Synergy of the electric power and gas transmission system regulation in the Republic of Croatia

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***Abstract* – This paper analyzes the possibilities of simultaneous regulation of the electric power and the gas transmission system in the Republic of Croatia. A brief description of the current legal framework in the Republic of Croatia, which regulates balancing both of the systems, is carried out. There are mentioned two variants in which there is a possible regulation synergy both of the systems. Electricity and gas market prices, as well as the prices of the balancing energy in both of the systems, over a period of 18 months, are compared. In the example of the different schedule of the CCGT plant Sisak, there is shown a calculation of potential additional revenues from participation in the regulation synergy both of the systems.**

***Keywords* – regulation synergy, electric power system, gas transmission system, balancing energy, tertiary control**

I. Introduction

Electric power system and gas transmission system are certainly the most complex energy systems nowadays. Whether the energy market integration is implemented at a regional or a country level, each of these systems is characterized by a lack of energy analysis and synergic benefits of a multi-criteria planning and operation of interrelated systems. Considering the geographic position, the structure of the energy sources and the energy storage, the consumption structure and consumption characteristics, the time horizon and the planning intervals, the complexity of the synergic planning and the optimization of the system operation are compounded with the continuation of the increasing trend of the intermittent renewable energy sources (RES) share and with the increased needs of energy storage capacity. The interdependence of impacts on the system operation of electric power and gas transmission system is more evident in the systems with the significant share of RES and combined heat and power (CHP) plants, especially in the areas with a strong temperature influence on the consumption variability. Wind power plants (WPP) have the largest share in the RES. Fig. 1 shows the trend of increased installed power of WPPs and their generation in Croatian electric power system in the past 8 years. There is a continuous growth throughout observed period that certainly affects the balancing of electric power system, as well as the required range of balancing energy and frequency of its activation. Certainly, one of the main tasks of the electric power transmission system operator, as well as of the gas transmission system operator is to ensure

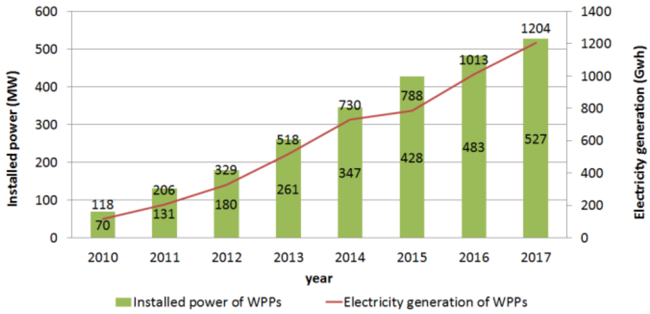

Fig. 1. Installed power and electricity generation of WPPs[1]

sufficient regulation capacity and the balance of the concerned systems. In addition, operators should keep these systems within the prescribed operative parameters, considering the continuous planned exchange of electricity and gas between neighboring systems.

II. Legislative Framework

In the Republic of Croatia, the Croatian Transmission System Operator (HOPS) controls the electric power system while the Croatian Gas Transmission System Operator (Plinacro) manages the gas transmission system.

A. Electric power system

Electric power system operation combines the function of planning, managing, supervising the elements of transmission network and process parameters of the power system in real time, ensuring ancillary services and analysis of transmission network operation. HOPS manages the power system in accordance with ENTSO-E rules and the network codes of transmission system. HOPS makes the operation plan of the power system based on the received plans of cross-border exchange, generation and electricity consumption plans in accordance with the valid rules of the organization of the electricity market. In addition, HOPS coordinates the operation of primary, secondary and tertiary power and frequency control in the power system to achieve a reliable and secure operation of power system and supplies the balancing energy [2, 3].

[1] Data source: [1]

The transmission system operator reduces the control error in the Croatian power system, as well as in the control block. In the case of a deficit or a surplus of electricity, it supplies balancing energy in the following ways:

- activation of contracted ancillary services;
- buying and selling on the market principles;
- buying and selling from other transmission system operators.

All network users, who have proven that they are technically trained, can provide ancillary services. Technical ability to provide specific ancillary services is proven through the ability to provide this ancillary service in accordance with the network codes of the transmission system. Ancillary services are ensured in a transparent and non-discriminatory way, with a mandatory ancillary service provider, and/or through the procurement procedure of the public bidding with predetermined requirements. In accordance with legislation, the transmission system operator, as well as the distribution system operator, is obliged to provide ancillary services in the Republic of Croatia. Nonetheless, only the transmission system operator currently contracts the availability of ancillary services. In the case of ensuring the ancillary services from multiple providers, transmission system operator activates bids by their economic priority [4]. In the context of this paper, among the ancillary services in Croatian power system, regarding to the technical communication solutions and the consequent limitations of the secondary control operation within the control area and/or the control block, it is sensible to observe only the tertiary control, which is briefly described below.

Tertiary control in Croatian electric power system has two functions:

- frequency and power exchange control of the Croatian control area within the control block Slovenia-Croatia-Bosnia and Herzegovina;
- release of the activated secondary control range.

Transmission system operator, taking into account the need to cover the loss of the largest generation unit/maximum load, the need for power reserve from previous periods and the need to release the scope of secondary control, determines the required range of tertiary control. Range of tertiary control must be fully activated within 15 minutes of the transmission system operator's order. The balancing energy, activated in the interval from the setting the order to the deadline of 15 minutes, is recognized when calculating the balancing energy. The transmission network users, who have concluded a contract with the system operator for providing tertiary control, provide the available range of tertiary control. Transmission system operator determines and implements the procedure of verifying the ability to provide the service. Furthermore, it monitors and verifies the declared parameters and the ability of the network users related to the tertiary control [3]. The range of the tertiary control that HOPS is obliged to provide is currently ± 120 MW/h.

B. Gas transmission system

Gas transmission system operator continuously monitors the operation of the gas transmission system to ensure reliable and safe gas transport, efficient and reliable managing of the transmission system, balancing the transmission system and fulfilling contractual obligations under prescribed pressure conditions and gas quality. Monitoring and managing the transmission system operation is carried out continuously in the dispatching center of the gas transmission system operator. Systematic operational control of transmission system, anticipating changes in transmission system accumulation, timely forwarding of information and systematic preventive and corrective maintenance of transmission system facilities enables its safe and reliable operation [5]. Available capacities from the underground gas storage and the gas quantity in the pipelines of the transmission system make the accumulation of the gas transmission system. The characteristics of Croatian gas transmission system are insufficient gas storage capacity and the trend of decreasing domestic gas generation, as well as the dependence on gas imports and the state of cross-border storage capacity.

The gas transmission system operator implements the balancing of the transmission system in accordance with the Commission Regulation (EU) no. 312/2014 about establishing a network code on gas balancing of transmission networks and rules on gas market organization. The balancing zone includes all entries to the transmission system, all exits from the transmission system and the virtual trading point. The transmission system operator establishes the limits of the estimated total imbalance taking into account technical characteristics and physical constraints of the transmission system. If the amount of the estimated total imbalance is outside the published limits of the estimated total imbalance, the transmission system operator takes the following balancing action:

- uses available products at the gas market operator's trading platform as a positive or negative balancing energy;
- uses balancing energy for the balancing service.

The transmission system operator may undertake balancing operations four times during the gas day (from 06:00 AM on the current day until 6:00 AM on the following calendar day), except for extraordinary situations in the transmission system. During the one gas day, the system operator can use positive and negative balancing energy, depending on the needs. Products of a trading platform have the advantage during the balancing unless it is economically justified to activate balancing energy for the balancing service [5]. Since the 1st of April 2017, the limits of the estimated total imbalance are ± 2,500,000 kWh. The transmission system operator does not undertake balancing actions inside of these borders [6]. In the context of this paper, the gas transmission system balancing is observed through the trading platform.

The trading platform is an electronic platform provided and managed by the gas market operator. It allows transparent, non-discriminatory and anonymous trading in accordance with the instructions published by the market operator. Products can be offered within a gas day or for the next gas day. A balance group manager and a gas transmission system operator have the permission to trade in a trading platform [7].

III. The sinergy of regulation

Although the balancing of these two energy systems takes place at the completely different time levels, there are several potential ways of cooperation between regulations both of the systems due to physical dependence. For example, combined cycle gas turbine (CCGT) plants have the ability to increase or decrease the electricity generation according to the needs of the electric transmission system operator, through the participation in tertiary control. On the other hand, if necessary, they can regulate their gas consumption depending on the needs of the gas transmission system operator. The mentioned possibility of regulation is particularly expressed in systems with a significant share of generation from storage hydroelectric power plants (HPP) and with the redundant generation portfolio of boilers for the needs of central heating systems.

If there is a surplus of electricity, and there is a need for the activation of the electricity generation reduction or the downward tertiary control, and, at the same time, in the gas transmission system is present a trend of decreasing pressure during unplanned cold days, which means that there was a lack of natural gas, CCGT plants can simultaneously provide regulation in both systems. Consequently, there occurs the lack of heat energy, which can be solved by starting the peak boilers that generate only thermal energy (hot water and/or industrial steam). In that way, total gas consumption is reduced in the area of the observed central heating system, which was also regulation requirement of the gas transmission system. In this case, large thermal units, such as CCGT unit C in the CHP plant Sisak or CCGT unit K in the CHP plant TE-TO Zagreb, have the opportunity to make the most of their flexibility by reducing electricity generation through tertiary control and consequently lower the natural gas consumption than previously planned. They can achieve additional financial benefits on the market, depending on the electricity and natural gas market price trends, by providing balancing services to the electric power system and gas transmission system. The identical situation is in the opposite direction. If there is a lack of electricity generation in electric power system and, at the same time, a surplus of gas in the gas transmission system, generation units of HEP-Proizvodnja, while respecting the technical limitations, are possible to simultaneously increase both of the electricity generation and gas consumption. In this case, it is necessary to provide sufficient quantities of transport capacities at the observed power plants for potentially increased natural gas consumption. Although, depending on the market prices of electricity and natural gas, it is sometimes more profitable to break the reserved transport capacities if the profit of participating in regulation synergy both of the systems covers additional costs due to exceeding the reserved capacity.

A brief analysis of the activated balancing energy in the Republic of Croatia in the gas transmission system and the activated tertiary control in the electric power system is made. A period of 18 months has been observed. In the period from the January 2017 to the June 2018, there were analyzed days in which the balancing energy is activated in both observed systems. Although the balancing of the electric power system is performed on an hourly or even on a minute level, the analysis is made at daily level due to the longer time intervals of regulation in the gas transmission system. The gas transmission system operator archives data on the activated balancing energy at daily level for each gas day, as the gas transmission system balances over a period of several hours. In one gas day, it is common to activate balancing energy only in one direction. The tertiary control in the electric power system activates almost every day, at least in one direction. Consequently, in the first step, there are separated days with activated balancing energy in the gas transmission system. Thereafter, days with the activated tertiary control in the electric power system, but in the appropriate direction, are searched. If the negative balancing energy in the gas transmission system is activated, which means there is a surplus of gas in the gas transmission system, days with the simultaneous activation of positive tertiary control in electric power system are observed. Reverse situation is also valid. If there is a lack of natural gas in the gas transmission system, hence the positive balancing energy in the gas transmission system is activated, there are observed days with the simultaneous activation of negative tertiary control in the electric power system. In both of the described situations, HEP-Proizvodnja, as a dominant electricity generator and one of the largest natural gas consumers in Croatia, has the ability to participate simultaneously in balancing of the both systems. Fig. 2 shows a number of days, in a given month during the observed period, with the balancing energy activation in the gas transmission system and a number of days with the simultaneous balancing energy activation in both systems. The brighter columns show the number of days with the activated balancing energy in the gas transmission system while the darker columns show the number of days with simultaneous balancing energy activation in both systems. Balancing energy in gas transmission system is activated in 200 days of total 546 days in the observed period. The number of days with activated balancing energy in the gas transmission system is greater during the winter months. It is the consequence of higher natural gas consumption during the colder period of the year, and thus greater deviations from planned consumption. The number of days with the simultaneous activated balancing

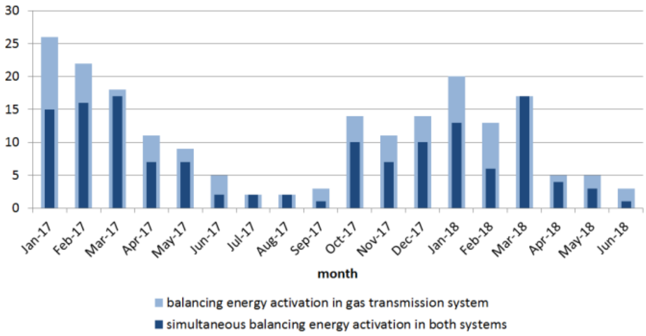

Fig. 2. Number of days with balancing energy activation in both systems[2]

[2] Data source: [8], [9]

energy in the gas transmission system and the tertiary control of the appropriate direction in the electric power system is significant. On average for the observed period, 70% of days with activated balancing energy in the gas transmission system have simultaneous activation of tertiary control of the appropriate direction in the electric power system. Mentioned data shows that there is a significant space for regulation synergy by simultaneously participating in balancing both of the systems and potentially achieving additional profit.

A. Balancing energy prices

Balancing of the Croatian power system is carried out at the hourly level. Balancing electricity prices are related to the hourly prices on the regional electricity exchange, Hungarian power exchange (HUPX) and BSP Energy exchange (BSP South Pool). The price of positive balancing energy that the system operator purchases from service provider through tertiary control is higher by 30% than the current market price for the observed hour. Symmetrically, the price of negative balancing energy, which the operator sells to the service provider, amounts to 70% of the current market price for the observed hour. This way, the balancing service provider is always motivated to provide the service, regardless on direction of the required balancing. For example, we could have a situation when the service provider is a generator. When activating positive tertiary control, service provider increases generation and gets higher price for additional electricity. In the second case, if it is necessary to activate negative tertiary control, service provider reduces generation and replaces it with the energy he buys at a lower price than it is currently on the market. The average hourly prices of electricity on the mentioned regional electricity exchanges for the observed period of 18 months are shown in Fig. 3. The blue line shows the average hourly prices on a work day and the red line the average hourly prices over the weekend. The dash lines show the average hourly prices of positive and negative balancing energy on a work day. A period of 16 hours during the day, from 07:00 AM to 11:00 PM, is additionally marked with vertical black lines. During that period the average electricity prices were higher and partly constant. In addition, in that period thermal power plants (TPP) in the Croatian power system are scheduled at higher power levels and thus they have greater control capacity for downward balancing.

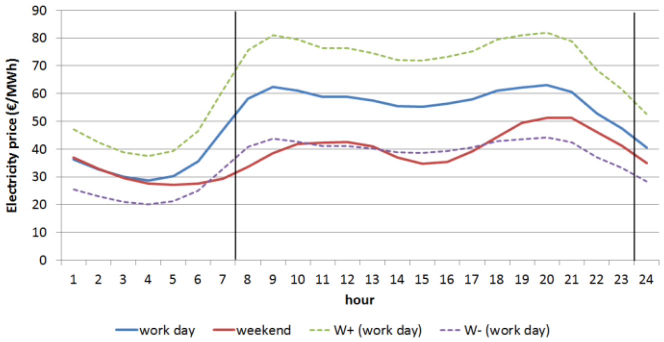

Fig. 3. Average hourly electricity prices[3]

[3] Data source: [10], [11]

Balancing of the gas transmission system in the Republic of Croatia is carried out at the daily level. The gas transmission system operator has the ability to activate the necessary balancing energy several times during the day. If activation of balancing energy occurs, it is most common once a day. Since the April 2017 a trading platform has been in operation. It allows users of the gas transmission system to participate intraday balancing services. Depending on the needs of the gas transmission system, the system operator expresses the need for positive or negative balancing energy. Potential service providers may, within a limited period of time, offer the gas quantities they can take or leave in the gas transmission system. The bid price is determined by the potential service providers. The gas transmission system operator activates the bids to meet the expressed balancing needs. Average monthly prices of gas and balancing energy are shown in Fig. 4. The blue line shows the total average monthly price of natural gas in HEP-Proizvodnja, over the observed period of 18 months. The red dash line shows the average monthly price of positive balancing energy in the gas transmission system, and the green dash line shows the average monthly price of negative balancing energy. In the period from the June to the August 2017, there was no activation of positive balancing energy in the gas transmission system. For this reason, the curve in Fig. 4 is discontinued. In the Croatian gas transmission system, the price of balancing energy is not directly related to the market price, as in the electric power system. Therefore, as can be seen in Fig. 4, it is possible that the price of the positive balancing energy is lower than the total realized gas price. This situation is not stimulative for balancing service providers. It should be mentioned that the conclusion of the long term gas supply contracts is the partial cause of this. Most of the price is predetermined for a longer period while the price of balancing energy partly reflects the situation on the gas market.

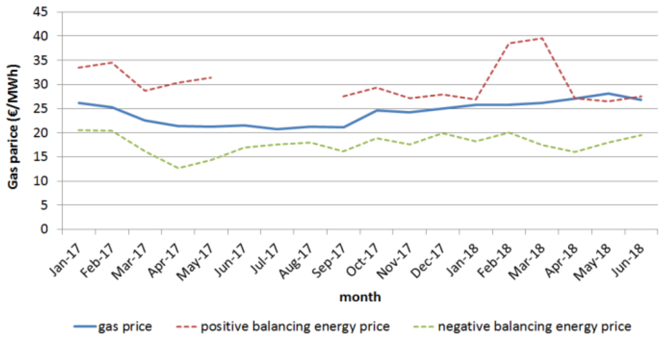

Fig. 4. Average monthly prices of gas and balancing energy[4]

B. Possibilities of CCGT Sisak in the synergy of regulation

In the CHP plant Sisak is installed a CCGT unit (unit C) with nominal power of 230 MWe and 50 MWt. Due to the relatively low heat consumption of the city of Sisak and a significant nominal electric power, unit C is suitable for participation in the synergy of the electric power and gas transmission system regulation in the Republic of Croatia. There are several CCGT units in the HEP-Proizvodnja, such as unit K in the CHP plant TE-TO Zagreb that also have the

[4] Data source: [12]

possibility of simultaneously balancing both of the systems. In the July 2018, a construction contract for a new CCGT unit in the CHP plant EL-TO Zagreb was concluded. Furthermore, a replacement CCGT unit in the CHP plant Osijek is in the high stage of preparing. This paper analyzes the realized data and there are observed possibilities of synergy balancing in the example of the CCGT plant Sisak. For the purpose of analyzing the participation of the CCGT Sisak in the tertiary control in both directions, the range of ± 30 MWe was observed. The chosen range does not disturb the technical limitations of the unit C so it can provide this range of tertiary control throughout the year. In certain periods of the year, depending on the needs of the electric power system, market and hydrological circumstances, as well as the heat consumption and the possibilities of the CCGT Sisak, it is possible to choose a larger range of tertiary control, which further enhances the results of the analysis carried out. Also, it is not necessary that the selected range is the same in both directions. Symmetrically, the gas consumption of the CCGT Sisak of ± 48 MWh was considered, which approximately corresponds to the power change of ± 30 MWe.

As described at the beginning of the chapter, there are two variants in which there is a possibility of simultaneously balancing both of the systems. Within the observed period of 18 months there is a total of 140 days in which the balancing energy of the gas transmission system and the tertiary control of the appropriate direction in the electric power system are activated at the same time. More detailed analyzes were given for days in which the positive balancing energy in the gas transmission system and negative tertiary control in the power system were activated. In total, there were 31 these kinds of days in the observed period. Both balancing energy were also activated in the remaining 109 days, but in the opposite direction. So, in these days the negative balancing energy of the gas transmission system and the positive tertiary control in the power system were activated. An analysis was made for the first variant since there was a less of data and the graphic display was simpler. Within one day, data on electricity generation of CCGT Sisak were analyzed in the period of 16 hours, from 07:00 AM to 11:00 PM. This part of the day is actually the period of the higher electricity tariff (expensive electricity). If CCGT Sisak is scheduled in that period of day, it operates usually at 160 MW or more, which is a precondition for participation in negative tertiary control. During the night hours, actually in the period of the lower electricity tariff, CCGT Sisak operates at minimum power or it is out of operation. This precondition was met in 15 days. Fig. 5 shows the potential additional revenues of CCGT Sisak from the regulation synergy both of the systems. Calculated revenues could be achieved without correcting the schedule of the remaining power plants in the observed days. The analysis includes the revenues from the positive balancing energy for the gas transmission system (blue), the lower CO_2 emission (red), the secured range of tertiary control (green) and the negative balancing energy in the power system (purple). Revenue from balancing energy in the gas transmission system was based on the difference between the average monthly gas price and the price of positive balancing energy that operator pays to the service provider. Because of the lower gas consumption, the cost of CO_2 emission units is

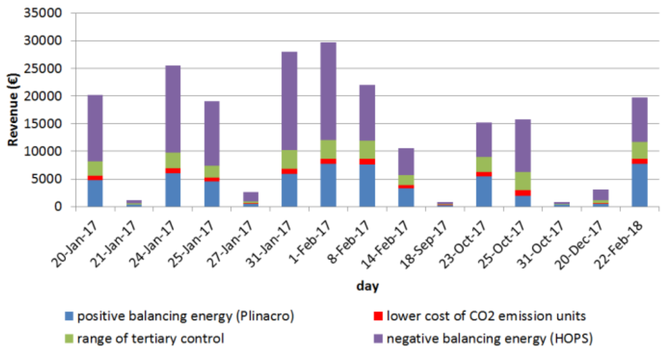

Fig. 5. Potential revenues of CCGT Sisak from synergy of regulation

lower. Revenue from the provided range of tertiary control in the electric power system is included only for the amount of reduced electricity generation. When scheduling a power plant for participating in the synergy both of the systems, secured range of the tertiary control, as well as its part of the revenue would be higher than the actually activated balancing energy through the tertiary control. Revenue from the balancing energy of tertiary control in the power system was based on the difference in the market price of electricity and 30% lower price of the negative balancing energy that the operator sells to the service provider.

In the second variant, when there is a surplus of gas in the gas transmission system and a lack of the electricity in the power system, CCGT Sisak should increase its gas consumption, as well as the electricity generation. In that case, an additional cost of the CO_2 emission would occur. Although the price of the CO_2 emission has increased several times over the past year [13], the additional cost, as a result of the higher gas consumption, can be covered by the provided range of tertiary control. If the schedule of the CCGT Sisak would be planned in advance for possible simultaneously balancing both of the systems, the base power should be planned at approximately 180 MW. This ensures a range of 30 MW for tertiary control in both directions, which covers additional costs of CO_2 emission. The additional realized income from balancing energy in both systems, in this variant as well, justifies the profitability of regulation synergy. In this variant, it is necessary to ensure additional amounts of transport capacity for increased gas consumption during the possible activation of balancing energy. That also creates additional costs. Good planning and optimization of the annual capacity purchase could minimize this extra cost.

Apart from the carried out analysis of potential revenues with achieved schedule of CCGT Sisak, the possible revenues along with the planned schedule that is made with the aim of participation in regulation synergy both of the systems were analyzed. Here is considered the option that the CCGT Sisak was in operation every day, from the observed 31, when regulation in both of the systems was activated simultaneous. The difference is in maximizing the profit from the activated balancing energy. The amount of activated balancing energy in the electric power system is usually smaller (in megawatt hours) than the balancing energy in the gas transmission system. Consequently, the balancing energy in the power system is the main constraint of participation in regulation

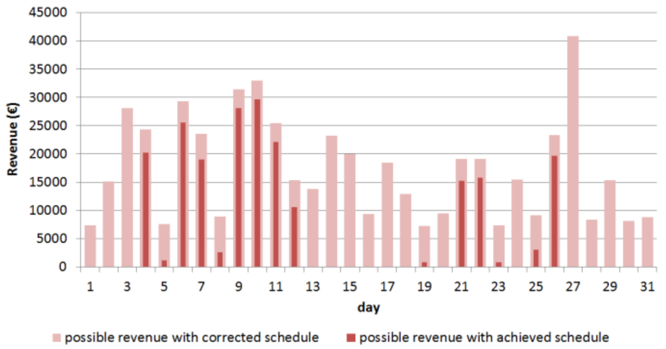

Fig. 6. Comparison of possible revenues with corrected and achieved schedule

synergy both of the systems. The comparison of the total revenue in the variant without the correction in the schedule and the total revenue with the corrected schedule is shown in Fig. 6. The brighter color shows the total possible revenue with the corrected schedule while the darker color shows the possible revenue along with the achieved schedule. In this case, the revenue from the provided range of ± 30 MW of tertiary control, over the observed 16 hours on each day, was calculated. There is considerable space to gain additional financial benefit of participating in regulation synergy both of the systems. The base power of 180 MWe for CCGT Sisak, in the observed period of time during a day, is not a significant deviation from the usual schedule. However, with this amount of base power it is possible to generate significant additional revenue. If CCGT Sisak is scheduled at maximum power, there is always an option of regulation synergy at least in one direction.

IV. Conclusion

The regulation and balancing of the electric power system, as well as the gas transmission system, are complex processes. The operator of the particular system is in charge for these processes. Balancing each of the systems in the Republic of Croatia is currently carried out independently from each other. There is a possibility of achieving additional financial benefits of simultaneously participating in balancing both of the systems.

When there is a simultaneous imbalance in the electric power system, as well as in the gas transmission system, TPPs in portfolio of HEP-Proizvodnja have an opportunity to participate in regulation both of the systems at the same time. Flexible electricity generation and flexible gas consumption enable them adaptation to the needs both of the systems. Considering the balancing of the electric power system, in most cases, is carried out in a minute level and of the gas transmission system over a few hours, providing regulation in both systems is possible even when these deviations do not occur at the same time. Furthermore, there are also newer technologies, such as gas engines, electric boilers and heat accumulators, which can also participate in or support combined regulation of the relevant energy systems. These technologies are not currently largely represented in the Republic of Croatia, but their potential to generate additional revenues through flexibility and the ability to react quickly, depending on market changes, is becoming more and more apparent, when selecting and designing new generation units and energy storage.

The gas transmission system operator in the Republic of Croatia in mid-2017 launched a trading platform for intraday deviation trading with the balance responsible parties. In this way, all customers of the gas transmission system are enabled to participate in the trading of natural gas surpluses on a daily basis. HEP-Proizvodnja, as a market participant and a simultaneous user both of the electric power and the gas transmission system, has the ability to make the most of described benefits and they can be achieved through the synergy regulation both of the systems. The generation portfolio of HEP-Proizvodnja enables flexibility in balancing the electricity generation between HPPs and TPPs, as well as intraday reschedule in order to provide necessary regulation.

It is an undeniable fact that negligible natural gas storage capacities, a significant generation share and storage capacities of HPPs, as well as the legally revised status of the pumped-storage hydroelectric power plants (PSHPP) in the Republic of Croatia ensure a specific positioning of the generation portfolio of HEP-Proizvodnja on the market and contribute to the development of the regional, as well as the domicile, ancillary services market. Also, the benefits to the end-customers are certain in both systems because the synergy of regulation reduces the actual cost of regulation services, regardless if they are regulated by the rate of service providing or there is an ancillary service market established.

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