

COMPARISON OF ANCILLARY SERVICES AND RENEWABLE ENERGY SOURCES' IMPACT ON BALANCING OF THE POWER SYSTEM IN ENTSO-E

USPOREDBA POMOĆNIH USLUGA I UTICAJ OBNOVLJIVIH IZVORA ELEKTRIČNE ENERGIJE NA URAVNOTEŽENJE ELEKTROENERGETSKOG SISTEMA U ENTSO-E

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Abstract: This paper specifies and compares the ancillary services used by transmission system operators in selected countries within ENTSO-E (European Network of Transmission System Operators-Electricity) for operational needs of their transmission systems. The comparison of the ancillary services' unit prices is also given. In addition, analyses of various experiences gained by ENTSO-E countries within their electric power systems in relation to initiatives supporting the power generation from renewable energy sources (RES) and the methods of their integration into the electric power system were made. Namely, depending on the total amount of RES, depending on the incentive system for electricity production from RES and the development of an organized electricity market, different balancing responsibility models for electricity producers from RES were established.

Keywords: Electric power system (EPS), renewable energy sources (RES), ancillary services, ENTSO-E (European Network of Transmission System Operators-Electricity), system balancing, balancing energy market

Sažetak: U ovom radu naznačene su i uspoređene pomoćne usluge koje operatori prijenosnih sistema u odabranim zemljama u ENTSO-E (European Network of Transmission System Operators-Electricity) koriste za potrebe pogona svojih prijenosnih mreža kao i osvrt vezan za usporedbu jediničnih cijena pomoćnih usluga. Također, analizirana su iskustava u elektroenergetskim sistemima (EES-ima) zemalja ENTSO-E s obzirom na poticaje proizvodnje električne energije iz obnovljivih izvora električne energije (OIE), te načina integracije u EES. Naime, zavisno od ukupnog udjela OIE, vrsti sistema poticaja i razvijenosti organizovanog tržišta električne energije, uspostavljeni su različiti modeli odgovornosti povlašćenih proizvođača OIE za odstupanja od planova proizvodnje.

Ključne riječi: Elektroenergetski sistem (EES), obnovljivi izvori električne energije (OIE), pomoćne usluge, ENTSO-E (Evropska mreža operatora elektroenergetskih sistema), uravnoteženje sistema, tržište balansne energije

INTRODUCTION

This paper specifies and compares ancillary services used by transmission system operators in selected countries within ENTSO-E for operational needs of their transmission systems. The comparison of ancillary services' unit prices in those countries is also given. It is important to notice that ancillary services are inconsistently defined and have different specific details in different countries. For this reason ENTSO-E promotes adoption and implementation of common grid codes on ENTSO-E level with the purpose of harmonization and unification of all rules

related to the operation and managing of the electric power system and the electricity market [1], [2].

For introduction we will shortly define the roles of different phases of the frequency regulation. Primary regulation or generation reserve is the active power reserve available to contain system frequency after the occurrence of the imbalance. Secondary regulation is the active power reserve available to restore system frequency to the set point value frequency and to restore power balance to the scheduled value. Tertiary regulation is the active power reserve available to restore or support the required level of secondary reserve to be prepared for possible additional system imbalance, including generation reserve.

Operation and managing of the electric power systems having a significant amount of renewable energy sources are lately becoming increasingly complex. Since it is im-

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possible to expect that "the energy only market" (existing in Western Europe in different variations) would solve the problem of real-time balancing of power systems, it is important to rely on engagement of additional regulation capacities, primarily of secondary and tertiary reserves. This means that in case of a significant increase in the share of renewable energy sources, flexible power capacity for control must greatly increase. Mainly for that reason, there are no organized flexible capacity markets today, and hence there are no market signals for investors to get motivated and to invest balancing capacity building. Also, it becomes the problem to "force" electricity producers to follow "the explosive" development of renewable energy sources if their installed flexible capacities are limited in regard to installed capacity of renewable sources. This problem could be solved by purchasing ancillary services outside of organized markets, or by acquiring the services through some business deals, by purchasing them from transmission system operators, or by offering financial motivation to service providers through incentives and their specific treatment in certain ENTSO-E systems from which data are available [1]–[4].

1. EVALUATION OF PROVIDING AND USING ANCILLARY SERVICES

Ancillary services used by selected transmission system operators in ENTSO-E were analysed. With the purpose of gaining objective insight into ancillary services and situation in some electric power systems it is important to emphasise that there are significant differences between countries. Even main geographic and demographic characteristics and countries' population and land areas indicate differences existing between systems of the selected countries. For example, Germany covering an area of 357 thousand square kilometres, with the population of 82 million, and Italy covering an area of 301 thousand square kilometres, with the population of 59 million, are significantly larger than, for example, Slovenia with an area of 20 thousand square kilometres and the population of 2 million.

Some of the German states such as Bavaria with 71 thousand square kilometres and the population of 12.6 million or Baden-Württemberg with 36 thousand square kilometres and the population of 10.6 million are larger than some of the examined countries [4]. Due to their economic improvement, differences in electricity consumption are even bigger and consequently differences in the system operation and the ancillary services mechanism are bigger as well.

It is also important to emphasise that in some countries, where voltage is under the transmission system operator's liability, there are differences between voltage levels. Also, in some countries the transmission system operator is, beside 400 kV and 220 kV voltage level, liable for 110 kV voltage level, while in other countries the 110 kV voltage level is under the liability of distribution system operators as is case in Hungary and Germany.

In addition to electric power parameters in analysed countries, it is also necessary to indicate variations in the share of renewable energy sources in generation of electricity and in total amount of electricity consumption. The information on the share is based on Eurostat data whose methodology eliminates the impact of meteorological conditions such as a wet or dry year. The share of renewable energy sources in the analysed EU countries is given in Table I.

As there are significant differences between some of the analysed countries and transmission systems, it is also very easy to notice the differences between the ways of collecting network fees i.e. of the ancillary service fee.

The analysis has shown that in Austria even 43% of network fees are paid by producers, in Slovakia this amounts to 3% while in other countries the network fee is paid only by electricity buyers. Slovenia has a separate ancillary services fee, which is paid monthly in accordance with the installed capacity. In some countries, like in Slovenia, primary regulation is not paid and the liability is regulated by the Grid Code while in other countries, like in Germany, this regulation presents large market whose annual amount reaches almost 100 million Euros [5].

Table I: The Share of RES in the analysed EU countries (Eurostat) [4]

State	Slovenia	Austria	Italy	Germany	Hungary	The Czech Rep.	Slovakia	Croatia	EU 28
The share of RES in total electricity consumption	21.5%	32.6%	16.7%	12.4%	9.8%	12.4%	9.8%	18.0%	–
The share of RES in total electricity production	32.8%	68.1%	31.3%	25.0%	6.6%	12.8%	20.85	38.7%	25.4%
The share of HPP in total electricity production	29.5%	56.6%	13.6%	3.7%	0.5%	3.3%	15.5%	34.5%	10.8%
The share of WPP in total electricity production	-	4.2%	4.3%	8.9%	1.7%	0.7%	0.0%	2.5%	7.0%
The share of SPP in total electricity production	1.5%	0.85	6.5%	5.2%	0.1%	2.9%	2.1%	0.1%	2.6%

For all facts given it is not possible to make direct comparison between engagement of certain ancillary services or their unit prices in selected countries.

2. COMPARISON OF UNIT PRICES OF ANCILLARY SERVICES

Based on available data and information this section will provide a review regarding the comparison of ancillary regulation services unit prices (f-P) in examined countries in ENTSO-E.

In case of primary regulation in Austria, The Czech Republic, Germany and Slovakia only so-called capacity reservation (probability) is being valued. In Italy is obligatory to provide certain range of primary regulation and, therefore, no price of capacity reservation (probability) is presented in relation to other systems [6].

Globally calculated fee for providing the service of primary regulation is 97.72 €/MWh for "positive" regulation and 27.08 €/MWh for "negative" regulation.

Slovenian capacity reservation price (probability) is also not presented since no fee is charged for providing the service of primary regulation (f-P).

Without taking into account the price in Hungary due to the specific annual tender for primary regulation procurement and relatively small number of producers, it can be claimed that the average price of capacity reservation (probability) in other analysed systems is nearly 31.75 €/MWh.

Figure 1 presents a diagram comparing prices of capacity reservations (probability) for primary regulation (f-P).

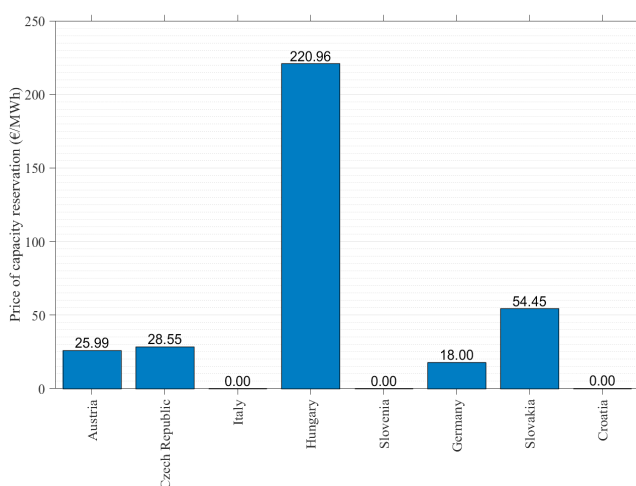


Figure 1: Comparing prices of capacity reservation (probability) for primary regulation [6]

Figure 2 presents comparison of prices of capacity reservation (probability) for secondary regulation. In most of the systems power reserves are procured commonly for "positive" and "negative" secondary regulation. The price in Italy is not

presented since the required regulation is procured through bids related to sale/purchase of energy in €/MWh given for hourly intervals, therefore only data on regulation energy price is given for Italy.

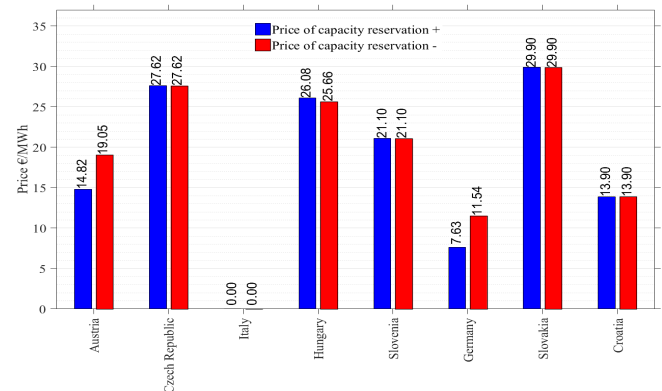


Figure 2: Comparison of capacity reservation prices (probability) for secondary regulation [6]

The average price of capacity reservation (probability) for "positive" secondary regulation in examined systems amounts to nearly 21.19 €/MWh, and for "negative" regulation it is 22.48 €/MWh.

The price of "positive" and "negative" regulation energy activated out of the secondary regulation reserve is presented on Figure 3.

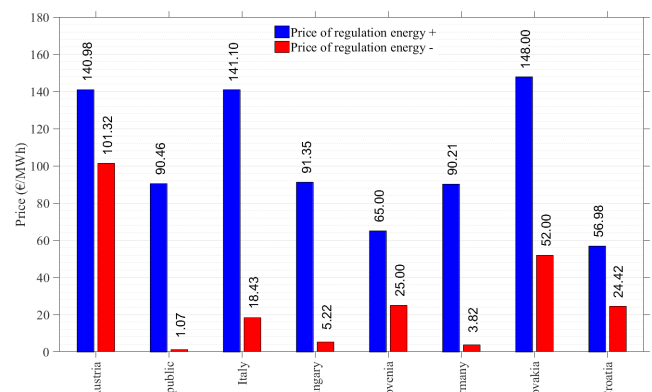


Figure 3: Comparison of regulation energy prices for secondary regulation [6]

It is important to note that the prices presented for Italy and The Czech Republic are not related only to secondary regulation. In case of Italy they are related to secondary and tertiary regulation, and in case of The Czech Republic they relate to total regulation energy.

The average price of "positive" regulation energy in analysed systems amounts to nearly 109.59 €/MWh, and of "negative" regulation energy to 29.55 €/MWh; those prices are significantly higher than 56.98 €/MWh and 24.42 €/MWh as they amount in Croatian system.

Figure 4 presents data on capacity reservation (probability) prices for tertiary regulation. Similar to secondary regulation the price of the capacity reservation (probability) in Italian EPS is not presented, but only the data related to regulation energy price is given.

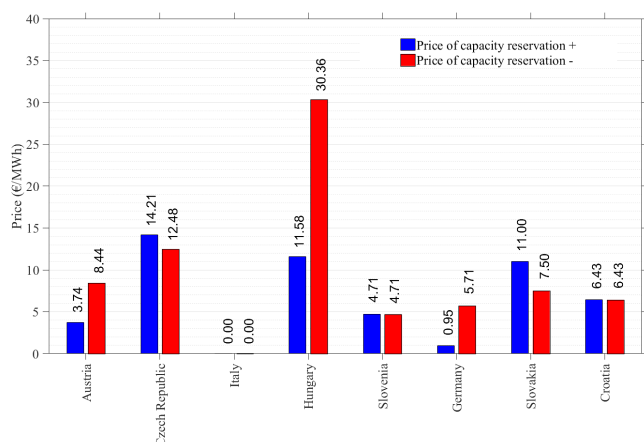


Figure 4: Comparison of capacity reservation (probability) prices for tertiary regulation [6]

The average price of capacity reservation (probability) for "positive" tertiary regulation in the analysed systems amounts to nearly 7.70 €/MWh, and to nearly 11.53 €/MWh for "negative" tertiary regulation.

It is important to point to the fact that higher average price of capacity reservation (probability) for "negative" regulation is the consequence of the price in Hungary which was determined based on only one publicly announced tender in the year 2017. For comparison, in Croatia the average price is lower and amounts to 6.43 €/MWh for both "positive" and "negative" regulation.

Prices for "positive" and "negative" regulation energy activated out of so-called tertiary regulation reserve are presented in Figure 5. As in comparison of regulation energy prices for secondary regulation needs, the prices presented for The Czech Republic and Italy are not referred only to tertiary regulation.

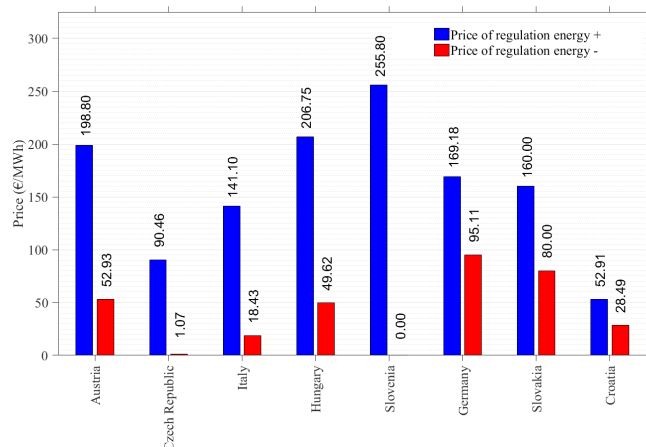


Figure 5: Comparison of regulation energy prices for tertiary regulation [6]

The average price for "positive" regulation energy in selected systems is nearly 174.58 €/MWh and for "negative" regulation energy the price is 49.53 €/MWh. In Croatian EPS those prices amount to 59.91 €/MWh for "positive" and 28.49 €/MWh for "negative" regulation energy.

3. IMPACT OF RENEWABLE ELECTRICITY GENERATION ON THE EPS BALANCING

The methods of integration of privileged producers from RES into the electric power system, as well as promotion of renewable energy source electricity (RES), differ among EU countries.

Depending on total amount of RES (especially of unmanageable wind power plants and solar power plants), and a type of the incentive and the development of organized electricity market, various responsibility models were established for privileged producers from RES in case of their generation schedules deviations [6], [7].

The need to make privileged producers responsible for deviations was increasing as their share was becoming larger in the total structure of electricity production. Privileged producers (primarily unmanageable wind power plants and solar power plants) were not originally responsible for balancing because they had a small share in total system generation mostly consisted of classic "manageable" energy sources (thermal power plants, hydro power plants with large installed capacity, nuclear power plants). As privileged producers' share was increasing and the market was being developed, privileged producers from RES were becoming more "active participants" in the market with clearly defined responsibility for generation schedule deviations.

In countries where privileged producers are responsible for their own deviations this responsibility is related mostly to its financial aspect. Namely, transmission system operators are responsible for managing the power system and procurement of regulation energy in order to ensure real time "physical" balancing to total generation, consumption and exchange. In these circumstances privileged producers are financially responsible for their deviations i.e. they are taking over that part of balancing costs incurred due to their generation schedule deviations.

Sixteen out of twenty-eight EU member states introduced some type of financial responsibility for balancing to all electricity producers including privileged producers. Overall, there were defined three levels of financial responsibility of privileged RES producers for balancing (Table II) [8]:

- No responsibility (responsibility level for balancing 0 in Table II);
- Partial responsibility (a specific mode of balancing for privileged producers or only for those supported by incentives (responsibility level for balancing 1 in Table II);
- Full responsibility (responsibility level for balancing 2 in Table II).

The policy of market exposure is one of the factors playing a part in sharing responsibilities for privileged producers balancing. There is a difference if privileged producers are in the incentive system protected from market influences, for example, the system of guaranteed purchase prices/ fixed tariffs (*Feed-In tariffs* – FIT), or if they are fully or partially present in the market, for example through the premium system (*Feed-in Premium* – FIP), guaranteed quotas (*Quota Obligations* – QO) or competitive procurement procedures.

Larger market exposure of privileged producers is closely related to the level of development of organized electricity market (day ahead market, intraday market, balancing market) [9]. Highly developed, liquid and organized electricity market enables privileged producers or a responsible entity (mostly transmission system operator) to update generation schedules in an intraday electricity market thus significantly reducing schedule deviations and conse-

quently the balancing cost. The level of balancing responsibility of privileged producers is not uniquely identified not even in countries with equal or identical incentive systems and with developed organized market. Crucial points are goals set by each EU country, the policy of privileged producers' exposure to the market, promotion of responsible behaviour of unmanageable RES in the system, establishment of cost control mechanism etc. Comparison of existing incentive systems and financial responsibility levels for balancing of privileged producers in EU member countries is presented in Table II.

Generally it can be concluded that privileged producers are, in non-market oriented incentive systems (e.g. *fixed tariffs* i.e. FIT systems), protected from taking over the responsibility for deviations i.e. for balancing costs. The entity overtaking RES generation (usually TSO) is in most cases responsible for privileged producers' deviations and the balancing cost is paid by the other users of the system.

Table II: Systems of incentives supporting renewable energy generation and responsibility of privileged producers for balancing in EU member countries [10]

Country	System of incentives	Balancing responsibility	Exemption from RES	The level of responsibility for balancing
Austria	FIT	no	-	0
Belgium	quotas	yes	yes	2
Bulgaria	FIT	no	-	0
Croatia	FIT/other	no	-	0
Cyprus	premiums	no	-(planned)	0
Hungary	FIT	yes	yes	1
Ireland/N.Ireland	FIT/(SEM)	Only for SEM	yes	1
Italy	FIR/premiums/other	Partially	yes	1
Latvia	FIT/premiums plan.	yes	yes	1
Lithuania	FIT	no	-	0
Luxembourg	FIT	no	-	0
Malta	FIT	no	-	0
Netherlands	premiums	yes	no	2
Poland	Quotas/FIT and plan	yes	no	2
Portugal	FIT	no	-	0
Romania	quotas	yes	yes	1
Slovakia	FIT	no	-	0
Slovenia	FIT/premiums	Only for premiums	no	1
Spain	FIT/premiums	yes	no	2
Sweden	Quota	yes	no	2
The Czech Rep.	FIT/premiums	no	-	0
Denmark	premiums	yes	no	2
Estonia	Premiums	yes	no	2
Finland	Premiums	yes	no	2
France	FIT	no	-	0
Germany	FIT/premiums	Only for premiums	no	1
Great Britain	Quota/FIT	yes	For FIT	1
Greece	FIT	no	-	0

The method of cost allocation differs among EU countries but ultimately final electricity buyers pay these costs, and producers are involved in some rare cases (without privileged producers). Also, in some countries privileged producers in non-market oriented incentive systems of fixed tariffs are partially taking the responsibility for such deviations and are therefore being encouraged to plan their generation and responsibly behave in the system.

Privileged producers in market-oriented incentive systems (for example premiums i.e. FIP system) are exposed to market principles but not always to market risks. Since RES operators in FIP system directly participate in the market, they also take the responsibility for deviations but in such cases protective mechanisms are introduced with the purpose of reducing their exposure to market risks. Even in countries with functional and liquid electricity market privileged producers who receive premiums are additionally paid for balancing costs through fees paid by final users of the network (mostly final buyers).

It should be noted that whether being supported by an incentive system or not, evaluation of wind power plants' balancing costs (WPP being the dominant RES in EU) is based on the following assumptions and operational experience [11]:

- Forecast error for consumption (the average of 2%);
- Forecast error for wind power plants' generation in regard to planned daily generation (the average of 9% in regard to wind power plants' installed capacity);
- Forecast error for hydro power plants' and thermal power plants' generation (assumed 0%)
- Exchange of electricity performed with neighbouring systems equals to planned exchange;
- Required power reserve for automated secondary regulation is defined in line with ENTSO-E requirements (power depending on hourly load of the system) and on the assumption that it is fully available;
- Remaining deviation is covered by tertiary reserve;
- Assumed time of using wind power plants' connection capacity on an annual basis (2200 hours or more).

4. CONCLUSION

In this paper we compared elements of planning, procurement and contracting of certain ancillary services with comparison of unit prices among EU countries (ENTSO-E). We also showed differences among electric power systems (their size, characteristics) and shares of RES in total electricity generation in selected countries along with different approaches to their treatment. Elements of procurement planning and contracting for a specific ancillary service along with comparison of unit prices in ENTSO-E countries lead to the fact that ancillary services are differently defined across countries, not only by the methodology definitions but also by their specificities, static and dynamic parameters of each EPS.

Due to the above mentioned i.e. by comparing examples from ENTSO-E it can be concluded that it is not possible to directly compare a volume of ancillary services' deployment or their unit prices in selected countries.

The analysis of experience in electric power systems of ENTSO-E in regard to incentives supporting electricity generation from RES and their integration in EPS shows differences between EPSs across different countries. Namely, depending on total share of RES (especially of unmanageable WPPs and SPPs), a type of incentive and the development of organized electricity market, there were established various responsibility models for privileged producers from RES for their generation schedules deviations.

It should be added that planning and forecasting of generation from RES are among the most important activities related to balancing in each EPS with significant share of RES.

Finally, the impact of RES, specifically the impact of wind power plants as the most dominant RES in ENTSO-E, on balancing of the power system is always present whether being supported by an incentive system or not, and the risk i.e. costs are ultimately allocated to final users.

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BIOGRAPHY

Omer Hadžić was born on 25 November 1962 in Sarajevo, Bosnia and Herzegovina. He had completed his primary and secondary education in Sarajevo before he received his B.Sc. and M.Sc. degrees at the Faculty of Electrical Engineering, University of Sarajevo. He was employed at Public Enterprise Electric Utility of Bosnia and Herzegovina in Sarajevo, at ZEKC (Common Electricity Coordination Centre) in Sarajevo, and he now works at NOSBiH (Independent System Operator in BiH). He occupies the position of the Management consultant at NOS-BiH.

Zijad Bajramović was born in 1960 in Bileća, Bosnia and Herzegovina. He graduated in 1983, received his master's degree in 1986, and doctorate degree in 2009 at the Faculty of Electrical Engineering, University of Sarajevo. He has been employed at the Faculty of Electrical Engineering in Sarajevo as Associate Professor and at Public Enterprise Electric Utility of Bosnia and Herzegovina. His area of interest is related to the testing of power equipment, analysis of stationary and transient phenomena in the power systems and electromagnetic compatibility. He is a member of IEEE, International CIGRÉ and BH K CIGRÉ.

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