,

$E_{BWM}, E_{DAM}, E_{IDM}, E_{ASM}$ – the electricity traded on BWM, DAM, IDM and ASM,

$I_{total}(E)$ – total income obtained by trading the entire amount of electricity, during the analyzed period,

$I_{BWM}, I_{DAM}, I_{IDM}, I_{ASM}(E...)$ – income obtained by trading the volume of electricity on the respective market,

P_{max} – maximum power available for trading for each time interval,

$P_{BWM}, P_{DAM}, P_{IDM}, P_{ASM}$ – hourly power traded on each electricity market and system services.

As can be seen, the problem caused by relations (1) ÷ (4) is not a problem with a unique solution, and consequently it may be necessary to use iterative calculation methods to solve it. An iterative calculation method is a method that starts from a randomly determined operating point and then, through repeated iterations, approaches one of the optimal operating points step by step. The use of such a method requires the definition of criteria that verify, at the end of each iteration, the approximation or distance of the optimal points.

In the case of the simulator, the criterion of approaching the maximum point is the increase of the total income value (I_{total}), under the conditions of compliance with the constraints (2), (3) and (4). Another useful indicator for the user can be the report: I_{total} / E , which provides information on the financial efficiency of the simulated transactions.

In the case of electric generators that do not use renewable energy sources, a useful indicator may be the ratio between the income obtained from transactions and the amount needed to purchase fuel (gas, coal, nuclear fuel): $I_{total} / \text{Fuel cost}$.

As mentioned above, the function described by relation (1) does not have a single optimal point. Under these conditions, two or more optimal operating points can be identified by the iterative calculation (the value of the total income is equal or very close). In order to provide the user with an objective way of making the decision, the simulator calculates, for each value of the income, an associated **level of risk**. Knowing this indicator, for each value of the total estimated income, the user can opt for the operating point to which a lower level of risk is associated (the total income resulting from the simulation is practically equal).

The risk level can also be used as an independent indicator. For example: the user may decide that he does not want an operating point that is associated with a level of risk above a certain value, regardless of the value of the total revenue resulting from simulation for that operating point.

3.2. Individual indicators for electricity market simulator

For the analysis of simulations at individual level for a certain period, the following indicators can be analyzed for each of the markets for which transactions can be simulated:

a. The volume of electricity traded during the selected period p on m market, $m \in \{BWM, DAM, BM, ASM\}$ for participant k :

$$E_m^k = \sum_p E_m^{kp}$$

b. The average risk associated with trading during the selected period p on m market during the selected period p : $risk_m^k$

c. The income realized by trading on the m during the selected period p :

$$I_m^k = \sum_p I_m^{kp}$$

d. The share of the volume of energy traded on m in the total volume traded on all markets during the selected period, p :

$$\frac{E_m^k}{E_{BWM}^k + E_{DAM}^k + E_{BM}^k + E_{ASM}^k} \times 100\%$$

e. The weight of the income obtained on m in the total income from the trading on all markets during the given period p :

$$\frac{I_m^k}{I_{BWM}^k + I_{DAM}^k + I_{BM}^k + I_{ASM}^k} \times 100\%$$

b. The average risk associated with trading during the selected period p on DAM during the selected period p : $risk_{DAM}^k$

c. The income realized by trading on the DAM during the selected period p :

$$V_{DAM}^k = \sum_p V_{DAM}^{kp}$$

d. The share of the volume of energy traded on DAM in the total volume traded on all markets during the selected period, p :

$$\frac{E_{DAM}^k}{E_{BWM}^k + E_{DAM}^k + E_{BM}^k + E_{ASM}^k} \times 100\%$$

e. The weight of the income obtained on DAM in the total income from the trading on all markets during the given period p :

$$\frac{I_{DAM}^k}{I_{BWM}^k + I_{DAM}^k + I_{BM}^k + I_{ASM}^k} \times 100\%$$

At the level of the participant, to simulate the participation transactions in all markets:

a. The total volume of electricity traded in the selected period p for participant k

$$E_{total}^k = E_{BWM}^k + E_{DAM}^k + E_{BM}^k + E_{AMS}^k$$

b. Total average risk for the selected period p for participant k

$$risk_{total}^k = \frac{I_{BWM}^k \times \frac{risk_{BWM}}{2} + I_{DAM}^k \times risk_{DAM} + I_{BM}^k \times 70\% \times risk_{BM} + I_{ASM}^k + I_{ACT}^k \times risk_{ACT}}{I_{total}^k}$$

Where:

$risk_{BWM}$ – represents the financial risk associated with trading on the BWM market due to imbalances (default is 10%),

$risk_{DAM}$ – represents the risk associated with trading on the DAM market (default is 25%),

$risc_{BM}$ – represents the risk associated with trading on the BM market (default is 30%),

I_{ACT} – represents the revenues obtained from activation on ASM,

$risk_{ACT}$ - represents the risk associated with the activation on ASM (default is 60%).

c. Total income from trading for the selected period p for participant k

$$I_{total}^k = I_{BWM}^k + I_{DAM}^k + I_{BM}^k + I_{ASM}^k$$

d. Weights of the volume of energy traded on the different markets in the total traded on the markets during the selected period p

$$\frac{E_m^k}{E_{total}^k}, \text{ where } m \in \{PCCB, PZU, PSS\}$$

e. Weights of the income obtained from the different markets in the total obtained from the trading during the given period

$$\frac{V_m^k}{V_{total}^k}, \text{ where } m \in \{PCCB, PZU, PSS\}$$

4. Power BI dashboards

Microsoft Power BI was used to perform advanced analyzes of the data resulting from the simulation of participation in transactions on the electricity market. Power BI, a market leader according to Gartner [10], is a modern dashboard tool that offers a multitude of graphical objects for making suggestive and interactive reports for decision making.

Power BI offers the possibility of easy development of suggestive visualizations, filtering at the visualization level, at the page level and at the report level. New columns or measures can be added when needed and navigation hierarchies can be used to view reports at different aggregation levels. Figure 1 shows an example of report for analyzing the energy quantity traded by the selected participant according to the type of transaction, for the selected month, in parallel with the evolution of minimum and maximum prices by trading interval.

Figure 1. Analysis of the energy quantity traded by the selected participant according to the type of transaction

The reports can be published in the Power BI Workspace in Cloud, and can be viewed online.

5. Conclusions

The utility of a simulator for transactions in the electricity market cannot be called into question. The participant is faced with complex decisions, with medium-term implications that he cannot anticipate, both due to the complex business rules, as well as due to the large number of participants and transactions. The simulator briefly presented in this paper aims to support the users, by offering the possibility to anticipate the financial results that they could obtain and the possibility to adjust their behavior to improve these results. The use of suggestive dashboards facilitates easy understanding of market trends and parameters.

On the other hand, the analysis of indicators at the level of all market participants can provide important feedback on the quality of the models used. If the analysis results indicate a high level of maturity of the simulator, in a future scenario, the simulated transactions could be automatically transformed into real market offers.

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