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RELIABILITY INDICES IN THE BOSNIA AND HERZEGOVINA TRANSMISSION NETWORK – THE BASIS OF AN INCENTIVE REGULATION MODEL

POKAZATELJI POUZDANOSTI PRIJENOSNE MREŽE BOSNE I HERCEGOVINE – PODLOGA MODELU POTICAJNE REGULACIJE

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Abstract: The Transmission Company keeps records of contingency events, while the obtained reliability indices for the whole transmission network are presented on a monthly/annual basis and as such they can be used for benchmarking with other power systems. In view of the territorial organisation of the Company (four Operational Areas-OAs), a new approach to calculation of the reliability indices for each OA separately has been presented in this paper. For the period 2009 – 2016, the obtained indices were compared per OAs and appropriate recommendations and conclusions were provided accordingly. The interdependency of the indices and some specific costs which are determined through the tariff proceedings for the Company has also been analysed. The obtained indices can be a starting point for policy creators to determine an initial minimum standard of the continuity and reliability of supply which can be used in the future to introduce some of the incentive regulation models into the BiH transmission network.

Keywords: reliability, transmission network, unplanned interruption, SAIFI, SAIDI, CAIDI, incentive regulation

Sažetak: Prijenosna kompanija vodi statistiku pogonskih događaja, a pokazatelji pouzdanosti za cjelokupnu prijenosnu mrežu prezentiraju se na mjesečnoj/godišnjoj razini i kao takvi mogu poslužiti za usporedne analize s drugim elektroenergetskim sustavima. S obzirom na teritorijalnu organizaciju kompanije (četiri operativna područja), u radu je predstavljen novi pristup izračuna pokazatelja pouzdanosti za svako operativno područje pojedinačno, za razdoblje 2009. - 2016. godine, te su date odgovarajuće preporuke i zaključci. Analizirana je i međusobna ovisnost pokazatelja s nekim specifičnim troškovima koji se utvrđuju kroz tarifni postupak za kompaniju. Dobijeni pokazatelji mogu biti inicijalna vodilja kreatorima elektroenergetske politike za određivanje početnog minimalnog standarda neprekidnosti i pouzdanosti napajanja, koji bi u budućnosti mogao poslužiti u svrhu uvođenja nekog od modela poticajne regulacije za prijenosnu mrežu Bosne i Hercegovine.

Ključne riječi: pouzdanost, prijenosna mreža, neplanirani zastoj, SAIFI, SAIDI, CAIDI, poticajna regulacija

INTRODUCTION

The energy sector, usually including electricity, gas and heating, has some inherent features and, therefore, all companies in this sector are subject to regulation by regulatory bodies. When it comes to the energy sector, and, specifically, its transmission part in Bosnia and Herzegovina (BiH), one can say that it is organised into a separate corporate structure made of two companies: “Neovisni operator sustava u BiH” (Independent System Operator) Sarajevo (NOS BiH) and transmission company “Elektro-prijenos BiH” d.d. Banja Luka (Company). With regard to the transmission system in Bosnia and Herzegovina (en-

tities with natural monopoly), regulation is carried out by the BiH State Electricity Regulatory Commission (SERC). The main task of the NOS BiH is to manage the transmission system for the purpose of ensuring the reliability of the BiH power system. The activities of the Company are the transmission of electricity and all activities related to the transmission of electricity, including, but not limited to, the transmission of electricity, maintenance, construction and expansion of the transmission network in Bosnia and Herzegovina. The Company is organised based on territorial, operational and functional principles, with divided competences, responsibilities and authorities [1].

The Company includes four Operational Areas for operation, maintenance and expansion of the transmission system, in the following geographical units:

OA1: Operational Area Banja Luka, includes two field units: Banja Luka and Bihac,

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OA2: Operational Area Tuzla, includes two field units: Tuzla and Doboje,

OA3: Operational Area Sarajevo, includes three field units: Sarajevo, Zenica and Visegrad,

OA4: Operational Area Mostar, includes two field units: Mostar and Trebinje.

The paper presents the reliability indices for planned and unplanned interruptions at the level of the Company, and they were calculated also for the Operational Areas, based on data on unplanned interruptions in the transmission network under the competence of the Company.

1. RELIABILITY INDICES IN TRANSMISSION NETWORK OF BIH

The reliability of power supply, as an important parameter of power quality, is gaining the importance among different users of the energy sector. Analysing the reliability of power supply, as a regulatory function, one usually considers the quality of power-related activities of distribution and supply. However, the reliability of supply is also of significant importance when it comes to the transmission network, because the unwanted interruptions in electricity connection points can lead to interruption in supply for a large number of consumers, and sometimes a total collapse of a part or the whole system. It is, therefore, of utmost importance to keep the reliability of transmission system on a high level. The quantification of transmission system reliability in BiH is carried out through the reliability indices usually extracted from the data on volume of undelivered power and energy, length of interruption period and frequency of interruptions in supply.

1.1. Load and Power Oriented Indices

As for the power supply system in BiH (its transmission part), the quality of operation is monitored through analysis of the Company's data on technical aspects of the transmission system operation, presented through traditional indices of uninterrupted and reliable supply (URS) of transmission network consumers, i.e. the energy not supplied index - ENS, and the average interrupted time index - AIT on high-voltage transmission network, as a measure for evaluation of transmission network reliability. These indices have already been analysed and processed in [2] and are now only stated.

1.2. Consumer-Oriented Indices

Considering that the Company owns all 110/x/y kV substations, including also middle-voltage feeders (35, 20 or 10 kV), in these substations, usually being in function of distribution, monitoring of supply interruptions on that lev-

el is given an additional attention. Namely, the quality of URS in the transmission network in BiH is shown also by the SAIFI and SAIDI parameters. The SAIFI index (System Average Interruption Frequency Index) indicates an average number of interruptions in supply (outages) per consumer during a year or an average frequency of interruptions of the system, while the SAIDI (System Average Interruption Duration Index) indicates average interruption duration in minutes per consumer, during a year, or an average duration of system interruption. The SAIFI and SAIDI indices result from monitoring the number and duration of long-term interruptions (planned and unplanned), in the facilities of Elektroprijenos, which led to interruption in supply of consumers directly connected to the transmission network and/or voltage-free feeders exceeding three minutes. The focus of this paper will be placed on an analysis of consumer-oriented indices, which are calculated for the transmission network based on contingency events statistics kept by the Company. The indices are related to a specific field of electricity consumption (a part or the whole network) with a known number of consumers, observed through a specific time period. A total of 1,421,763 consumers were covered by this analysis for each year.

The third derived reliability index of power supply for the needs of analysis in this paper is the CAIDI index, (Customer Average Interruption Duration Index), and it indicates an average annual duration of one interruption per consumer, in minutes, where the consumer was affected, i.e. an average duration of consumer interruption. If it is assumed that an observed area of power consumption has N_T consumers, and during the reporting period (usually one year) m number of interruptions occurs, then N_i number of consumers with total consumption power of P_i was affected by each i supply interruption of D_i minutes. [3]. The supply reliability indices for the given area can be mathematically calculated using the following equations:

$$SAIFI = \frac{\sum_{i=1}^m N_i}{N_T} \quad (1)$$

$$SAIDI = \frac{\sum_{i=1}^m D_i N_i}{N_T} \quad (2)$$

$$CAIDI = \frac{\sum_{i=1}^m D_i N_i}{\sum_{i=1}^m N_i} \quad (3)$$

All four distribution companies (JP EP BiH and JP EP HZHB in FBiH, MH ERS in RS), for whom the responsibility lies with the Entity regulatory bodies (FERK and RERS), and JP "Komunalno Brcko" in the Brcko District (responsibility of SERC) also calculate the standard SAIFI and SAIDI indices, but for lower voltage levels.

2. TYPES OF INTERRUPTIONS IN TRANSMISSION NETWORK

The Transmission Company maintains a register of planned and unplanned interruptions in the transmission network facilities.

2.1. Planned Interruptions

A planned interruption is a condition of an observed unit put out of operation, created consciously, through planned disconnection but not an outage, for the purpose of implementing a plan, such as a maintenance plan, fixing shortcomings, preventive diagnostics, etc. Such an interruption does not usually affect the system users, but only impacts the redundancy of the system. The users are usually informed on planned interruptions beforehand. The data on planned interruptions are not included in the calculation of characteristic system reliability indices. Planned non-availabilities should not lead to supply interruptions, because they are planned interruptions and it is assumed that the planning process provided for alternative supply in accordance with the level of system's development. The exception to this is radially supplied areas, where planned interruptions create costs for the users [4]. Collection of data on planned disconnections is also necessary for other purposes, such as system planning, keeping statistics for the given system component, etc. Table I shows numerical values of consumer-oriented reliability indices for planned interruptions from 2009 to 2016. The TSAIFIp (Transmission SAIFIp) and TSAIDIp (Transmission SAIDIp) indices consider planned interruptions on middle-voltage feeders in TS 110/x/y kV due to works in the network under the responsibility of Elektroprivrenos BiH, while the SAIFIp and SAIDIp indices consider planned interruptions on middle-voltage feeder in substations, but caused by works in the distribution network, under the responsibility of DSOs. For better visualisation of tabular values, the reliability indices due to planned interruptions TSAIFIp and SAIFIp, or TSAIDIp and SAIDIp are shown in Figure 1 and Figure 2 respectively.

It is obvious that an average number of supply interruptions decreases year after year, when it comes

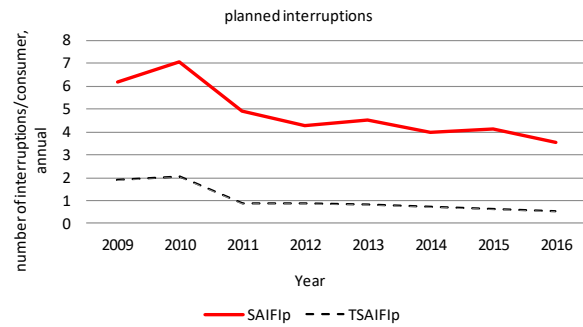


Figure 1: Aggregated TSAIFIp and SAIFIp indices in the BiH transmission network

to planned interruptions. This is specifically so for the TSAIFIp indices with presence of an almost linear trend of reduction over the last six years. An average value of the aggregated TSAIFIp and SAIFIp indices in the BiH transmission network for the 8-year period, amounts to 2.94 interruptions per consumer.

Interestingly, according to the sixth CEER (Council of European Energy Regulators) Benchmarking Report on the quality of electricity and gas supply twenty European countries have an average number of interruptions less than one in total, in the period 2002 - 2014. This average for the power system of the Republic of Croatia, as an EU member state and a neighbouring country to us, in

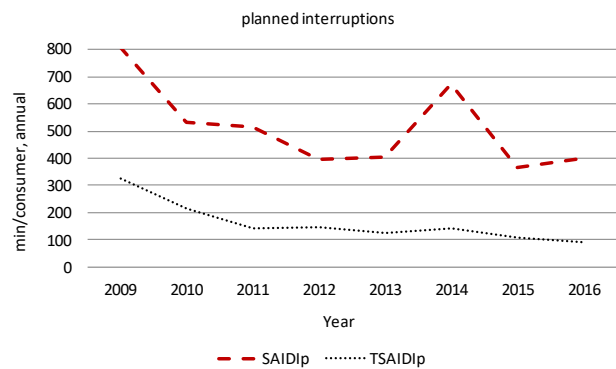


Figure 2: Aggregated TSAIDIp and SAIDIp indices in the BiH transmission network

Table I: Reliability indices for the transmission network in BiH (planned interruptions)

	2009	2010	2011	2012	2013	2014	2015	2016
TSAIFIp (number of interruptions/ consumer, annual)	1.89	2.06	0.9	0.87	0.83	0.72	0.65	0.55
TSAIDIp (min/consumer, annual)	324.46	213.07	142.69	146.62	124.36	143.84	108.53	92.92
SAIFIp (number of interruptions/ consumer, annual)	6.16	7.08	4.93	4.27	4.52	3.99	4.12	3.53
SAIDIp (min/consumer, annual)	810.02	533.78	516.17	393.93	404.33	671.6	365.77	399.12

the period from 2006 to 2014, amounts to 2.17 interruptions [4].

Average supply interruption time also has a declining trend in the observed period. The exception is 2014, marked by extreme flooding in May and August in BiH, when the distribution network was affected harsher than the transmission network, as shown in Figure 2. An average value of the aggregated TSAIDIp and SAIDIp indices in the BiH transmission network for the 8-year period, amounts to 336.95 interruptions per consumer. During the period from 2002 to 2014, fourteen European countries had the average supply interruption time value of less than 100 minutes. This average for the power system of the Republic of Croatia in the period from 2006 to 2014 amounts to 335.55 minutes [4]. Generally, the value of the SAIFI and/or SAIDI for planned interruptions indicates the need for reorganisation of maintenance services, as well as the need for rational planning of the sequence of works, in order to avoid unnecessary interruptions.

2.2. Unplanned Interruptions

Unplanned failures within the power system, lead to disconnection of system components and depending on the size of network affected by the failure, as well as an adequate protection system response, it may lead to a supply interruption for the affected consumers, which is then considered as an unplanned interruption. The interruptions exceeding 3 minutes are usually considered. In a number of countries, unplanned interruptions are exclusively the field of regulation. In the analyses thereof, unplanned interruptions do not include unplanned interruptions caused by a major event (or any other exceptional event), or damages done by third parties [5]. A major event means all events and circumstances that could not have been prevented even if they had been foreseen, and those that one cannot influence, reduce, eliminate or cancel. Lack of explicit information when analysing the category of exceptional events for BiH transmission network, limits the impact of indices on the final result. Namely, a good portion of the events can be listed under the category of "exceptional events" or "external causes", and those do not have to be directly reflected in the statistics of events, but are rather treated separately. It is sometimes difficult to evaluate based on available data whether to list an event under third party responsibility or as an exceptional event. Therefore, it is important to establish clear criteria to define the cause of interruptions and strive towards their accurate classification. Should the statistical data contain interruptions caused by exceptional events, then it is of utmost importance to know their share when analysing the URS data. An exceptional event is outside the control of the system operator (transmission or distribution) and it is characterised as follows:

unpredictable, unavoidable, unpreventable. For example, in 2002, the Austrian power network was exposed to an outage due to serious flooding and the national operator of transmission system APG (Austrian Power Grid) removed a number of unplanned interruptions from the statistic of contingency events, because they were not representative of the network situation.

Furthermore, the unplanned interruption, considering its duration, can be: permanent, temporary and transient (the terminology Company uses are: active, forced and transient). The permanent interruption is the one caused by failure of a component or an element of a unit, where the unit continues its operation after the repair. The temporary interruption is the one where the unit continues operation after its disconnection without repair or replacement of any of its components, while the transient interruption is the one where the unit continues operation after disconnection and successful operation of APU (automatic reconnection). The age of a unit will have an impact only on the scope of permanent interruptions, while temporary and transient interruptions will occur regardless of the age of the observed unit, and are, therefore, of interest for the reliability analysis. Interruption causes can be classified into three basic categories:

1. own or internal cause, presenting the responsibility of the entity,
2. alien or external cause, presenting the responsibility of a third party,
3. exceptional event and/or major event.

The IEEE System Design Working Group developed a statistical methodology for automated recognition of interruption cause. The procedure is known as "2.5 Beta Method", classifying all events into two sets of data. Using this method, the power entities are able to identify "Major Event Days" - MED, and correct abnormal deviations of the system [6].

Table II shows consumer-oriented indices for the previous eight years for unplanned interruptions considering all previously listed causes. The given data cover the whole BiH transmission network and they are published in the SERC's report [7] (together with other indices).

We differentiate two types of consumer-oriented indices, calculated by the Company when it comes to unplanned interruptions. The TSAIFlu (Transmission SAIFlu) and TSAIDlu (Transmission SAIDlu) indices consider unplanned interruptions of middle-voltage feeder, caused by events in the network under the responsibility of Elektroprivnos BiH. Hence, they show the responsibility of the entity (Company). The SAIFlu and SAIDlu indices take into consideration unplanned interruptions of middle-voltage feeder in Elektroprivnos' substations, caused by the events in the distribution network, which would mean the

Table II: Reliability indices for the transmission network in BiH (unplanned interruptions)

	2009	2010	2011	2012	2013	2014	2015	2016
TSAIFlu (number of interruptions/consumer, annual)	1.73	1.00	0.94	1.16	1.01	0.80	0.90	0.97
TSAIDlu (min/consumer, annual)	77.14	94.17	52.00	142.24	55.69	277.15	76.00	68.61
SAIFlu (number of interruptions/ consumer, annual)	11.85	10.04	9.07	8.53	9.35	7.61	7.76	5.78
SAIDlu (min/consumer, annual)	661.66	742.87	459.32	729.96	474.87	678.42	532.99	371.99

responsibility of DSOs. It is important to emphasise that due to lack of classification of causes for interruptions by the Company, both categories include interruptions caused by exceptional events/major events, and acts of third parties. The term of exceptional event and/or major event has not been explicitly defined in the Network Code by NOS BiH, either. Chapter 9.6. of the Network Code, mentions the unforeseen circumstances only [8]. The above is clearly presented in Figure 3, showing the TSAIFlu and SAIFlu indices, and Figure 4 presenting the TSAIDlu and SAIDlu indices for other unplanned interruptions, including all events (causes of interruptions).

The average value of the number of interruptions per consumer for the TSAIFlu and SAIFlu indices in the presented 8-year period amounts to 4.9 interruptions/consumer.

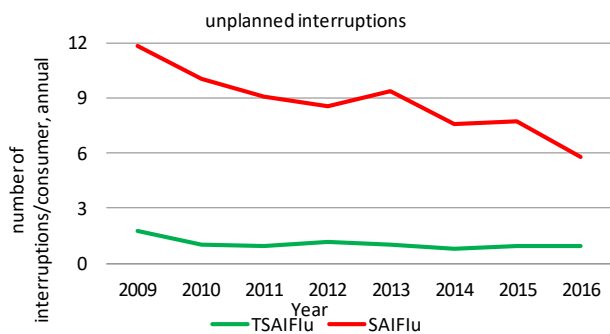


Figure 3: Aggregated TSAIFlu and SAIFlu indices in the BiH transmission network

It is obvious that the SAIFlu and SAIDlu indices (red line) are significantly less favourable considering expansion and size of distribution network, susceptible in practice to different types of failures. Namely, a failure in the distribution network often leads to an outage of the interconnected middle-voltage feeder in TS 110/x/y kV, owned by the Company. Nonetheless, a declining trend can be noticed, i.e. a decrease of the number of interruptions during the observed period. Therefore, the SAIFlu index in 2009 had an average of 12 interruptions per consumer, while the same number in 2016 was cut in half amounting to 6 interruptions per consumer.

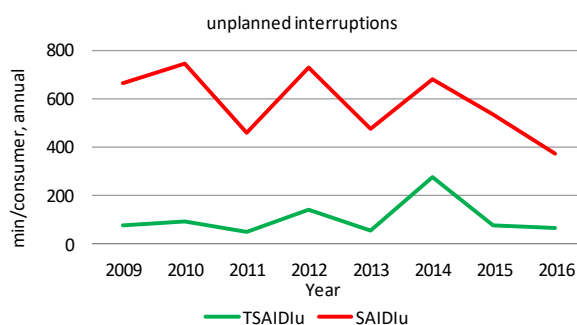


Figure 4: TSAIDlu and SAIDlu indices in the BiH transmission network

The average supply interruption time in minutes per consumer for the TSAIDlu and SAIDlu indices in the presented 8-year period amounts to 343.44 min/consumer. Comparing Figure 3 and Figure 4, one can say that the variation of interruption instances, year after year is lower than variation of interruption time. This is because more extreme events in the system more frequently result in a smaller number of longer interruptions than a higher number of short-term interruptions.

For comparison purposes, the values of SAIFI and SAIDI indices related to unplanned long-term interruptions, including all events (also major events), happening on all voltage levels for the Polish power system in the period from 2007 to 2014, amounted to an average of 3.62 interruptions/consumer, i.e. about 340 min/consumer, respectively. Nonetheless, the following needs to be emphasised: majority of electricity generated in Poland comes from thermal power plants (similarly to BiH). Poland is six times larger in territory than BiH; installed fossil fuel power plant capacity amounts to 29420 MW or 84.22%, while the share of hydro power plants and power plants using renewable energy sources amounts to 2344 MW or 6.71% and 3169 MW or 9.07% respectively (situation as of 31/12/2012, source EGE 5/2014). Generation from renewable sources only, amounts to more than 12 GWh annually, and the transmission network is more than six times longer than the BiH transmission network [4], [9].

Furthermore, for the purpose of this analysis, we will analyse only the TSAIFlu and TSAIDlu indices, having in mind that

they are the only ones that can be subject to regulation by a regulatory body, because they take into the consideration the resulting unplanned interruptions in the transmission network, under the control of the Company and without classification (by cause of interruption). Namely, due to the currently undefined procedure for the statistics of interruptions, kept by the Company, the TSAIFlu and TSAIDlu indices take into consideration *de facto* unplanned interruptions, occurred by the responsibility of the Company, but they also consider the interruptions occurred due to action of a third party, as well as those characterised as major events. Unplanned middle-voltage feeder interruptions, caused by events in the distribution network, are described by the SAIFlu and SAIDlu indices, and they are not used in the following analysis.

3. OPERATIONAL AREA BASED RELIABILITY INDICES - METHODOLOGY

As previously stated, the Company is made of four Operational Area. Nonetheless, the introduction of URS index by operational areas is not current practice of the Company. Lack of such a break-down of indices and their comparison per Operational Areas creates an additional obstacle in making regulatory decisions on the required measures for the purpose of URS improvements. Although the transmission network is technically almost the same all over BiH territory, these indices can significantly differ for different areas of consumption. A logical question is: "What would then be the value of these indices per Operational Areas?"

The new methodology proposed is to have URS indices calculated per OAs. In this regard, an analysis of unplanned interruptions for each OA individually was car-

ried out, based on the statistics of contingency events, which the Company was responsible for, and using the equation (1). The resulting values of TSAIFu for the four OAs (Figure 5) and their average for the period from 2009 to 2016, (Figure 6), are presented in Table III.

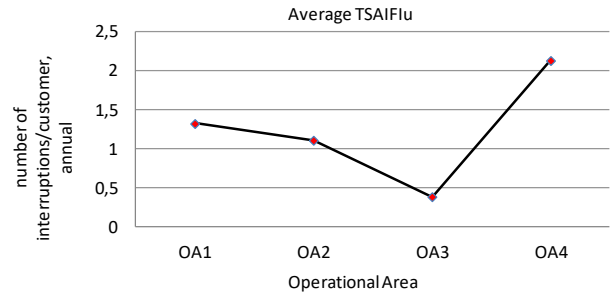


Figure 6: TSAIFlu average per OA (2009 - 2016)

Obviously, the lowest average value of TSAIFlu index is for OA3, followed by OA2 and OA1. The highest average value for the eight observed years is with OA4.

Statistical analysis of the available data (containing all unplanned interruptions, broken down per cause of interruption in the BiH transmission network) for the period 2009 - 2016, with use of equation (2), provided for calculation of unplanned interruption time per OA, i.e. the TSAIDlu index presented in minutes per consumer and per year is presented in Table IV.

These values are graphically presented in Figure 7, with a remark that the values of the TSAIDlu index have been limited to the maximum value of 200 min/consumer, providing for easier overview. Otherwise, the values of TSAIDlu in individual cases go even higher (713.9 min/consumer for OA2 in 2014, and 690.8 min/consumer for OA4 in 2012).

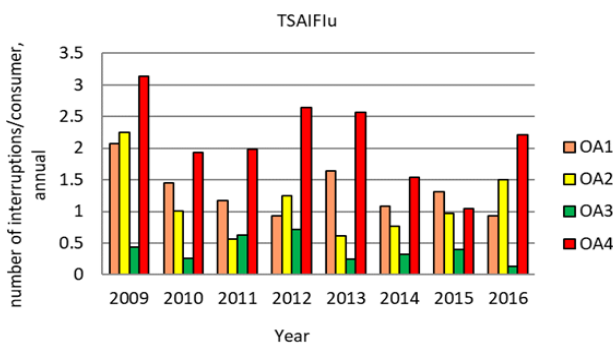


Figure 5: TSAIFlu per Operational Areas

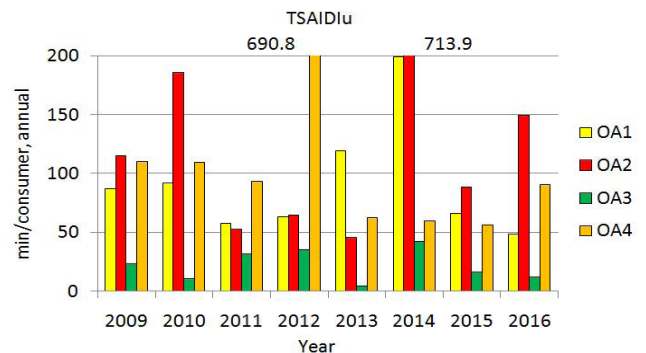


Figure 7: TSAIDlu per Operational Areas

Table III: TSAIFlu indices per Operational Areas

	2009	2010	2011	2012	2013	2014	2015	2016	TSAIFlu average (number of interruptions/consumer)
OA1	2.075	1.455	1.176	0.935	1.646	1.082	1.3109	0.9335	1.327
OA2	2.247	1.001	0.565	1.242	0.613	0.771	0.9636	1.4998	1.113
OA3	0.441	0.258	0.623	0.720	0.244	0.318	0.3944	0.1269	0.391
OA4	3.140	1.929	1.987	2.644	2.573	1.545	1.0397	2.2092	2.133

Table IV: TSAIDlu indices per Operational Areas

	2009	2010	2011	2012	2013	2014	2015	2016	TSAIFlu average (number of interruptions/ consumer)
OA1	87.047	91.837	57.683	63.088	119.545	199.394	66.26	48.27	91.685
OA2	114.889	185.549	52.779	64.574	46.003	713.919	88.85	149.21	176.972
OA3	23.036	10.522	31.775	35.021	4.410	42.341	16.35	12.07	21.941
OA4	110.475	109.506	93.443	690.788	62.468	59.966	56.18	90.60	159.178

Average values per OA for the observed period are given in Figure 8. The lowest values of TSAIDlu index are observed in OA3 again, while the highest value is with OA2 which is also significantly higher in the 8-year average, followed by OA4 and OA1.

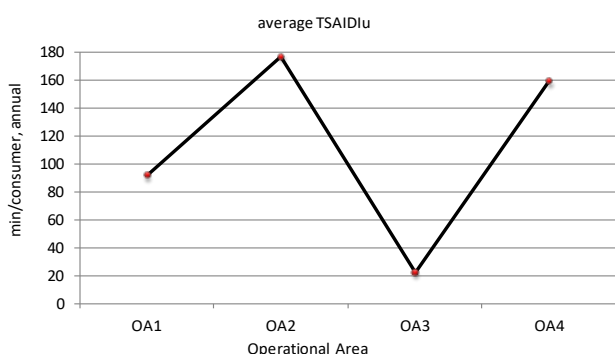


Figure 8: TSAIDlu average per OA (2009 - 2016)

Significant deviations of the TSAIDlu index are noted in 2012 (OA4) and in 2014 (OA2), and they are directly linked to the unplanned interruptions in the transmission network, due to major event (snowstorm and flood), giving an evidence that these indices are a good indicator to describe significant events in the system. Namely, large values of the TSAIDlu index in OA2 can be attributed to the heavy flooding in May and August 2014, when some transmission substations were under water for days. These events led to the average values of the TSAIDlu index being higher in OA2, for the observed period 2009 - 2016, amounting to 176.97 min/consumer, while at the end of 2013, they were the highest in OA4, amounting to 133.33 min/consumer.

Although the transmission network is technically similar in all operational areas, it is obvious that other causes lead to such a high deviation of the TSAIDlu index in OA2, compared to other OAs. Certainly, such poor indices can be greatly attributed to the impact of major event in 2014.

Contrary to this, the best TSAIFlu and TSAIDlu indices are achieved by OA3. Although this area has three radial substations 110/x/y kV, one 35/x/y kV, and one rigid connection (T connection), but also being the only one using 110 kV cable for power transmission of a total length of 32 km, one of possible reasons for good indices is the sole topology of the network in the area, compared to other areas, as well as the fact that this area is characterised by

the shortest length of transmission lines (about 23% of the total transmission network, based on SWOT analysis for the Transmission Company) [10]. In distribution jargon, this area would be called an "urban" one, and as such it achieves good results in indices.

As for the high values in OA4, the following could be the possible causes: difficult and unapproachable terrain through which power-transmission lines are stretched, problems with high voltage in the network, the area with the highest number of generation facilities connected to the transmission line (10 hydro-power plants and one thermal power plant), the area with the longest transmission line within its area of responsibility (about 28.5% of the total transmission network), geographical location of the transmission network between the areas with surplus and those with shortage of electricity, and accordingly insufficient transmission capacities. Additionally, this is one of the areas characterised with the highest number of transient failures in the transmission system, due to highest level of atmospheric discharge per km² in Europe [11].

The majority of intermitting sources for power generation (windmills and larger solar plants), according to the available plans, was foreseen to be built in the territory under the competence of OA4, due to undoubtedly best potential for the use of wind and solar energy, as shown by a number of studies done at the request of the NOS BiH [12], [13], [14]. On the other hand, the analysis of the TSAIFlu index, for the observed period 2009 - 2016, showed the worst average for OA4, while the analysis of the TSAIDlu index, showed the worst results for OA2 and OA4. It is, therefore, necessary to find causes that have negative impacts on the indices, in order to decrease the number of interruptions and interruption time.

Having in mind that the CAIDI index also presents the average time required to re-establish supply, it is interesting to see its average values per Operational Areas, when it comes to unplanned interruptions, using equation (3), for the period 2009 - 2016.

On average, the longest time required to re-establish normal connection after an unplanned interruption was recorded in the Operational Area (OA2). It is followed by OA4, OA1 and OA3 (Table V).

Table V: TCAIDlu per OAs (average 2009 - 2016)

Operational area	OA1	OA2	OA3	OA4
TCAIDlu (min/consumer)	69.09	159.05	56.12	74.63

Knowing the TSAIFlu, TSAIDlu and TCAIDlu indices, one gains a clearer picture of the network's situation per Operational Areas. Nonetheless, having in mind that we stated at the beginning of the paper that each OA is organised based on territorial and functional principle, the proposed methodology could be applied up to the level of field units, for the purpose of even more precise identification of problematic locations in the transmission network. Namely, when connecting the intermitting sources in the future, it will be interesting to evaluate the reliability of electricity supply from these sources to the transmission network, should no additional measures be secured.

To mention, in the first Indicative Generation Development Plan 2007 - 2016, prepared by the BiH Independent System Operator, Sarajevo, and approved by the State Electricity Regulatory Commission (March 2007), the expansion of renewable energy sources, primarily windmills, was announced. The implementation of the first projects was supposed to be completed within the period of two to three years. Nonetheless, ten years later, the BiH transmission network does not have any announced wind-parks (WP) in operation (some are in various construction phases, while trial operation of WP Mesihovina was announced for the beginning of 2018). Numerous obstacles could be classified as technical, economic, legal and political.

The experience shows that the operators in many countries were sceptical in view of accepting unmanageable sources into the transmission network. On the other hand, what would certainly be of interest to potential investors, who would build those sources on optimal locations, are the data on reliability of transmission network in those areas, especially if we consider that it presents the connection between generation centres and distribution network for placement of electricity towards end consumers, as well as the fact that such sources can be built only in specific locations, which are, almost by a rule, distanced from the consumption centres.

4. ORGANISED INDICES IN FUNCTION OF A METHOD OF ECONOMIC REGULATION

Based on the Tariff pricing methodology for services of electricity transmission, operation of independent system operator and ancillary services - consolidated text (Official Gazette of BiH, 93/11, 61/14, 95/16), the used method of economic regulation (when determining the tariffs for the operation of the Company) is the traditional rate of return (ROR) method, defining a maximum amount of in-

come during a regulatory period, i.e. the price of electricity providing for coverage of justified costs of operations and return on investments. Due to its simplicity, it was generally evaluated as a very good form of regulation in the beginning of the application, and was generally accepted by regulated entities and consumers. Nonetheless, over the time some issues arose indicating its shortcomings, of which the following can be emphasised: lack of incentive to reduce costs, lack of incentive to improve business performance, overly short regulation period (often one year), high costs of regulation. With this regulation method, regulatory bodies have a primary goal to decrease the costs of regulated companies, without paying sufficient attention to technical indices, such as the quality of electricity, i.e. continuity and reliability of supply, as the most important segment of the electricity quality.

Indeed, these parameters are also monitored, but not in the sufficient scope to serve their true purpose, i.e. to send a signal to encourage the performance of the regulated entity. Realising the given problems, regulatory bodies have been developing increasingly complex methods of economic regulation over time. This is how URS issues gain more attention in many countries of the world. With traditional methods of regulation by rate of return, it is of a lesser significance, but becomes extremely important with some of the methods of incentive regulation. The USA have the longest history in providing performance-based incentives for improvement of URS.

4.1. Correlation dependency of reliability indices and costs of material

Elektroprijenos Bosne i Hercegovine filed an application in November 2016 to modify tariffs for transmission of electricity, presenting the requests for income and expenditures, as well as costs the Company intended to charge for its services. The request sought for an average tariff for transmission to amount to 1.058 fening/kWh, meaning an increase of 19% (currently amounting to 0.889 pfenigs/kWh). Out of all presented costs, the cost of materials will be mentioned here, including costs of fuel, materials and spare parts, Figure 9. From a historical perspective, the cost of material has been fluctuating from 3.26 to 5.33 million BAM, while in the last four years, a significantly lower cost realisation is noted compared to approved amounts. Over the last two observed years (2015 and 2016), the approved cost (red bar) amounted to 4.8 million BAM, while its realisation in 2015 (blue bar) was significantly lower. The realisation in 2016 amounted to around 2.5 million BAM.

The request of the Company for costs of material in 2017 (orange bar) also amounted to 4.8 million BAM, and it was 60% higher than estimated realisation in 2016 (green bar), i.e. 40% compared to realisation in 2015.

Another type of costs, costs of services (they comprise, among other things, costs of material and current and investment maintenance) for 2017 were requested in the amount of 5.5 million BAM. For example, period from 2014 to 2016, saw an approval of 17 million BAM for this group of costs, followed by realisation of 13.3 million BAM.

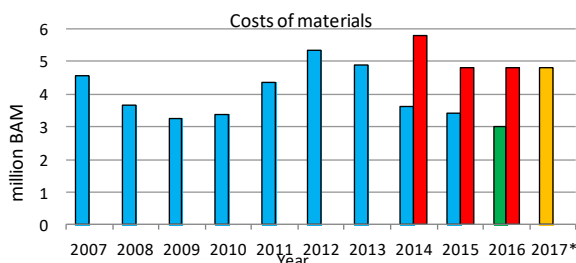


Figure 9: Realised and approved costs of materials

Nonetheless, as already shown (Figure 1 and Figure 2), the indices of average number of planned interruptions TSAIFIp and SAIFIp, have been decreasing year after year (similarly goes for TSAIDIp and SAIDIp). This is an obvious sign that the reliability of transmission equipment is at a high level. For example, with the current technology progress, low-voltage and middle-voltage network equipment in power facilities keeps having longer periods between regular maintenances and lower maintenance costs.

Hence the question: does the Company present the realistically required values in its request for approval of the previously mentioned costs? It is a good circumstance that the average number of unplanned interruptions has been decreasing (TSAIFlu and SAIFlu indices, Figure 3).

In this way, an inter-connection between costs of material and analysed indices is shown, and as such, it could be mathematically defined. An organised set of indices could be a basis to define an initial minimum standard of the continuity and reliability of supply, to serve for the purpose of introducing assumptions for an incentive regulation method in the transmission network.

4.2. Incentive regulation methods

Numerous regulatory bodies in the world have started introducing other, more complex forms of economic regulation for the purpose of providing more quality and efficient regulation. Introducing incentive regulation aimed at removing shortcomings specific for rate of return regulation. With the aim of stimulating regulated companies to increase efficiency and decrease costs, the traditional method of price regulation was replaced with other incentive-based methods, of which the most used was the method of price cap regulation. Its significance was in the fact that each saving a regulated company makes through

an increase of efficiency, would present profit a company would have at its own disposal. Nonetheless, experience has shown that the regulated companies usually improve efficiency and decrease costs at the expense of the quality of electricity and service, down to the level that is not always acceptable. Incentive regulation received a lot of attention in literature, and it can be briefly described as a type of regulation which provides a regulated company with a profit increase through lowering prices, i.e. increase of efficiency.

A regulated entity is the best judge of its own possibilities to decrease costs, and incentive regulation stimulates them in that direction. Other known incentive-based regulation methods include:

- Revenue Cap Regulation,
- Yardstick Regulation,
- Performance Based Regulation, and
- combination of these methods.

Nowadays, electricity consumers seek the highest possible quality, at affordable (meaning, lowest possible) prices. However, all of the listed methods of incentive regulation are not equally acceptable, and one should be careful when selecting any, because the methods are very complex for the implementation. In the recent years, the issue of optimum quality level of supplied electricity is in focus, i.e. continuity and reliability of supply from distribution and/or transmission networks, along with the correct choice of incentive regulation methods, which is quite a large challenge for many electric power entities involved in regulation.

When it comes to the neighbouring countries, incentive regulation, in the form of revenue cap regulation, was introduced in: Croatia, Montenegro, Kosovo* and the former Yugoslav Republic of Macedonia, the price cap regulation was introduced in Albania, and ROR (in addition to BiH), was introduced by Serbia [15].

5. CONCLUSION

Regulation of continuity and reliability of supply will surely be a subject of further changes and development in the future, both globally and in the BiH transmission network. The focus on improvement of regulation should be based on the experiences and good regulatory practices of the EU countries. Comparing the values of received indices with the values of the EU countries, presented in the last CEER benchmarking analysis, shows that the BiH reliability indices are higher. Additionally, the Operational Areas with good/bad indices were identified and the correlation dependency of reliability indices and costs of materials was presented.

For the purpose of having organised indices, it is necessary to carry out classification of unplanned interruptions based on causes (provide definition of major event, responsibility of third party, responsibility of Company) in order to more efficiently analyse interruption types and their impact on the system, with the aim of establishing suitable initial standards of the continuity and reliability of supply, which would be the starting point towards the introduction of a model of incentive regulation in the transmission network.

With the aim of making regulatory decisions on required measures for improvement of the continuity and reliability of supply, but also for a more precise definition of reliability of the transmission network at the level of micro-locations, which could be useful to potential investors when constructing new facilities, the Company should be requested to calculate not only aggregated reliability indices, but also those that were broken down to the level of the Operational Areas, i.e. field units because it would enable identification of problematic locations in the transmission network while the priorities to be solved could be directly determined.

Interest in implementation of the said increases with the energy market development, and strengthening of quality in supply of electricity. The issue of responsibility of electricity market stakeholders may be regulated by an incentive and compensation system depending on the targeted values of some reliability indices.

In addition, the introduction of incentive regulation for the transmission network should be legally based, in order for the regulatory body to act in accordance with defined competences.

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BIOGRAPHY

Milenko Tomić was born in Tuzla (BiH) where he also obtained a degree in electrical engineering. He gained the title of a Master of Technical Science in the field of electrical engineering in 2009, at the Faculty of Electrical Engineering of the University of Tuzla, within the "CEFES" international postgraduate study (Tempus Joint European Project, Tempus JEP-18126-2003). He is now attending the third study cycle (doctoral studies) at the Faculty of Electrical Engineering in Tuzla. He is employed at the BiH State Electricity Regulatory Commission, as Head of Licensing Department. His fields of interest include power system reliability, power system economics, electricity quality, renewable and dispersive sources of energy and a new paradigm in the power network – electric vehicles.

Tatjana Konjić graduated and received her masters and doctoral degrees at the Faculty of Electrical Engineering of the University of Tuzla in 1989, 1998 and 2003 respectively. She has been working at the Faculty of Electrical Engineering of the University of Tuzla since 1991. She has been appointed as an associate professor at the Faculty of Electrical Engineering of the University of Tuzla and the Faculty of Electrical Engineering of the University of Sarajevo. Her particular field of interest is application of artificial intelligence in electric power systems, electric power networks with distributed generation and electricity quality.