Data Analytics for the Transmission System Operators

Dan PREOȚESCU[1], Simona-Vasilica OPREA[2], Adela BÂRA[2], Niculae OPREA[3], Osman Bülent TÖR[2,4]
[1]Romanian Energy Center, Bucharest, Romania
[2]Bucharest University of Economic Studies, Bucharest, Romania
[3]Transelectrica S.A., Bucharest, Romania
[4]EPRA, Engineering Procurement Research Analysis, Ankara, Turkey
danpreo@yahoo.com, simona.oprea@csie.ase.ro, bara.adela@ie.ase.ro, niculae.oprea@transelectrica.ro, osman.tor@epra.com.tr

In the beginning the paper briefly presents the worldwide context determined by the global warming phenomenon evolution, and the foreseen impact on the power sector, with the focus on the massive integration of the RES powered electricity generators. Identifying the TSOs and grid operators as the main actors for implementing the necessary changes, the authors of the paper are proposing data analytics, designed to support the TSOs and grid operators in fulfilling their main functions and responsibilities.
The structure and the capabilities (analysis and reports) of the software product are presented, including practical examples for usage, and highlighting the potential usefulness of each analyze and/or report, from TSOs and grid operators' point of view.
Keywords: *power sector, Renewable Energy Sources, software, Transmission System Operators, grid operator, forecast.*

1 Introduction

It has been more than a decade since the meteorological specialists sounded an alarm regarding the global warming phenomenon and its potential impact on human life.
Starting with that moment the countries around the world began to become aware about the risks and started to implement measures to prevent as soon as possible this unwanted outcome.
From the beginning, European Union (EU) was among the states that took determined action on the way to prevent the causes of global warming.
The most recent milestone is the approval by the European Commission (EC) of the European Green Deal, in 11th of December 2019.
"The European Green Deal is a response to these challenges. It is a new growth strategy that aims to transform the EU into a fair and prosperous society, with a modern, resource-efficient and competitive economy where there are no net emissions of greenhouse gases in 2050 and where economic growth is decoupled from resource use"[1].
The measures proposed in the above-mentioned document [1] are targeting the following area of interest:

- Definition of new EU targets for achieving climate neutrality,
- Providing clean, affordable, and secure energy to its citizens,
- Implementation of clean and circular economy concepts,
- Building construction and energy efficiency,
- Development of sustainable smart mobility,
- Development of fair, healthy and environmentally friendly food system,
- Preservation and restoration of ecosystems and biodiversity,

and others.
In the energy sector, one of the most important measure is to continue the replacement of the electricity generation based on fossil and nuclear fuels with electricity generation based on Renewable Energy Sources (RES).
The route for achieving this challenging

objective started many years ago with the installation of RES powered generators in almost all EU member countries and will continue with the achievement of the new targets established by EC for 2021 – 2030.

The main barriers that need to be overcome are the funds for investments and the technical challenges of the integration into the power systems of large amounts of RES powered generators.

From the technical point of view the RES powered electricity generators (in case of the most significant technologies: wind and photovoltaic) are totally different to the steam or water powered electricity generators (conventional). The conventional electricity generators are rotating synchronous machines while the RES powered generators are convertor based.

Ensuring the compatibility of these two types of technologies, while maintaining the level of safety in operation of the power systems it is a challenging task.

The most important contribution to achieving this task is provided by the Transmission System Operators (TSOs).

2 Functions and Responsibilities of the TSOs in EU

According to the EU's law and regulations in force [2], [3] the TSOs have the following exclusive functions:

- to operate and ensure the maintenance of and, if necessary, develop a safe, secure, reliable, economical and efficient electricity transmission system, and to explore and develop opportunities for interconnection of its system with other systems, in all cases with a view to ensuring that all reasonable demands for electricity are met and having due regard for the environment;
- to ensure the availability of all ancillary services which are necessary for the transmission system operator to carry out its duty outlined in previous paragraph.
- to operate a system of dispatch and use of interconnectors on objective, non-discriminatory, economical, and technical criteria, without prejudice to the supply of electricity based on existing contractual obligations.
- to provide to the operator of any other system with which its system is interconnected sufficient information to ensure the secure and efficient operation, coordinated development and inter-operability of the interconnected system.
- to offer terms and enter into agreements, where appropriate, for connection to and use of the transmission system with all those using and seeking to use the transmission system.

Supplementary to the exclusive functions the TSOs must also prepare a plan (in the following referred to as the "development plan") for the development of the transmission system in order to guarantee security of supply, which shall relate to a period of 5 calendar years from the date on which the plan is prepared.

The TSOs must, at least once each year revise the development plan, and the revised plan, which shall relate to a period of 5 calendar years following the date on which the plan is revised.

In the context of the significant and continuous increase of the electricity generation based on RES and convertors, the operation of the power systems becomes more and more challenging, both from the complexity and speed of the phenomenon point of view.

The large volume of convertors operating in parallel creates technical conditions never encountered before and increase the complexity of the power systems operation. One of the most important consequence is the significant acceleration of the physical phenomenon that occur during the operation of the power systems.

Considering all the aspects mentioned

above, to support the TSOs to fulfill their functions and responsibilities it is necessary to develop modern software tools, suitable to the new technical environment.

According to [4] and [5] the main responsibilities of the TSOs are related to the following areas:

- electricity demand and generation structure and volume,
- electricity market,
- balancing the demand and generation.

In the following the authors will present the main features and capabilities of a modern software platform designed to support the activity of the TSOs. The platform provides useful tools for analyze and understand the operational situations, as a solid base for taking the right decisions in time.

The software is designed to be user-friendly and to provide a large set of options, covering almost all the possible operational situations a TSO may be challenged with.

3 Module for demand and generation structure analyses

Understanding the electricity demand and generation structure and behavior is one of the most important pre-requisites for a TSO to properly fulfill its functions. The software platform developed by the authors of this paper [6] is equipped with a module specialized on analyzing and providing support for overcoming the main issues related to this topic.

The input data for this module are the historical values of the electricity demand and generation, for period more than five years.

The "home" window (OTS Dashboard) of this module it is displayed in Fig. 1, below.

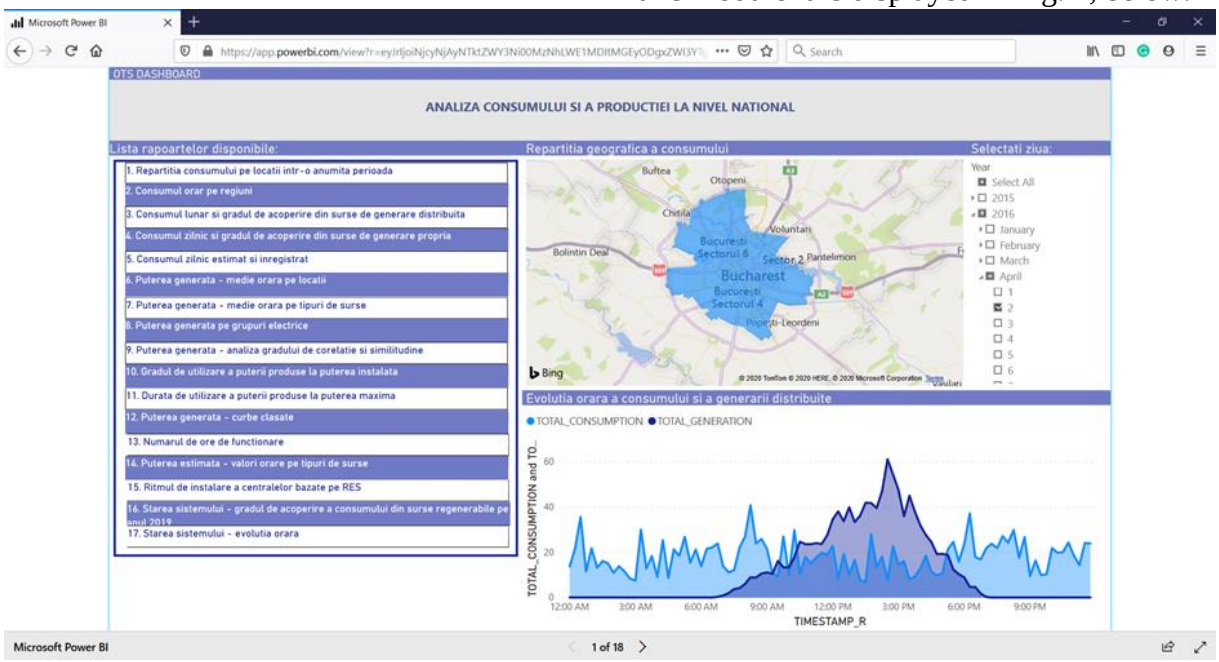


Fig. 1. OTS Dashboard

Using this module, the user may generate seventeen types of reports regarding the electricity consumption and generation, including:

- Time periods: day, month, year.
- Geographical areas: cities, counties.
- Relevant information based on statistic calculations: ranked curves, duration of rated power utilization, hourly percentage of RES based electricity generation and others.

Based on the analyses of the input data, the module may provide on request forecasts for both electricity consumption and generation.

In case of electricity generation, the module focuses on the distributed generation because this type of generation poses the most difficult and complex problems from

the power systems operation point of view.

Each of the reports are displayed in a separate window including charts in pie and stacked columns format, and tables. In Fig. 2 below, it is presented an example report.

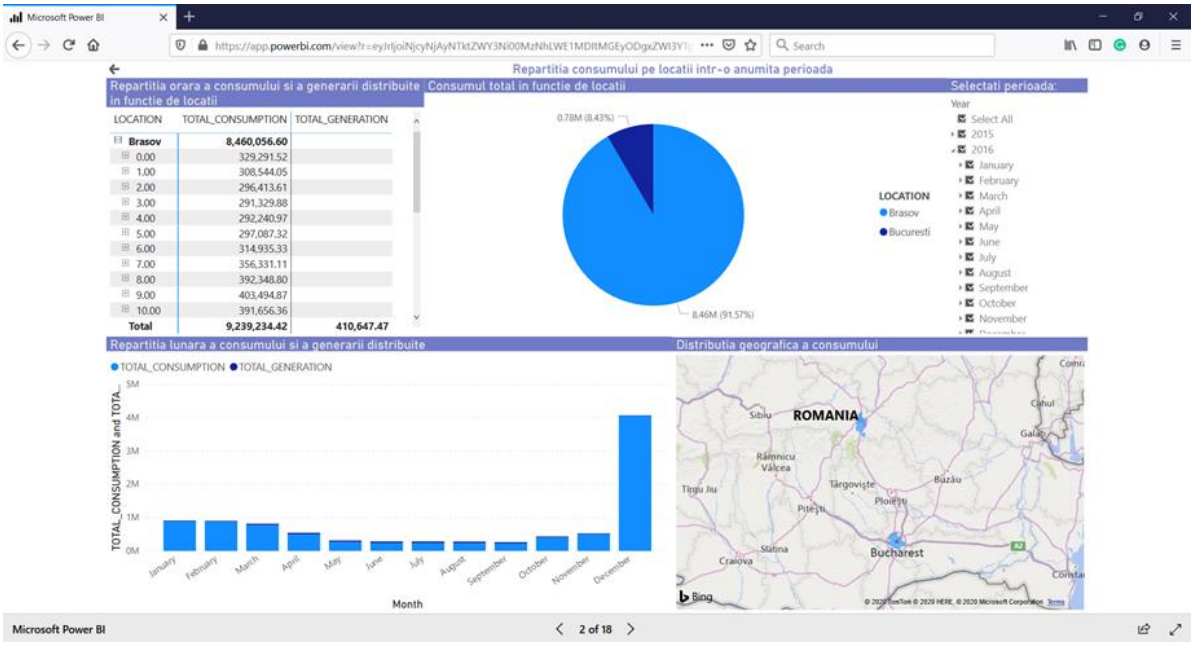


Fig. 2. Report for electricity consumption

Each report window includes editing facilities such us filters, navigation functions, selection functions and others.

In Fig. 3 below, are presented the editing facilities and the activation commands.

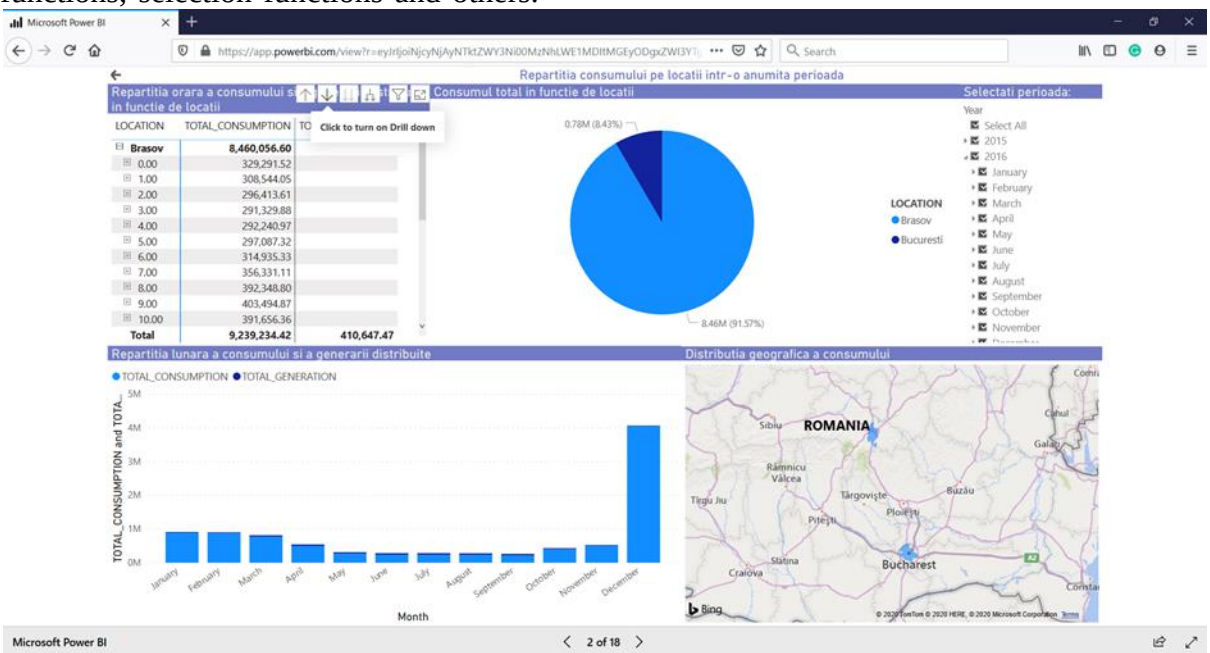
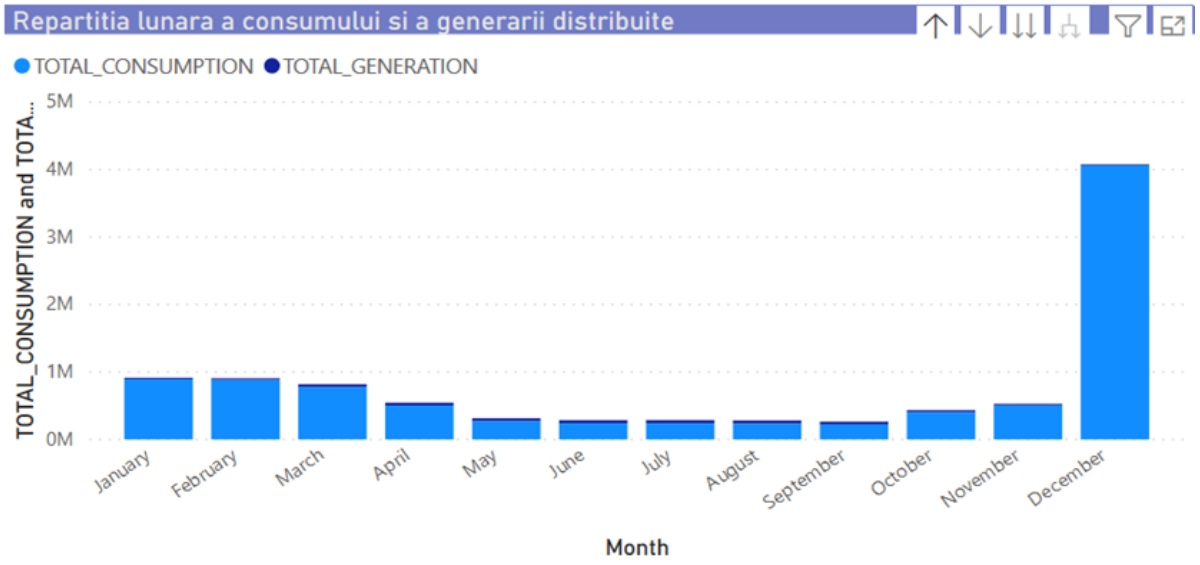
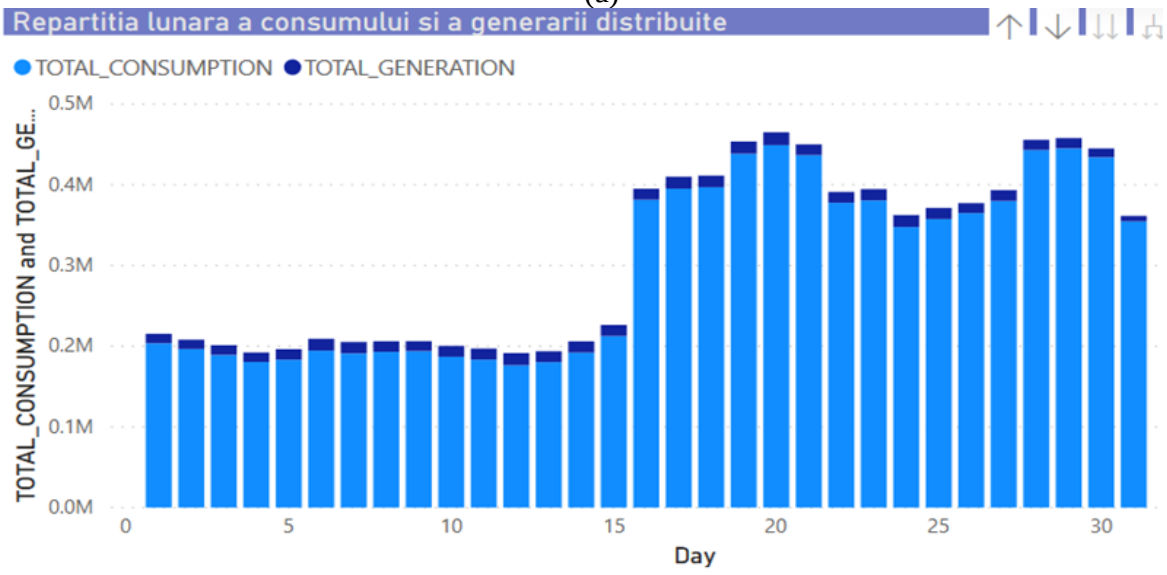


Fig. 3. Activation of the editing facilities

Utilizing the activation commands presented in Fig. 3, the user may change the data included in the tables and the charts format, according to its specific needs, in a very convenient way. In Fig. 4 below, are presented two types of charts (monthly – a or daily – b) that may be selected by the user according to its needs.



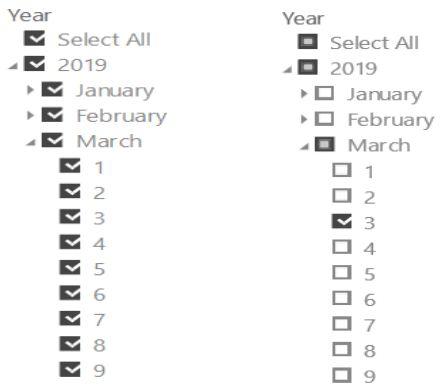
(a)



(b)

Fig. 4. Different charts formats

The selection of the period to be included in the reports is also design in a user-friendly manner. Fig. 5 (selection of full parameters – a or selection of specific parameters – b) below, shows the large margin of possibilities and the respective controls to be used.



a) b)

Fig. 5. Controls for selection of the duration in editing the reports

Up to seventeen different types of reports may be generated using the module for

electricity consumption and generation analyses. All the reports are useful for TSOs in fulfilling their functions and responsibilities. Besides, the authors have designed the structure of this model based on the feed-back received from several TSOs from South East Europe.

The electricity consumption and the distributed generation (including electricity self-consumption) are presented in the same reports because the obvious reason that electricity distributed generation is consumed locally (with very limited impact on the electricity distribution grid and practically no impact at all on the electricity transmission grid), in almost all cases. In Fig. 6 below, it is showed an example of the report for consumption and distributed generation, daily.

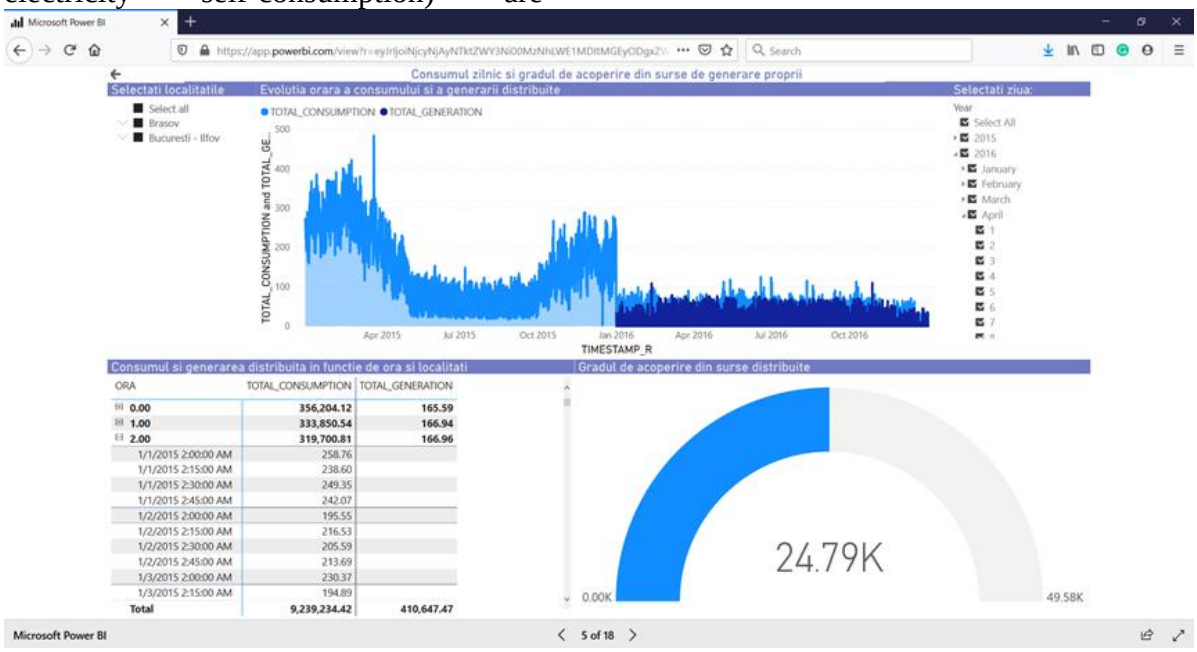
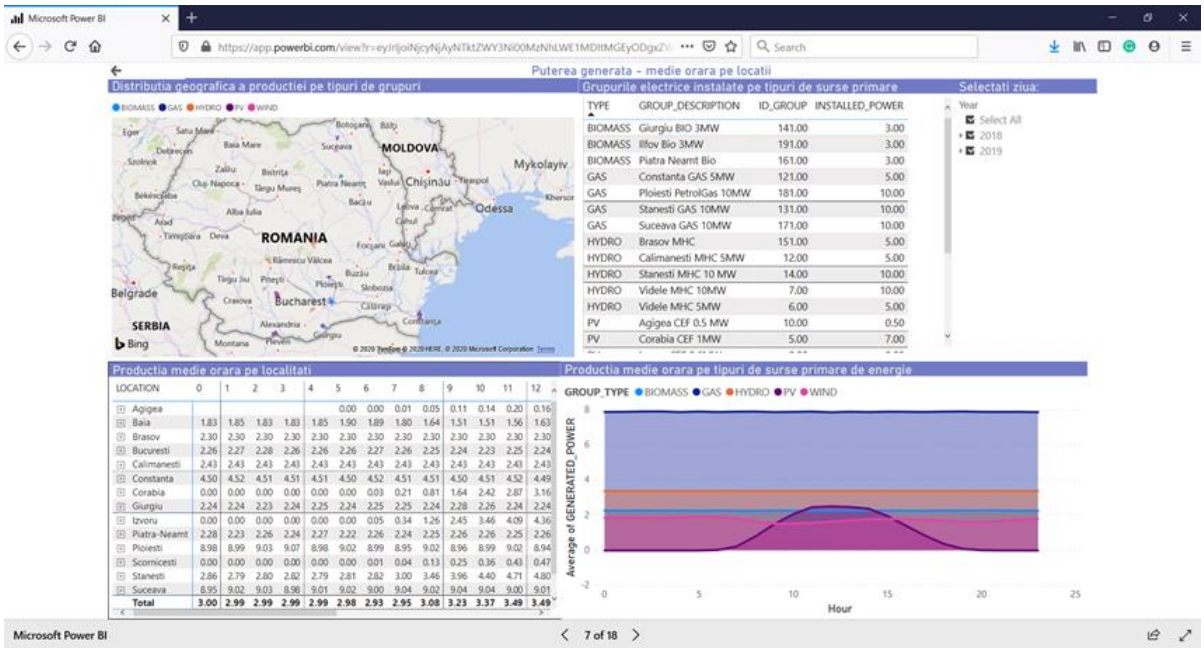


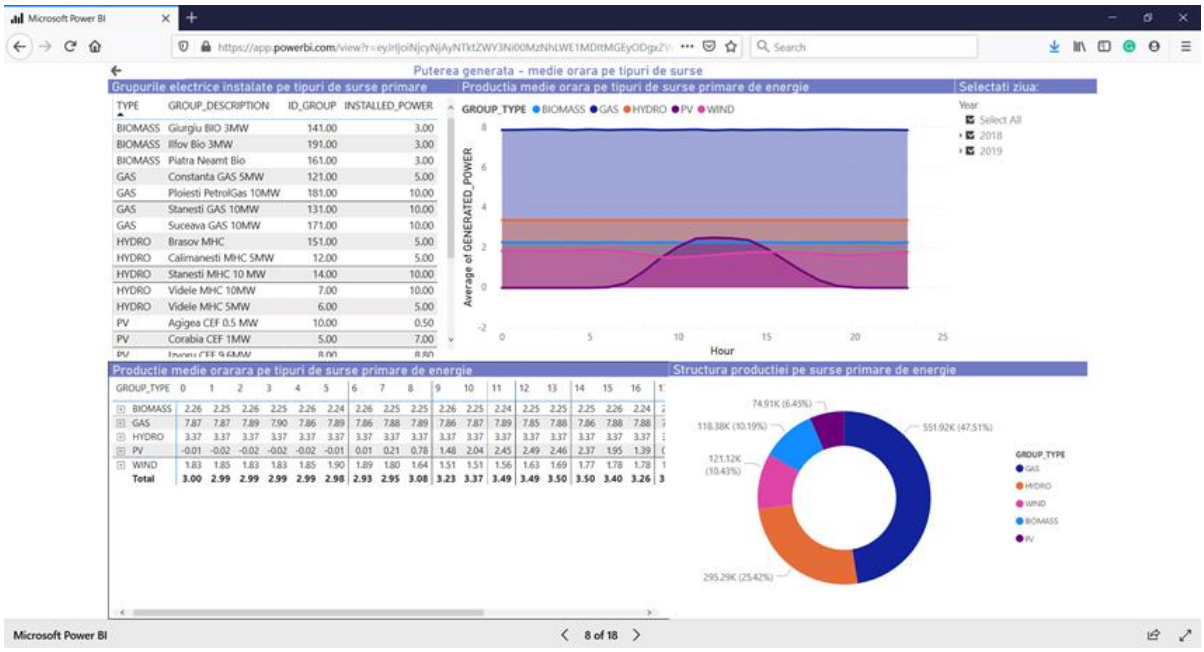
Fig. 6. Electricity consumption and distributed generation on daily basis

The electricity generation may be analyzed separately, and the results are displayed in several specialized reports. Of course, all the reports are equipped with the same editing facilities (filters, selection possibilities etc.) as the reports concerning the electricity consumption, presented above.

In the Fig. 7 below, are presented two examples of reports that may be generated to support TSOs in having a clear picture of the electricity generation structure. Fig. 7 – a) shows the geographical location, while Fig. 7 – b) shows the structure of the electricity generation based on technology (fossil fuels, hydro, RES etc.).



a)



b)

Fig. 7. Reports concerning the electricity generation

A particularly useful report includes the level of simultaneity in electricity generation, in determined region, and in determined period. This information allows TSOs to identify timely the potential bottleneck points in the electricity grid, and to identify and implement the appropriate measures.

The simultaneity indices are computed by a Pithon script integrated in Power BI, and it is displayed in a matrix format, as presented in the Fig. 8 below.

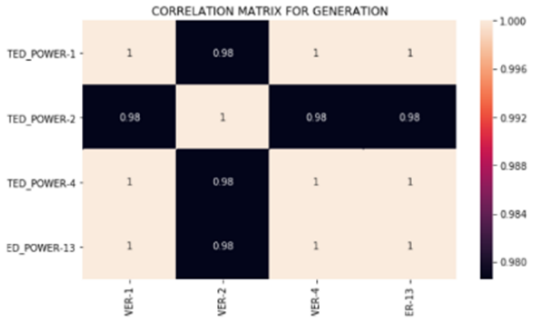
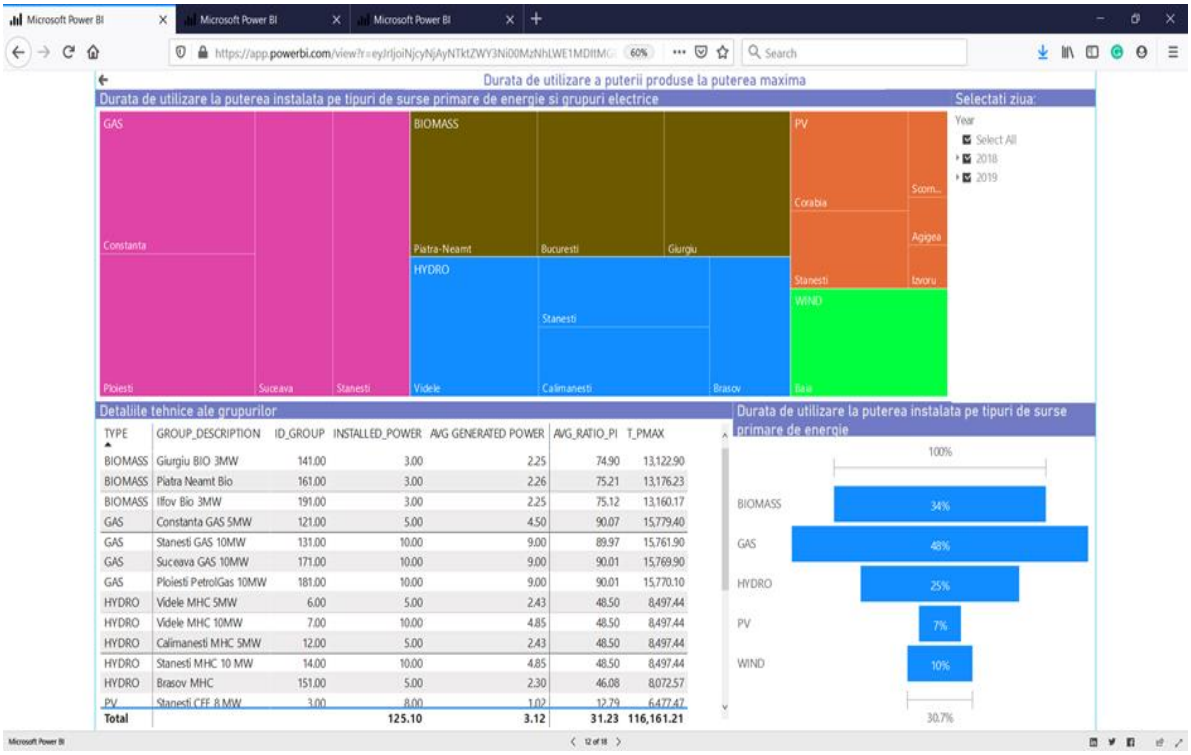


Fig. 8. Simultaneity indices for electricity generation

From the TSOs point of view, an especially useful information it is the charging level of the electricity generators. In this respect, the module makes possible to generate a specialized report, that may be edited to fit the needs of the user. In Fig. 9 below, it is presented an example for this type of report.



TYPE	GROUP_DESCRIPTION	ID_GROUP	INSTALLED_POWER	AVG GENERATED POWER	AVG_RATIO_PI	T_PMAX
BIOMASS	Giurgiu BIO 3MW	141.00	3.00	2.25	74.90	13,122.90
BIOMASS	Piatra Neamt Bio	161.00	3.00	2.26	75.21	13,176.23
BIOMASS	Ilfov Bio 3MW	191.00	3.00	2.25	75.12	13,160.17
GAS	Constanta GAS 5MW	121.00	5.00	4.50	90.07	15,779.40
GAS	Stanesti GAS 10MW	131.00	10.00	9.00	89.97	15,761.90
GAS	Suceava GAS 10MW	171.00	10.00	9.00	90.01	15,769.90
GAS	Ploiesti PetrolGas 10MW	181.00	10.00	9.00	90.01	15,770.10
HYDRO	Videle MHC 5MW	6.00	5.00	2.43	48.50	8,497.44
HYDRO	Videle MHC 10MW	7.00	10.00	4.85	48.50	8,497.44
HYDRO	Calimanesti MHC 5MW	12.00	5.00	2.43	48.50	8,497.44
HYDRO	Stanesti MHC 10 MW	14.00	10.00	4.85	48.50	8,497.44
HYDRO	Brasov MHC	151.00	5.00	2.30	46.08	8,072.57
PV	Stanesti CFF 8 MW	3.00	8.00	1.02	12.79	6,477.47
Total			**125.10**	**3.12**	**31.23**	**116,161.21**

Fig. 9. Average charging level of the electricity generators

The statistical analysis of the historical data concerning the electricity generation are used on one hand for a correct and detailed understanding of the power systems characteristics, and on the other hand for develop forecasts. Forecasting is a widely used tool for correctly and timely identify the potential operational problems in power systems operation. In this respect, the module makes available to the user a set of specialized reports covering: forecasts of the electricity generation differentiated per technologies (fossil fuels, hydro, RES etc.), forecasts for evolution of the installed power in RES based generators, and the percentage of RES based generation of the total of electricity generation, for a determined period of time.

The forecast for electricity generation may be reported for each generator unit, for groups of units or for groups of power plants, as it is shown in Fig. 10 below.

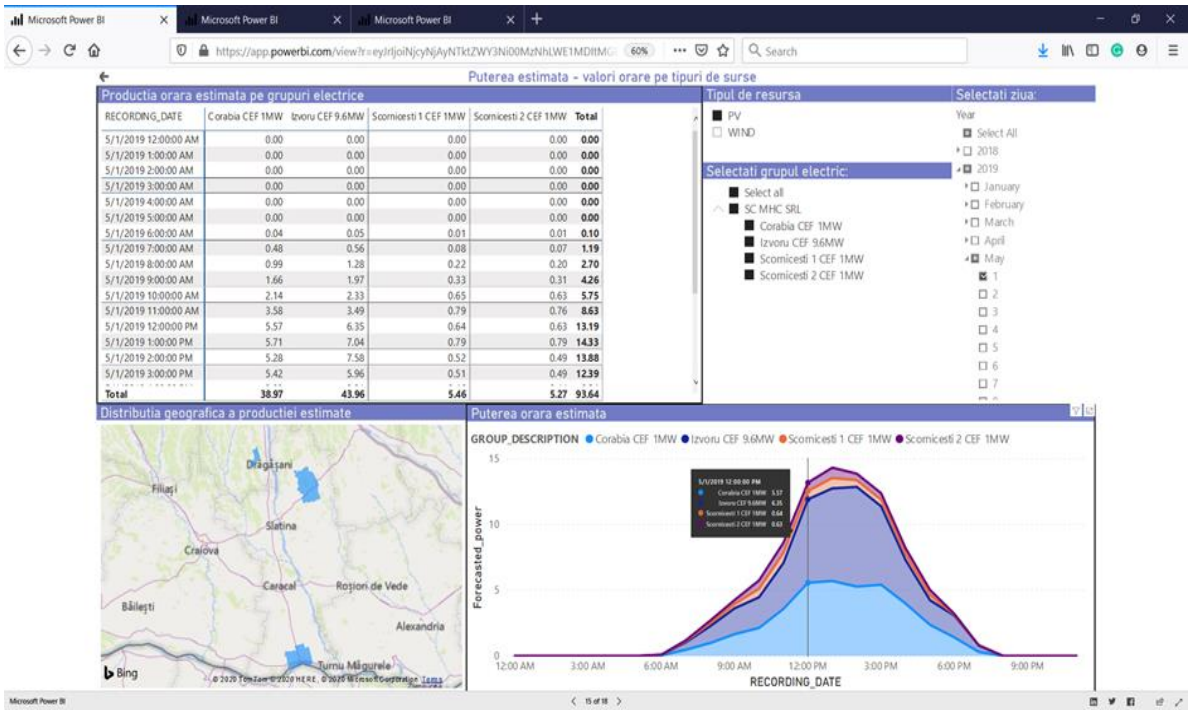


Fig. 10. Report including the electricity generation forecast

Based on the data and information available for the public [7] concerning the Romanian Power System, the authors have developed forecasts for RES based electricity generators, for the period 2020 ÷ 2022. The current databases will be updated at regular intervals to include all the relevant evolutions and thus to maintain the accuracy of the forecasts. In Fig. 11 below, it is presented the report including the forecast of RES based electricity generation, in the Romanian Power System.

As it was mentioned before in this paper, the RES based generation is currently using (mostly) convertors for connecting to the Power Systems. For the TSOs it is useful to be timely informed in this respect because this type of connection rises a lot of technical challenges in power systems operation.

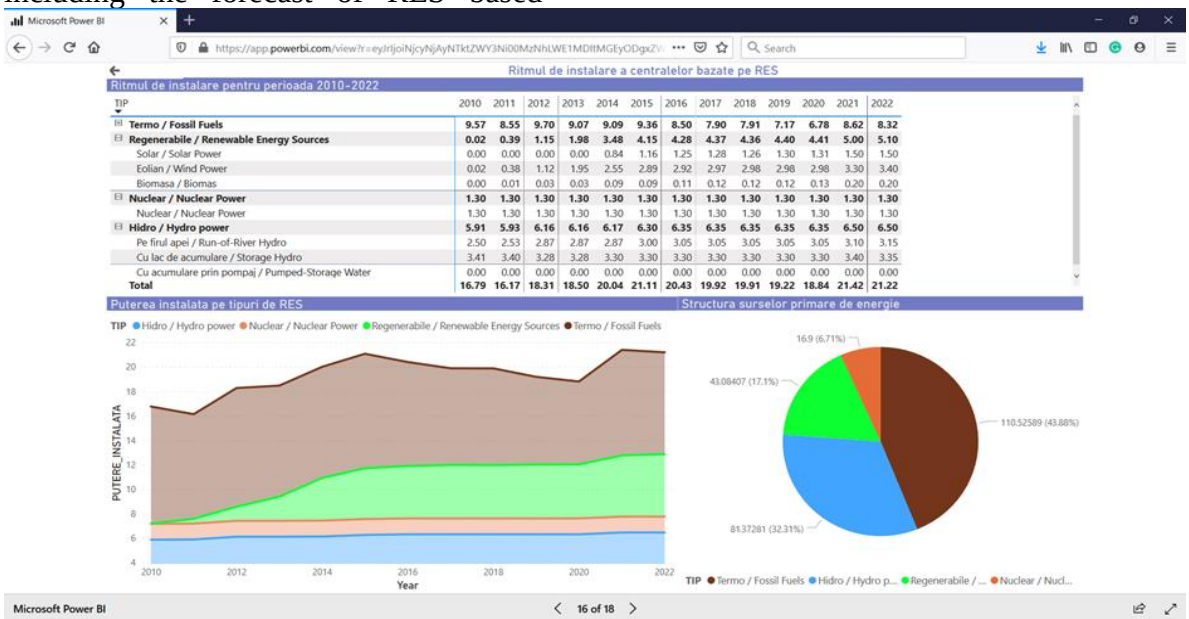


Fig. 11. Report including the forecast of RES based generation

4 Module for analysis of the electricity engross market

The unbundling of the power sectors and the implementation of the electricity markets have been two process which took place practically simultaneously.

From the beginning the electricity market has been structured in layers, based on the timeframe, as follows:

- Long time – engross market,
- Short time – spot market,
- On-Line – balancing (including ancillary services) market.

Electricity engross market is the commercial framework with the largest volume (MWh) of transactions in all countries (power systems) where it was implemented the electricity market system.

TSOs are normally involved in the operation of the balancing and ancillary services market (also normally, they are the designated as operator of this type of markets). Nevertheless, the electricity volumes traded on the engross market makes it one of the most relevant parts of the commercial structure, with a direct and relevant impact on the technical and operational conditions.

The above-mentioned aspects determined the authors to include this module in the software platform specialized for supporting the TSOs activity.

Similar with the previous module, the input data for the analysis are the historical values registered for last five years, in the Romanian Power System / Romanian Electricity Markets.

The module allows the user to perform analysis of the transactions according to different criteria, as follows:

- Geographical areas,
- Time periods (days, months, years),
- Primary energy sources used for electricity generation (fossil fuels, RES, hydro etc.),
- Market participants.

For a more complete understanding of the features and trends it was added the possibility to include the data and information concerning the Day Ahead Market (DAM) for electricity.

All the reports windows are designed in the same user-friendly manner with the module previously presented in this paper.

In Fig. 12 it is showed an example report including the aggregated traded volumes of electricity, for several selected cities (in alphabetical order): Brasov, Bucharest, Calimanesti, Constanta, Piatra-Neamt, Ploiesti, Suceava and Videle.

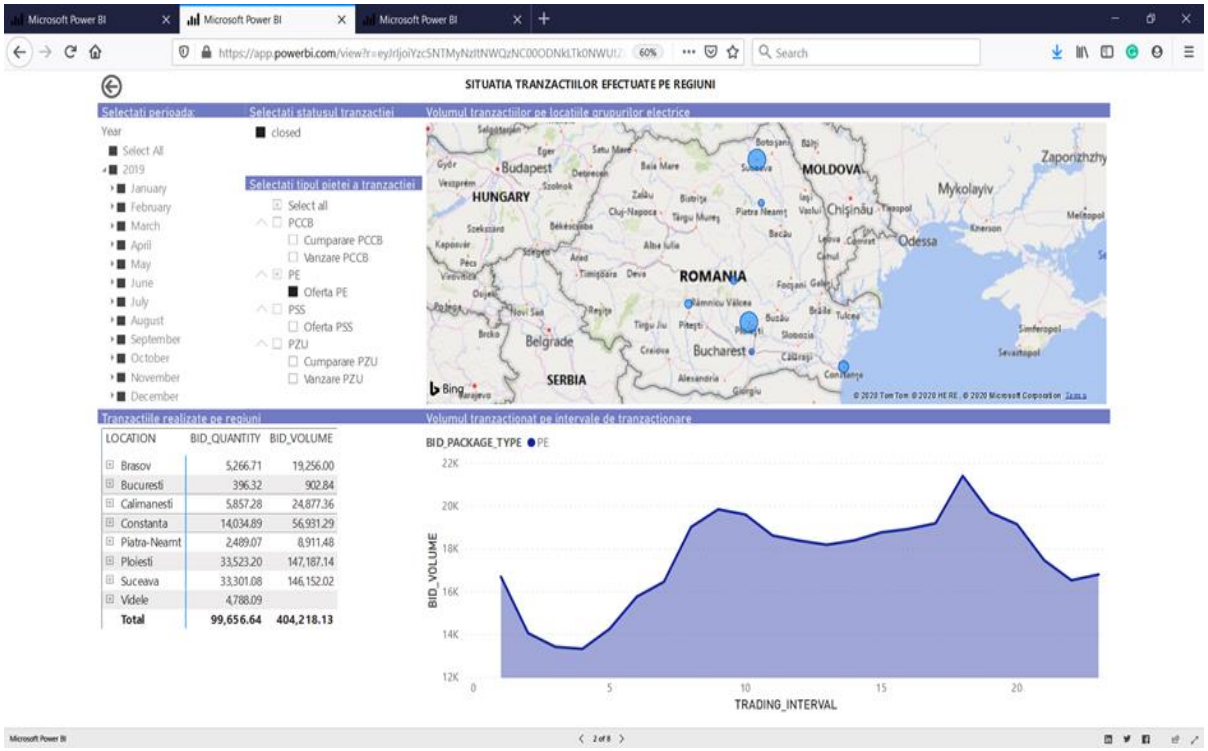


Fig. 12. Electricity traded volumes aggregated for several cities selected by user

Similar with the capabilities showed in the reports generated by the previous module presented in this paper, the reports concerning the volumes traded on the electricity markets may be generated for the time periods requested by the user: days, weeks or years. In the Fig. 13 below, it is presented an example report for a month period, including only the selling volumes traded, and the respective prices. The reports highlight the volumes traded for each type of primary energy source: fossil fuels, hydro, RES and nuclear.

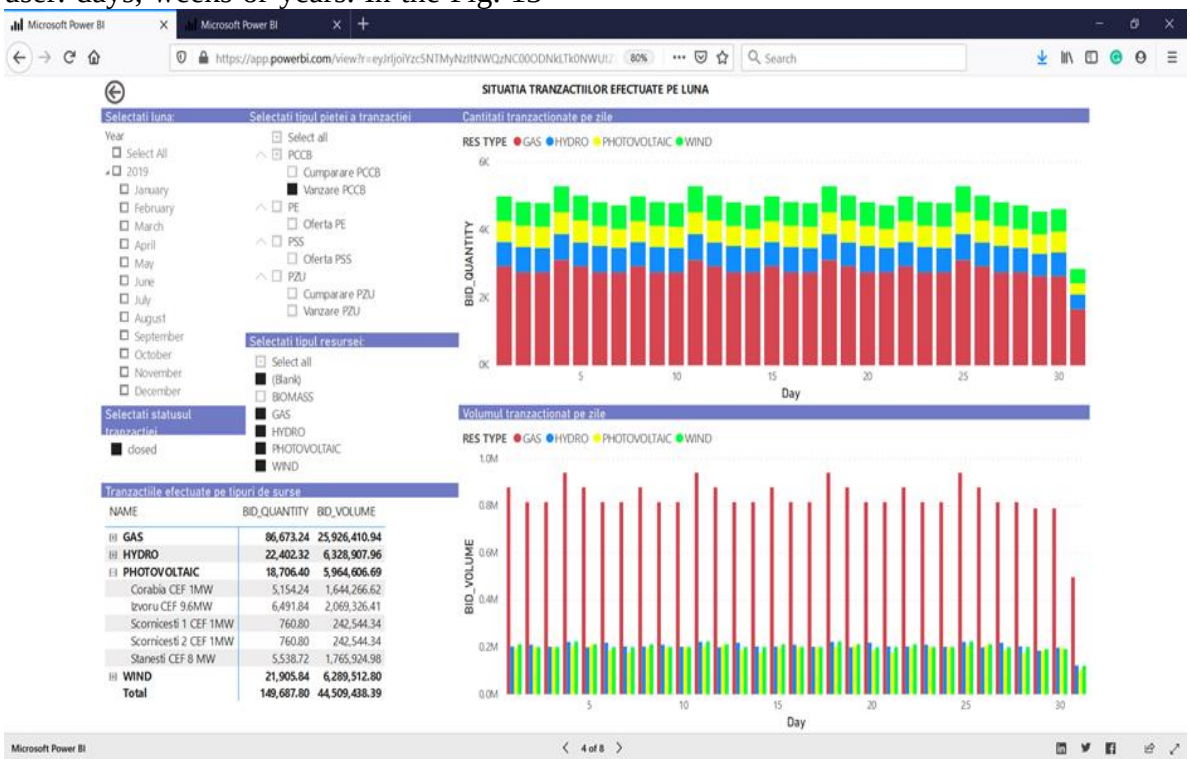


Fig. 13. Traded electricity volumes for one month, per primary energy source

For a more complete description of the electricity markets past evolution and identification of the future trends, the module has the capability to analyze and report the traded volumes of electricity differentiated for each market participant, for selected time periods. The database includes only the transactions finalized (not the offers). In the Fig. 14 below, it is presented an example report for a randomly selected number of electricity generators.

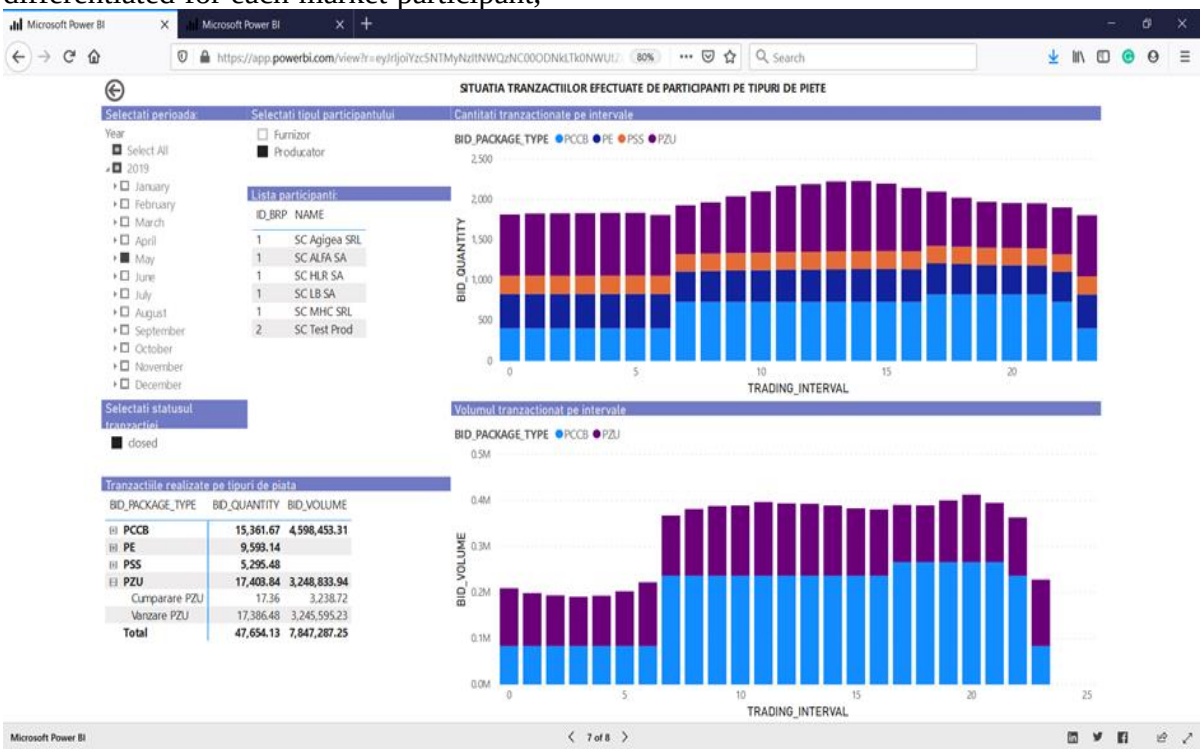


Fig. 14. Finalized transactions with electricity, for a group of generators

The data and information included in the previous report may be useful to be structured in a different format, displaying the traded electricity volumes in percentages, for all the electricity markets. This change of perspective highlights the impact of the selected group of market participants at the market level. In Fig. 15 below, it is presented an example report, in percentage format, for the same group of selected electricity generators, and the same period as in case of Fig. 14.

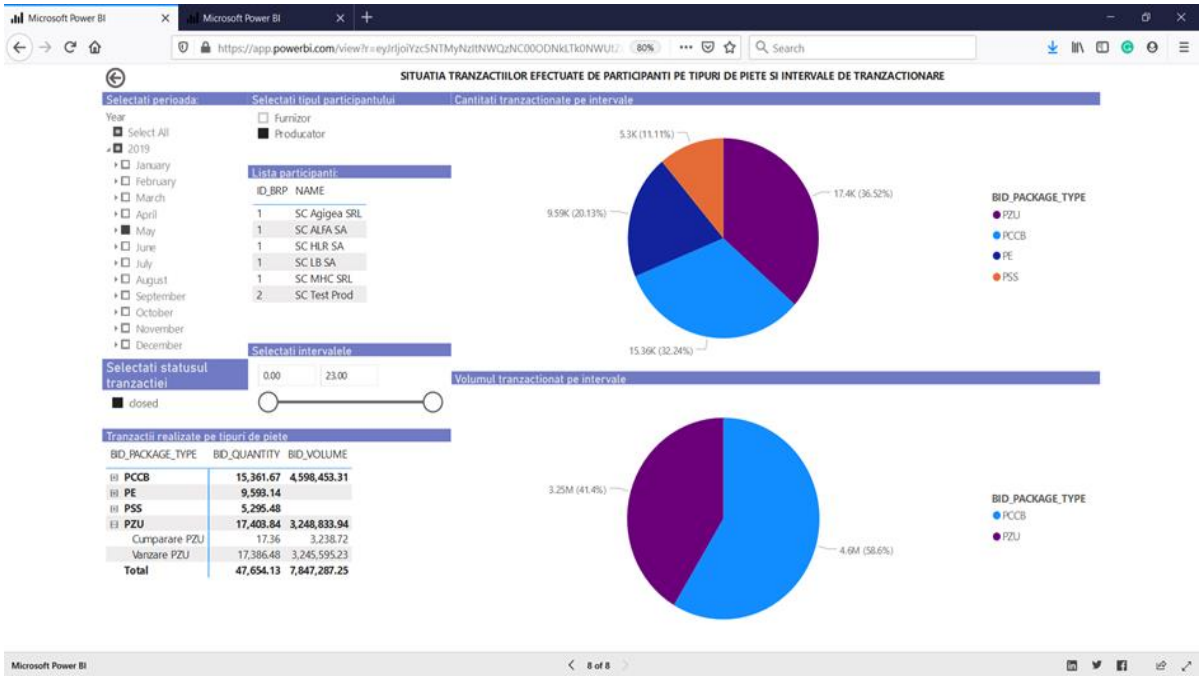


Fig. 15. Finalized transactions with electricity, for a group of generators, in percentage format

5 Module for analysis of the balance between consumption and generation of electricity

One of the most important function and responsibility of the TSOs is to take all the necessary measures to ensure the balance between electricity consumption and generation in each moment, continuously, and for indefinite period.

To fulfill this responsibility, the TSOs are carefully monitoring the electricity consumption and generation levels. In case an imbalance is detected the TSO is empowered to take timely all the necessary measures to restore the balance.

Reflecting the importance of this aspect in the power systems operation, a specialized electricity market has been created both at national and European level.

The European professional association of the TSOs: European Network of Transmission System Operators for Electricity (ENTSO-E) is the organization in charge with the elaboration and implementation of the regulatory framework concerning power systems operation and electricity markets design and operation, at European level.

According to ENTSO-E website [8] electricity balancing market is "a market where countries can share the resources used by their TSOs to make generation equal demand always. It is also about allowing new players such as demand response and renewables to take part in this market."

For the same purpose of providing TSOs with the necessary tools to meet its responsibility, ENTSO-E has issued grid code specialized on electricity balancing: Guideline on Electricity Balancing [9].

According to ENTSO-E the balancing activity means: "all actions and processes, on all timelines, through which TSOs ensure, in a continuous way, the maintenance of system frequency within a predefined stability range as set out in Article 127 of Regulation (EU) 2017/1485, and compliance with the amount of reserves needed with respect to the required quality, as set out in Part IV Title V, Title VI and Title VII of Regulation (EU) 2017/1485" [9].

Balancing market means: "the entirety of institutional, commercial and operational arrangements that establish market-based management of balancing" [9].

One especially important characteristic of the electricity balancing market is the

noticeably short timeframe of the transactions, namely the dispatching interval [10].

The duration of the dispatching interval was initially of one hour but in time the TSOs decided to reduce it step by step, to increase the accuracy of the balancing measures. Nowadays, the duration of the dispatching interval it is different in the EU member countries, ranging from 5 minutes to one hour, but the trend is to reduce it to 5 minutes all over the Europe.

Considering all the above-mentioned aspects the authors of the software platform have been developed a specialized module dealing with the following topics:

- Electricity balancing volumes,
- Electricity balancing costs,
- Electricity balancing prices.

In Fig. 15 below, it is shown the dashboard of the module for analysis concerning the electricity balancing market.

The databases used for statistics and computations include historical values registered in the operation of the electricity balancing market, in the Romanian power system, during the last five years [7]. In the Fig. 15 below, it is showed the dashboard of this module.

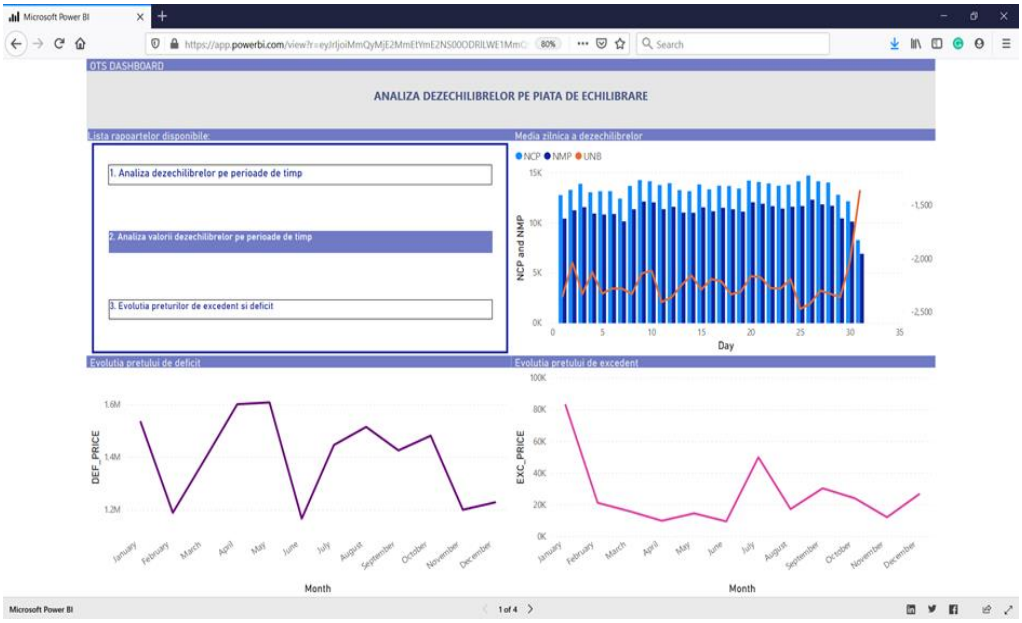


Fig. 15 Dashboard of the module for electricity balancing analysis

The volumes of electricity traded for each dispatching interval, for a determined period is an especially important parameter for the TSOs on its way to optimize the operation of the power system while maintaining an adequate level quality and costs of services.

Ideally, the electricity consumption and generation should be balanced for the most part by means of the other electricity markets (bilateral, DAM and IDM), and the volumes traded on the balancing markets to be around 10 % of the total electricity consumption of the power system.

The larger is the volume of electricity traded on this market, the most difficult is to operate the power system, and the most costly as well. On mention that the prices on the market in question are usually, on average about 40 % to 50 % higher than on any of the other markets.

In case the volumes traded on the electricity balancing market are exceeding 25 % it is strongly recommended to the TSO in charge to take active measures for improving the balancing activities at the level of each participant in the respective power system. The market price of electricity itself is such a measure but other supplementary levers may be implemented (incentives for forecasts improvement, incentives for storage facilities, incentives for demand side management actions, etc.).

The module may perform analysis for each market participant or for list of selected participants, according to the necessities of the user. In Fig. 16 below, it is showed the results of the analysis for a user-selected market participant, and for a user-selected period.

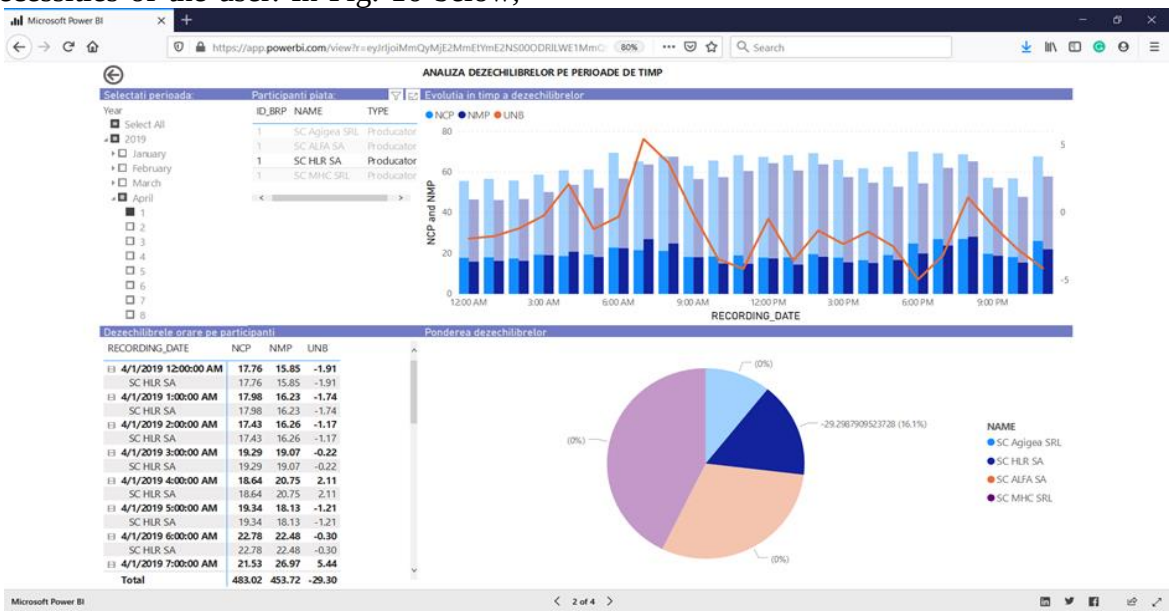


Fig. 16. Hourly volumes of electricity traded on the balancing market

Closely related to the volume of electricity traded are the associated costs.

The next function of the module allow the user to generate reports displaying the statistical analysis of the costs evolution. Similar with the previous function, the reports may be generated for a single market or for a group of market participants, in line with user necessities.

The databases used in the calculations and statistical analysis include information related to transactions finalized on the electricity balancing market in Romanian power system, in the last five years [7].

In Fig. 17 below, it is showed the results of the costs analysis for a user-selected market participant, and for a user-selected period.

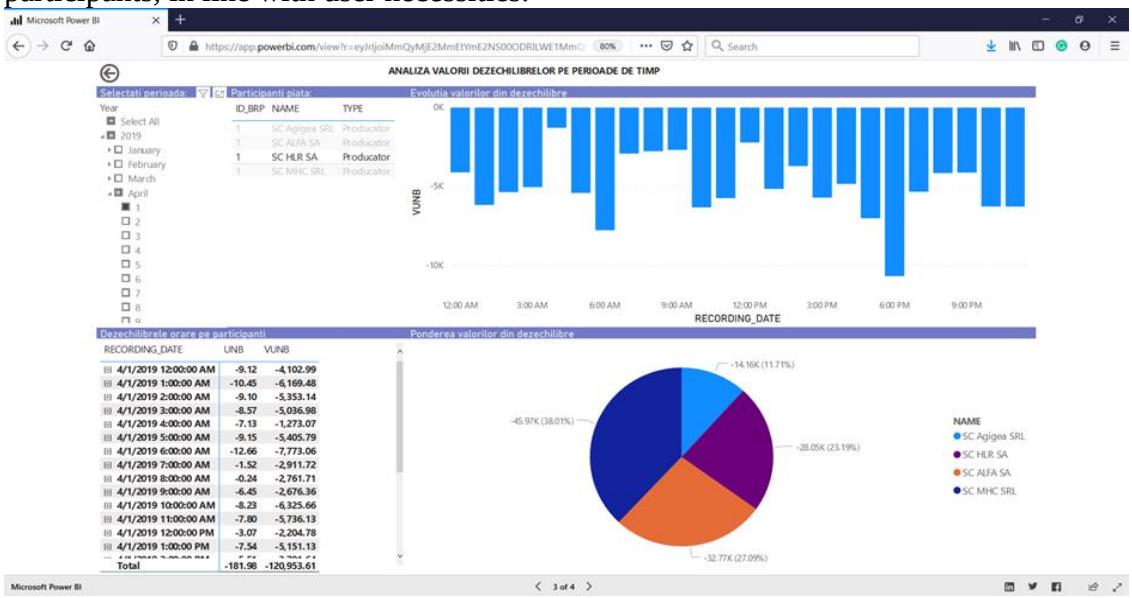


Fig. 17. Hourly costs of electricity traded on the balancing market

The transactions on the electricity balancing market are characterized by a dual structure:

- Transactions for deficit settlement,

- Transactions for surplus settlement.

In a determined dispatching interval (the time frame of the transactions on the market in question) only one type of transaction is possible. TSOs are in charge to identify which type is necessary and to implement it in due time.

In these conditions, the actors and the prices are both different and independent, for each of the types, and requires differentiated analysis and computations.

In Fig. 18 below, it is showed the results of the deficit and surplus prices analysis for an user-selected period that may not be shorter than one day (24 hours).

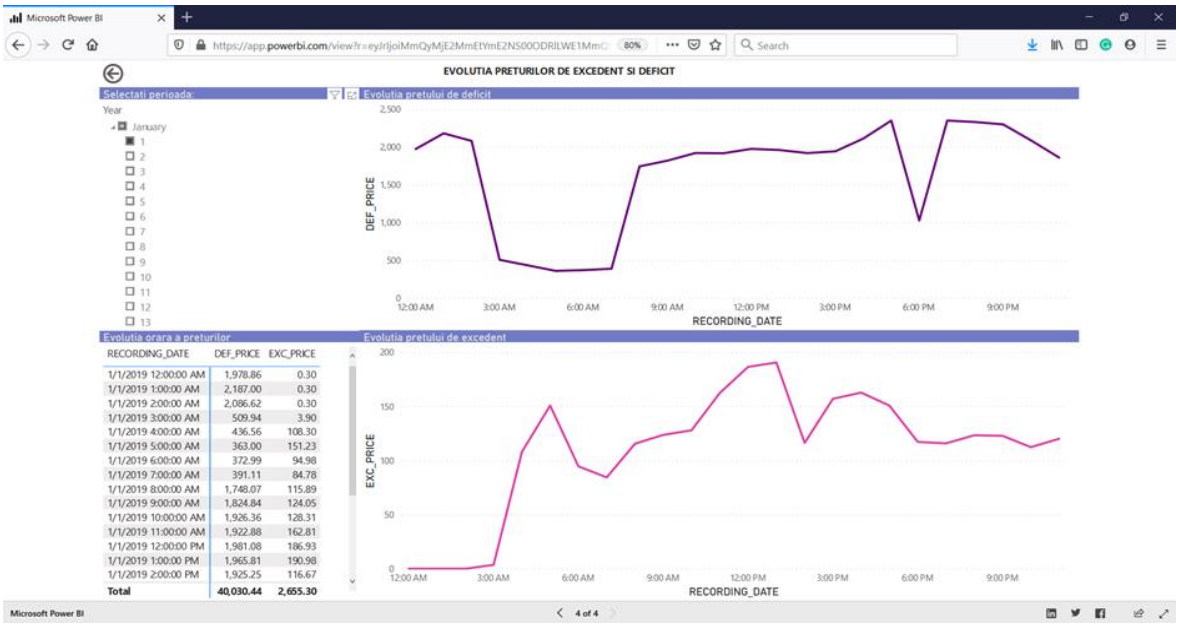


Fig. 18. Electricity deficit and surplus prices for one day (24 hours)

The functions and statistical analysis capabilites provided by this module may be very useful for the TSOs in case they are using the levers of the electricity balancing market for congestion management and capacity allocation purposes.

According to ENTSO-E's regulations [11], the congestion management and capacity allocation are the responsibilities of the TSOs, and one of the main tools to fulfill them is the electricity balancing market. In line with the same regulation [11], the related costs will be supported by the TSO in charge for the respective power system.

It must be mentioned that utilization of the electricity balancing market mechanism it is not always necessary in the performance of the congestion management and especially in the cacpacity allocation activities but when the time comes it is useful to be able to forecast the related costs.

6 Conclusions

The evolution of the global warming determined the countries worldwide to adopt more and more determined measures to fight against this phenomenon by reducing and even eliminating the main causes.

EU turned out to be, currently is and intend to be in the future one of the world leaders in this respect. The European Green Deal [1], elaborated by the European Commission and approved recently by the European Parliament, it is an undeniable proof of this statement.

In this environment, the power sector and the transportation sector are probably the most affected industries, facing a large variety of challenges: technical, financial, social, administrative and others.

Concerning the power sector, the main driver is the massive integration of the electricity generators powered by RES, replacing the electricity generators powered

by fossil fuels and nuclear fuel. The process has started at European level ten years ago and it is intended to continue for at least another decade.

The electricity generators powered by RES are using, in the vast majority convertors for connection to the electricity grid. This type of technology is totally different from the technical point of view, to the conventional synchronous rotating electricity generators.

The challenges are a direct result of the request to perform the process without reducing (increasing if possible) the quality level of supply service, while maintaining the affordability level of the electricity, at European level.

Considering the above-mentioned aspects, one may easily identify the TSOs as the main actors in charge to implement the changes, to monitor and assess the impact, to identify the necessary measures and the responsible parties.

In the desire to meet the needs of TSOs, the authors of this paper have developed a specialized software platform. The software product is designed to perform statistic analysis of historical values, and to elaborate forecasts, both for supporting the TSOs in identifying the sources of the problems and to timely take the right decisions.

The databases used for analysis and calculations include information collected in the last five years from the Romanian electricity markets: bilateral, DAM, IDM and balancing market.

The software product is structured in three modules, dealing with the following topics:

- electricity demand and generation structure and volume,
- electricity market,
- balancing the demand and generation.

Each of the modules is designed to be user-friendly and to provide a large set of editing options, covering almost all the possible operational situations a TSO may be challenged with.

In the frame of the module for demand and generation structure, the user may perform a set of seventeen analysis, and may generate reports for each of them. The topics addressed by this module are the following:

- Distribution of consumption by locations over a certain period,
- Hourly consumption by regions,
- Monthly consumption and coverage from distributed generation sources,
- Daily consumption and coverage from distributed generation sources,
- Estimated and recorded daily consumption,
- Generated power – hourly average per location,
- Generated power – hourly average by types of sources,
- Power generated by electrical groups,
- Power generated by the analysis of the degree of correlation and similarity,
- The degree of use of the power produced at the installed power,
- Duration of use of the power produced at maximum power,
- Generated power – ranked curves,
- Number of operating hours,
- Estimated power – hourly values by types of sources,
- The pace of installation of power plants based on RES,
- The state of the system – the degree of consumption coverage in RES,
- System status - hourly evolution.

In the frame of the module for analysis of the electricity engross market, the user may perform a set of seven analysis, and may generate reports for each of them. The topics addressed by this module are the following:

- Statement of the finalized transactions, by region,
- Statement of the finalized transactions, by types of resources,
- Statement of the finalized transactions per months,
- Statement of finalized daily transactions, by types of markets,
- Statement of transactions finalized per intervals, by types of markets,
- Statement of the transactions

finalized per participants, by types of markets,
- Statement of the transactions finalized per participants, by types of markets, and trading intervals.

In the frame of the module for analysis of the balance between consumption and generation of electricity, the user may perform a set of three analysis, and may generate reports for each of them. The topics addressed by this module are the following:

- Analysis of imbalances over time periods,
- Analysis of the value of imbalances over time periods,
- Evolution of surplus and deficit prices.

The paper includes a detailed presentation (practical examples for utilization) of each module with its functions / reports, highlighting the potential usefulness of them in the TSOs day to day activity.

7 Acknowledgment

The his paper presents the scientific results of the project "Intelligent system for trading on wholesale electricity market"(SMARTRADE), co-financed by the European Regional Development Fund (ERDF), through the Competitiveness Operational Programme (COP) 2014-2020, priority axis 1 – Research, technological develop-ment and innovation (RD&I) to support economic competitiveness and business development, Action 1.1.4-Attracting high-level personnel from abroad in order to enhance the RD capacity, contract IDP 37 418, no. 62/05.09.2016, beneficiary: The Bucharest University of Economic Studies.

References

[1] European Commission, *European Green Deal*, Brussels, Belgium, 2019.

[2] European Commission, *SI 445 of 2000*, Statutory Instruments, Brussels, Belgium, 2000.

[3] European Commission, *SI 60 of 2005*, Statutory Instruments, Brussels, Belgium, 2005

[4] A.N.R.E., *License for Operating the Romanian Power Transmission System*, A.N.R.E.'s Order 867/2009, Bucharest, Romania, 2009.

[5] Commission for Energy Regulation, *EirGrid Transmission System Operator Licence*, EirGrid website, 2017.

[6] Academia de Studii Economice din București, *MODULUL PENTRU ANALIZĂ (ABI) DESTINAT OTS/ANRE*, Contract: ID P_37_418, nr. 62/05.09.2016, Bucharest, Romania, 2020.

[7] Romanian TSO – Transelectrica, Transelectrica's website

[8] European Network of Transmission System Operators for Electricity – ENTSO-E, ENTSO-E website.

[9] ENTSO-E, *Guideline on Electricity Balancing*, EC Regulations, Brussels, Belgium, 2017.

[10] A.N.R.E., *Commercial Code of the Wholesale Electricity Market*, A.N.R.E. Order 25/2004, Bucharest, Romania, 2004.

[11] ENTSO-E, *Guideline on Capacity Allocation and Congestion Management*, EC Regulations, Brussels, Belgium, 2015.

PhD. Dan Preotescu studied power engineering at "Politehnica" University of Bucharest and he chose to specialize in the power sector. After graduating, for more than 10 year he worked for Power Studies and Design Institute, in Bucharest elaborating numerous studies in the Romanian Power Sector and Romanian industry. In 1998 he received the scientific title of Master in Power Systems Quality Management form "Politehnica" University of Bucharest and in 1999 he received the scientific title of Physician Doctor in the same university. From 2000 to 2011 he worked for the Romanian TSO – Transelectrica being in charge with the coordination of the development department. For more than 5 years Mr. Preotescu was Project Manager, on behalf of Romanian TSO, for international projects such as: Black Sea Regional Transmission System Planning Project and others. Currently Mr. Preotescu works for the Romanian Energy Centre as Project Manager. During his entire activity period Mr. Preotescu proved a steady interest for the scientific analyses and researches being involved in many papers and other works from the power sector and publishing a book in 2001.

PhD. Lecturer Simona-Vasilica Oprea (b. July 14, 1978) teaches Databases, Database Management Systems and Software Packages at the Faculty of Economic Cybernetics, Statistics and Informatics of the Bucharest University of Economic Studies. She received the MSc degree through the Infrastructure Management Program from Yokohama National University, Japan, in 2007, the first Ph.D. degree in Power System Engineering from the Bucharest Polytechnic University in 2009, and the second Ph.D. degree in Economic Informatics from the Bucharest University of Economic Studies in 2017. She is involved in several national and H2020 European research projects as member or project manager. She is currently project director for a H2020 project entitled Multi-layer aggregator solutions to facilitate optimum demand response and grid flexibility (acronym SMART-MLA).

PhD. Professor Adela Bâra (b. October 11, 1978) is director of the Data Science Excellence Center in the Bucharest University of Economic Studies. She is the author of 19 books in the domain of economic informatics, over 60 published scientific papers and articles (among which over 20 articles are indexed by Web of Science). She participated in 10 research projects (4 of them as principal investigator or project responsible), financed from national and international research programs. Domains of competence include Databases (relational, object-oriented, spatial, NoSQL); data warehousing; Big Data; data mining; Artificial Neural Networks; Machine Learning; IoT; Business Intelligence; Informatics solutions for energy systems (data integration, analytics, web-services, cloud-computing development).

Eng. Niculae Oprea (b. January 7, 1982) is a senior power system engineer that graduated the Polytechnic University of Bucharest in 2006. Between 2005-2008, he worked for SC ISPE SA, Power Systems Department (Secţia Sisteme Energetice). Since 2008, he works for the Romanian Transmission System Operator - Transelectrica joint stock company – ST Bucuresti, Technic and Grid Analysis Department.

PhD. Osman Bülent TÖR received the B.S., M.S. and Ph.D. degrees from Middle East Technical University (METU), Turkey, in 1998, 2001 and 2008, respectively. He has almost 20 years working experience in the electrical power sector. At this moment, he is working as Managing Partner and Director for EPRA. Prior to this position he was leading the Power Systems Analysis and Planning Department of TÜBİTAK-Ankara, as a chief power system R&D engineer for 12 years, before he left TÜBİTAK and joined to EPRA in 2013.