# Electricity Balancing: Challenges and Perspectives

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***Abstract* — The European electricity system undergoes significant changes driven by the EU common rules for the internal market for electricity, as well as by the climate action agenda. In addition to the balancing pan-European platforms that are under development, the European Commission supports different innovation initiatives for Smart Grids. In this paper some initial results from the PLATOON (Digital** PLA**tform and analytical** TOO**ls for** e**N**ergy) **projects are presents based on the specific objectives for supporting the modernization of electricity balancing services in Serbia. Main contribution of the study is the design of analytical services for more accurate load forecasting (as a central and integral process for planning), renewable energy sources production forecasting and calculation of effects of renewable energy sources integration.**

***Keywords* — challenges, electricity balancing, interoperability, perspectives, scenarios.**

## I. Introduction

The EU energy market legislation (see the EU's Third Package for the Internal energy market [1]) and the Commission Regulation (EU) 2017/2195 of 23 November 2017 establishing a guideline on electricity balancing (EB GL) lay down detailed rules for the integration of balancing energy markets in Europe. The EB GL requires the harmonisation of certain balancing market processes and rules, including the establishment of common principles for the activation and exchange of balancing energy. Therefore, several balancing pan-European platforms are under development including Platform for the International Coordination of Automated Frequency Restoration and Stable System Operation (PICASSO), Manually Activated Reserves Initiative (MARI), Trans European Replacement Reserves Exchange (TERRE), TRINITY (TRansmission system enhancement of regioNal borders by means of IntelligenT market technology) for cooperation and coordination among the transmission system operators of the South East European region.

The European electricity system undergoes significant changes driven also by the climate action agenda [2]. The penetration of variable renewable energy sources (RES) in the electricity sector is expected to increase significantly over the next two decades. The volatile production of renewable energy sources creates particular challenges for the daily balancing process, i.e. for balancing any deviations between the planned or forecast production and demand, on the one side, and the actual outturn in real time, on the other side. Hence, cooperation of national balancing markets, for instance in the West Balkan Region, according to the ongoing developments in the region and the propositions by the EB GL, can provide significant improvements in technical performance, competition and costs savings [3].

This paper is based on a case study from Serbia. The authors are currently involved in the H2020 project PLATOON (Digital **PLA**tform and analytical **TOO**ls for e**N**ergy) that will deliver different services that can be integrated with the Institute Mihajlo Pupin (PUPIN) proprietary VIEW4 Supervisory control and data acquisition (system). The VIEW4 SCADA is deployed at many parts in the energy value chain in Serbia, starting from control on production side (in the large hydro and thermal power systems), via transmission management to distribution and electricity dispatching. Taking into consideration the PLATOON vision of the future energy services and the emerging Big Data technologies, the goal of this paper is to introduce and analyse electricity balancing scenarios and discuss challenges and potential approaches for enhancing the existing PUPIN proprietary energy management tools.

The paper is organized as follows. Section 2 explains the existence of different types of balancing markets and the demand for balancing because of integration of independent producers (IPP) and producers from distributed and renewable sources (DER) as actors in the balance reserve market in near future. Section 3 discusses concrete scenarios for the SMM (Serbia – Macedonia – Montenegro) Control Block and points to PUPIN tools used in balancing services and potentials for innovation. Finally, Section 4 reports some preliminary results on design of PLATOON services and benefits from emerging PLATOON services for clients in Serbia.

## II. Electricity Balancing Defined

Electricity balancing is a set of actions and processes performed by a TSO in order to ensure that total electricity withdrawals (including losses) equal total injections in a

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control area at any given moment [4]. If the system runs out of balance, power stability and quality will deteriorate, which may trigger the disconnection of system components, and ultimately, power blackouts. Therefore, there is a need of operating reserves i.e. any type of capacity being used to support active power balance on country / regional level. Deviations from scheduled interchanges have significant financial consequences for responsible party (control area). Table 1 point to different exchange models (market types).

TABLE 1: TYPES OF BALANCING MARKETS.

| **Market Type** | **Time scale** |
|---|---|
| Day-ahead market | 24-hours forecasts |
| Intra-day market | Day-ahead profiles corrected by hour-ahead forecast |
| Balancing market of active power reserves | Real-time |
| • primary –FCR | within second |
| • secondary –aFRR | within minute |
| • fast tertiary –mFRR and slow tertiary –RR | from 5 minutes to 1 hour |

A balancing market consists of three main phases (balance planning, balancing service provision, and balance settlement) and concerns three main actors: the System Operator (TSO), Balancing Service Providers (BSPs), and Balance Responsible Parties (BRPs). There are two types of balancing services:

- balancing energy (the real-time adjustment of balancing resources to maintain the system balance) and
- balancing capacity (the contracted option to dispatch balancing energy during the contract period).

There are three types of balancing reserves: primary, secondary and tertiary reserves. The exchange of primary reserve between two (Serbian and other) TSOs is most developed one, while the process of activating secondary and tertiary reserves in order to maintain the sum of power exchange with the neighboring power systems and frequency at the planned value is part of the balancing (of power system) activities. The primary reserve is mandatory for all controllable generation units; Secondary (aFRR) is activated when the system is affected for longer than 30 seconds or it is assumed that the system will be affected for a period longer than 30 seconds. The activation of tertiary reserve is executed per minute, but the timeframe for imbalance settlement is 1 hour. Tertiary reserve consists of all plants that are not in operation, and are reported as available, and plants that are in operation but do not operate at maximum capacity.

## III. BALANCING IN SMM (SERBIA – MACEDONIA – MONTENEGRO) CONTROL BLOCK

*Current state:* The Serbian transmission system operator (TSO) (PE EMS - Joint Stock Company "Elektromreža" Srbije) [5] acts as single buyer for balancing energy and activates balancing energy based on market bids given by Balancing Service Provider(s) on hourly level [6]. EMS activates balancing energy from Electric Power Industry of Serbia (EPS Generation) and procures balancing capacity on regulated prices determined by Serbian National Regulatory Authority (NRA). PE EMS coordinates the balancing integration plans related to Serbia and the neighbouring countries Montenegro and Macedonia (SMM Serbia – Macedonia - Montenegro). Currently the most developed market in Serbia is the bilateral market.

*Near future:* Electricity production from solar and wind plants is subject to considerable forecast errors that drive demand for balancing i.e. for operational reserves. In order to enable a regional exchange of operational reserves, it would be necessary to ensure that the corresponding volumes could actually be made physically available when required. The short-term electricity markets (see Table 1), i.e. day-ahead, intra-day and balancing markets, shall provide non-discriminatory access to all technically capable technologies [7], should allow for cross-border trading as close as possible to real time. Thus, unplanned (intended and unintended) deviations from day-ahead schedules are required to be balanced in intra-day and balancing markets.

Fig. 1 gives a simplified UML (Unified Modelling Language) presentation of the balancing services at TSO side. In this study, we investigate the possibilities for integration of innovative services (see right side) with the existing Grid operator services (see left side).

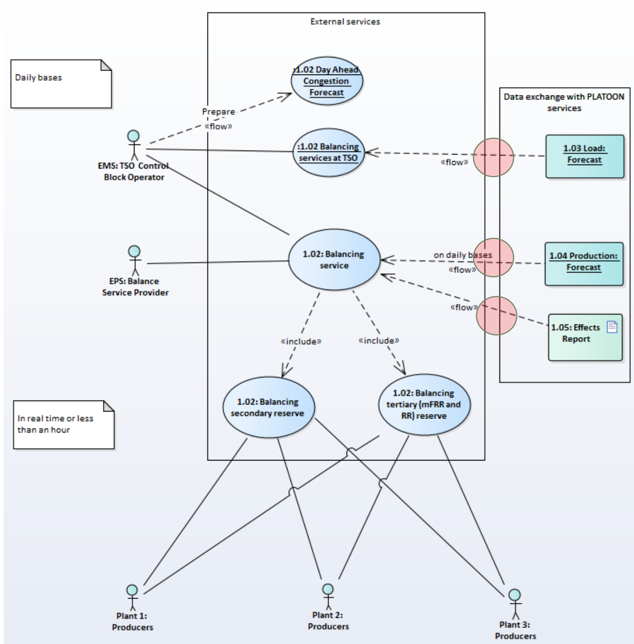


Fig. 2. Simplified presentation of balancing services.

*Scenario 1 - Load Demand Forecast:* Load forecasting is a central and integral process for planning periodical operations and facility expansion in the electricity sector. The aim is to predict the load pattern and involves accurate prediction of both magnitudes and geographical locations of electric load over the different periods of the planning horizon. Load forecasting can be divided into three categories: short-term forecasting, medium-term forecasting and long-term forecasting. The deep understanding of load characteristics is a prerequisite to creating an accurate load prediction model e.g. for day-ahead and intraday market. Thus, different factors can be taken into consideration for load forecasting, such as time factor, economic factor, weather condition and customer factor [8].

*Potential improvements:* Electricity load contains both linear and nonlinear components, hence recently hybrid models [9] are used that combined with linear and nonlinear models can better capture the characteristics of electricity load. Electricity load forecasting is mainly affected by historical influence factors and future weather conditions. While conventional short-term load forecasting methods are based on smoothing techniques and regression models (the relationship between load consumption and other factors) [10], the new STLF algorithm use artificial intelligence methods (AI) [11] that have shown the capability to perform better when dealing with non-linearities and other difficulties in modeling of the time series. New methods leverage neural networks (e.g. multilayer perceptron, radial basis function network, Kohonen network, recurrent networks) [12], fuzzy and neuro-fuzzy systems. Load forecasters are used to prepare the daily coordination plans. For more information about the methods used for forecasting, please see Table 2.

*Scenario 2- Balancing in real time:* The Automatic Generation Control (AGC) component of the TSO SCADA/EMS system [13], especially its load frequency control (LFC) part, plays very important role in continuous and secure operation of interconnected power system (SMM block). AGC (specifically it's LFC component) is the oldest balancing and control mechanism in large interconnected power systems in use, with gradual technological and algorithmic improvements, in various forms since 1920's. The main role of AGC is to maintain balance between generation and consumption and to, consequently, keep system frequency and interchanges as close to scheduled values as possible.

*Potential improvements on transmission level:* One of the challenges related to AGC is the introduction of "Imbalance Netting Process" [14]. Imbalance netting is process of automatic secondary (FRR – Frequency Regulation Reserve) reserve activation optimization in which two or more TSO's participate. It serves the cross-border electricity balancing, where the main idea is to avoid activation of secondary balancing reserves in opposite directions in participating TSO's. Imbalance netting platform typically includes two main functions: • Optimization module (Imbalance Netting optimization algorithm) which executes in real time. • Settlement module which executes in each "settlement cycle" (typically each 15 minutes or each hour).

*Potential improvements on generation and supply level:*

As presented in Fig. 1, the Serbian TSO (PE EMS) performs all balancing services (activates tertiary reserve using a merit order list, performs electricity trading for the purpose of balancing and optimization of single energy portfolio of BRPs). In the case of the generated energy from renewable energy sources, it is needed to improve the accuracy of prediction. PE EPS, as an aggregator, needs advanced analytical capabilities to support the balancing services. At present, EPS delivers balancing reserve, black start and voltage regulation services to EMS.

## IV. PLATOON Balancing Services – Design Issues

With the increasing number of distributed generation and consumption devices, energy power systems face big challenges to cope with grid integration demands. Having in mind the ENTSO-E Vision on Market Design and System Operation towards 2030, PLATOON develops specific and generic energy services that match the need of openness, interoperability, distributed flexibilities, and optimised operational processes through shared rules and platforms. In the project framework, distributed/edge processing and data analytics technologies for optimized real-time energy system management will be deployed that will simplify the work of energy operators and domain expert.


Fig. 2. Simplified presentation of PLATOON architecture for Smart Grid.

The PLATOON architecture (simplified illustration given at Fig. 2) has been defined on three pillars (1) semantic interoperability between services and actor organizations; (2) data governance among the different stakeholders for multi-party data exchange, coordination and cooperation in the energy value chain guaranteed through Industrial Data Space (IDS) connectors; and (3) analytical services.

The Industrial Data Space Association has defined a reference architecture [15] as a virtual data space that leverage existing standards and technologies, as well as accepted governance models for the data economy, to facilitate the secure and standardized exchange and easy linkage of data in a trusted business ecosystem. Based on IDS and the semantic layer, PLATOON will develop different new smart grids services that will reinforce the European efforts for modernisation of the European electricity grid.

### A. Interoperability and PLATOON Semantic Layer

The most common vocabularies and ontologies have been selected for the semantic metadata layer including the IDS Information Model, **CIM** - Common Information Model, SEAS - Smart Energy Aware Systems, and DABGEO - Domain Analysis-Based Global Energy Ontology [16].

### B. Analytical services

The PLATOON Data analytics toolbox is foreseen as a catalogue of Data Analytics tools that cover the needs of all stakeholders from the energy value chain, for instance the tools for Smart grid management focuses on managing a nation-wide smart electricity grid. The initial analysis of the methods (modelling approaches), relevant for the Serbian pilot (Electricity Balance and Predictive Maintenance), are given in Table 2. Developed forecasting models (for instance, source code written in Python) will be wrapped up in a form of a Docker container in order to be easily shipped and deployed into different environments (even if these are different from that used during development). Security, privacy and sovereignty will be ensured on Docker repository level, while Application Programming Interfaces (API) and semantic models will be used to facilitate the integration and deployment. Due to the high volume or complexity, and the need to manage scalable analytical pipelines, container orchestrators will be used. For scenarios, e.g. *Scenario 3 - Effects of Renewable Energy Sources (RES) on the Power distribution system*, there is a need to distribute the intelligence between the edge and cloud computing resources. Renewable energy resources such as photovoltaic and wind power plant have a significant impact on the stability and power quality of electricity transmission. Hence, in this scenario, the real-time power flows are analyzed by phasor measurement unit and effect of RES is calculated on the edge.

TABLE 2: FORECASTING METHODS.

| ***Service*** | ***Methods*** |
|---|---|
| Scenario 1: Load Forecast | Mathematical / statistical models (•Multiple regression •Exponential smoothing •Iterative reweighted least-squares •Adaptive load forecasting •Stochastic time series), artificial intelligence methods and neural networks, hybrid models |
| Scenario 2: Production Forecast | Mathematical / statistical models |
| Scenario 3: Effects Calculation | Mathematical / statistical models for signal processing and pattern recognition of power quality events |

## V. CONCLUDING REMARKS

This paper introduces three scenarios relevant for balancing the electricity in Smart grids. Taking into consideration that the penetration of variable renewable energy sources in the electricity sector will increase significantly over the next two decades, thus causing challenges for the daily balancing process, this paper analyse the possibilities for improving the accuracy and reliability of balancing services by using advanced analytical services (at central level and on the edge). According to observations and the long-term vision of ENTSO-E, key factors for successful realisation of future Smart Grids are

- assurance of system interoperability;
- using common analysis tools, harmonised standards and procedures.

Therefore, this paper analysed the forthcoming challenges and identified opportunities for the electricity system in Serbia from an operational and market perspective. Analysis is also related to possible integration of PLATOON smart services with energy management products and tools of Institute Mihajlo Pupin.

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