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ANALYSIS OF THE CONTINUITY OF ELECTRIC ENERGY SUPPLY IN POLAND

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Summary. The continuity of electricity supply to consumers located within the territory of individual Distribution System Operators in Poland was analysed. A concentration analysis was also performed, which allowed for the separation of Distribution System Operators who are similar in terms of the indices related to electricity supply interruptions recorded in 2010. These were divided into four groups.

Key words: concentration analysis, power supply continuity, electric energy, Distribution System Operator.

INTRODUCTION

Introduction of Directive 2003/54/EC of the European Parliament and of the Council, concerning common rules for the internal market in electricity and Regulation 1228/2003 on conditions for access to the network for cross-border exchanges in electricity has led to separation of the commercial and distribution activities of Power Distribution Companies. The Energy Law of July 1, 2007, however, allows free choice of electricity suppliers to all consumers of electricity in Poland. The result of deregulating the power sector is that electric energy is now considered as a product which, as any other goods on the market, is dependent on technical and economic criteria [Hanzelka, Kowalski 1999; Hanzelka, Wasiak, Pawełek 1998].

Unless the parties of a supply contract agree upon the individual quality parameters of electric energy, standards shall apply as laid down in the *Regulation of December 20, 2004* [Dz. U. z 2004 nr 2, poz. 5 i 6] and the *PN-EN50160* standard, which contains some more indices. The continuity of electric energy supply can be evaluated, among others, based on: the mean time of long interruption, average number of long and short term interruptions [Trojanowska 2007, 2008; Trojanowska, Nęcka 2010]. A full list of indices applied in practice and their determination methods are described in the subject literature [Paska 2004].

Under the normal operating conditions of a distribution network, the number of energy supply interruptions may be from several tens to several hundreds a year [Strzałka 2003]. The lack of continual supply of power causes a loss for the industry and discomfort to individual users. According to the information published by EPRI (Electrical Power Research Institute), the annual loss in

the US industrial sector, due to poor quality of electric energy and supply disruptions, is ca. USD 16 bln [Janiczek, Wasiluk-Hassa, Samotyj 1999]. In Poland, no such comprehensive studies have been made, yet due to the poor condition of the power distribution infrastructure, it can be assumed that the loss is also very high [Niewiedział, Niewiedział]. Power supply continuity is, therefore, a crucial factor for the choice of products and services in a competitive market for electric energy.

The aim of the present paper was to analyse the continuity of electricity supply to consumers located within the territory of individual Distribution System Operators (DSO) in Poland.

MATERIAL AND METHODS

SAIDI, SAIFI, MAIFI indices were applied to analyse the continuity of electric power supply based on supply interruptions in 2010 which, according to the Regulation of the Minister of Economy of May 4, 2007, as amendment, has been published by individual distribution system operators on their websites. The territorial diversity of power supply reliability was evaluated based on concentration analyses using the agglomeration method, which belongs to the group of hierarchical methods, as well as the k-average method, one of the most important non-hierarchical methods.

RESULTS

In Poland, eight Distribution System Operators are currently established supplying electrical energy to almost 16.5 million consumers. Figure 1 shows their respective service territories. The only exception to this is the DSO PKP Energetyka, which covers almost the entire country.

Fig. 1. Service territory of individual Distribution System Operators

Źródło: http://centrum-energetyczne.pl/o-nas/obszar-dzialania

Based on the Regulation of the Minister of Economy of May 4, 2007, as amended, a distribution system operator, by March 31 of each year, must publish the following energy supply interruption indices established for the previous calendar year:

1. **SAIDI** (the system average interruption duration index for long and very long term interruptions) – expressed in minutes per subscriber per annum, being a sum of the products of duration and the number of subscribers affected by the consequences of such interruptions during a year, divided by the total number of subscribers serviced,
2. **SAIFI** (the system average interruption frequency index for long and very long term interruptions) – being the number of subscribers affected by the consequences of such interruptions during a year, divided by the total number of subscribers serviced,
3. **MAIFI** (the momentary average interruption frequency index for short term interruptions) – being the number of subscribers affected by the consequences of such interruptions during a year, divided by the total number of subscribers serviced.

Pursuant to the Regulation, the DSO establishes the first two indices separately for planned interruptions, i.e. due to the power distribution systems maintenance schedule, and for any unplanned interruptions (due to distribution system breakdowns). They should also be published with and without the inclusion of catastrophic interruptions, i.e. those lasting longer than 24 hours.

The values of the indices for power supply interruptions to subscribers in Poland in 2010 are given in Table 1.

Table 1. Values of the indices for power supply interruptions in 2010

			Value			
			minimum	average	maximum	variability factor [%]
Indicator	SAIDI [min./sub./year]	planned	3,91	119,61	212,20	58
		unplanned including catastrophic interruptions	19,67	322,45	644,00	56
		unplanned not including catastrophic interruptions	13,99	276,28	579,87	55
	SAIFI [sub./sub.]	planned	0,01	0,63	1,15	55
		unplanned including catastrophic interruptions	0,09	3,21	5,03	43
		unplanned not including catastrophic interruptions	0,09	3,19	5,02	43
	MAIFI [sub./sub.]		0,03	3,46	8,87	72

According to the calculations, the average duration of long and very long term interruptions, including the catastrophic interruptions, all over Poland is ca. 422 minutes per annum. This varies in a broad range from 25 minutes for the areas serviced by PKP Energetyka to 812 minutes for the service areas of ENION S.A. The average SAIDI value has, for many years, been at a similar, very high level. In other European countries, its value in the years 2004-2006 varied from 23 min./year in Germany and the Netherlands, 30 min./year in Austria to 267 min./year in Portugal and 300 min./year in Slovakia. Higher values were found in Estonia and Romania, 469 and 1187 min./year, respectively [Attachment 9]. In 2010, higher frequency of very severe short term interruptions, i.e. with the duration from 1 second to 3 minutes, was observed. Each subscriber on average suffered

3.46 short term interruptions and 3.21 long term interruptions. The maximum values, however, were twice as high, 8.87 and 5.03 [sub./sub.], respectively.

Great diversification was also found in the analyzed parameters, depending on the prevalence in a given urban or rural area. The situation can be studied by analysing the information presented separately for DSO PGE Łódź Miasto and PGE Łódź Teren. For rural areas, a 6.7 hour increase in the annual duration of long and very long term interruptions was observed. However, the SAIFI index value for rural area was lower by 1.54 [sub./sub.]. The differences noted can be explained by the different nature of the systems.

A concentration analysis was then performed, aimed at separate Distribution System Operators similar in terms of the indices related to electricity supply interruptions recorded in 2010 and combining them in uniform groups. The concentration analysis was performed with the agglomeration method, which belongs to the group of hierarchical methods. The DSO grouping was performed with the Ward method, which, for separating concentrations, uses the inter-class variance minimisation principle, and between the objects, according to the recommendations of Sagan and Łapczyński [2009], the Euclidean distance was calculated. This method was chosen as it is considered to be the most effective in reproducing the actual data structures [Sokołowski 1992]. The effect of such algorithm in the form of a hierarchical tree is shown in Figure 2.

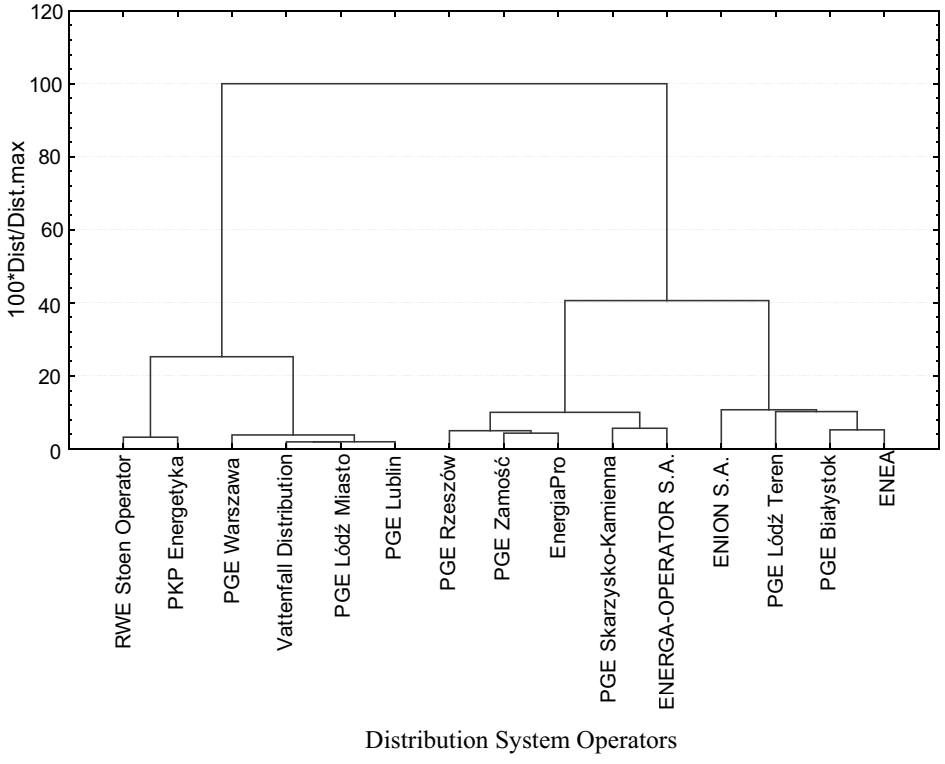

Fig. 2. Similarity agglomeration diagram of individual DSOs for the indices regarding electric energy supply in 2010

An optimum number of concentrations was determined by analysing the agglomeration distance graph (Fig. 3) for the subsequent joining stages at the point of its first noticeable increment, which was observed in the 12th step. Calculations performed with the k-average method proved the previous analyses and allowed for the separation of 4 DSO concentrations with the greatest similarity scale. The calculated mean values of individual indices characterising the continuity of power supply in individual groups are listed in Table 2.

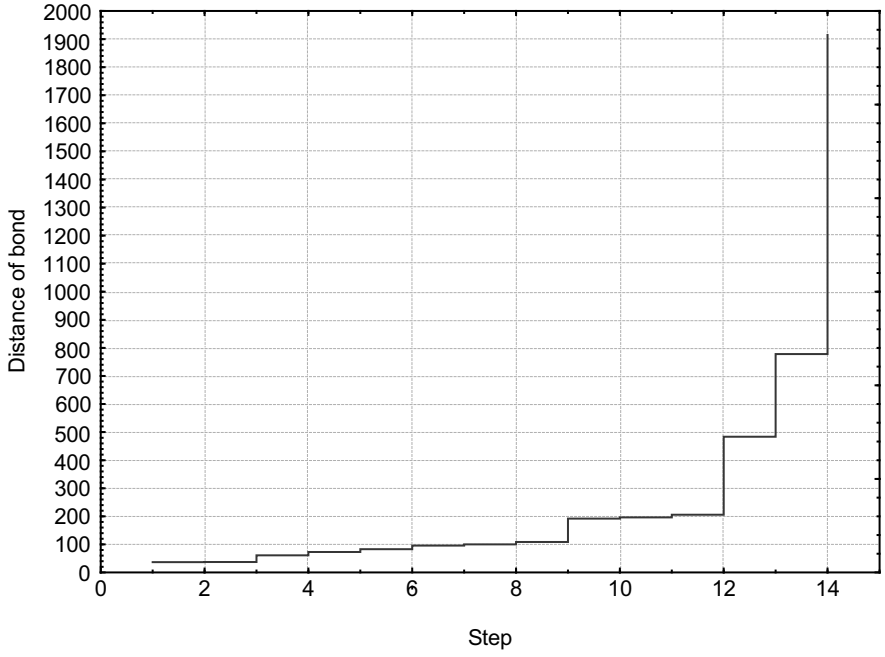

Fig. 3. Course of lining distance during linking stages

Table 2. Mean values of the indices for power supply interruptions in 2010 in individual groups

			Concentration			
			I	II	III	IV
Indicator	SAIDI [min./sub./year]	planned	4,82	74,26	174,55	153,7
		unplanned including catastrophic interruptions	43,67	181,81	363,64	551,00
		unplanned not including catastrophic interruptions	33,04	179,18	289,96	477,90
	SAIFI [sub./sub.]	planned	0,03	0,52	0,79	0,84
		unplanned including catastrophic interruptions	0,65	3,17	3,76	3,85
		unplanned not including catastrophic interruptions	0,65	3,17	3,72	3,82
	MAIFI [sub./sub.]		0,24	4,13	3,86	3,90

Two power distributors, i.e. RWE Stoen Operator S.A. and PKP Energetyka, were categorised as the first concentration, characterised by the lowest values of indices describing power supply continuity. The mean interruption time in that group was 48 min./year. Also, the average frequencies of short and long term interruptions in that concentration were the lowest – 0.24 and 0.68 [sub./sub.], respectively. All the distributors operating in urban areas were categorised under the first and second group, characterised by the lowest indices of long term power supply interruptions. However, in the last group, including DSOs: ENEA, ENION, PGE Białystok and PGE Łódź Teren, operating mainly in rural areas, the highest indices, characterised by long term interruptions were observed. The mean value of the SAIDI index increased to 704.7 [min./sub./year], whereas the SAIFI index reached the value of 4.69 [sub./sub.]. Only the MAIFI parameter value in that group was close to the first concentration and was 3.90 [sub./sub.].

CONCLUSIONS

According to the performed calculations, an electricity subscriber in Poland may expect at least 5 unplanned power supply interruptions in a year of total duration of up to 10.7 h.

The values of the indices characterising the continuity of power supply in areas serviced by individual Distribution System Operators varied considerably. An average value of the variability factor was almost 55 %, varying from 43 % for the SAIFI index to 72 % for the MAIFI.

Although the power supply reliability indices are published, individual subscribers still have limited access to the information regarding their regions. It appears reasonable to publish these indices with the division into subscribers located in urban and rural areas.

REFERENCES

1. Dyrektywa 2003/54/WE Parlamentu Europejskiego i Rady dotycząca wspólnych zasad dla wewnętrznego rynku energii elektrycznej i uchylenia dyrektywę 96/92/WE.
2. Hanzelka Z., Kowalski Z. 1999.: Kompatybilność elektromagnetyczna (EMC) i jakość energii elektrycznej w dokumentach normalizacyjnych. JUEE, IV(1).
3. Hanzelka Z., Wasiak I., Pawełek R. 1998.: Normalizacja jakości energii elektrycznej w Polsce. Jakość energii elektrycznej i wyrobów elektrotechnicznych. IV Konferencja Naukowo-Techniczna. Świnoujście.
4. Janiczek R., Wasiluk-Hassa M., Samotyj M. 1999.: How much does power quality cost: views from both sides of the meter; International Conference Electrical Power Quality and Utilisation". September. Cracow. Poland.
5. Niewiedział E., Niewiedział R.: Aktualny stan elektroenergetycznych sieci dystrybucyjnych w Polsce z punktu widzenia bezpieczeństwa zasilania odbiorców. [online]. [dostęp 14–07–2011]. Dostępny w Internecie: http://24ktp.pl/Dokumenty/Aktualny%20stan% 20elektroenegetycznych % 20sieci%20dystrybucyjnych.pdf.
6. Paska J. 2004.: Jakość zasilania. Elektroenergetyka 4. s. 1–10.
7. Polska Norma. PN–EN 50160. Parametry napięcia zasilającego w publicznych sieciach rozdzielczych.
8. Rozporządzenie (WE) nr 1228/2003 Parlamentu Europejskiego i Rady z dnia 26 czerwca 2003 r. w sprawie warunków dostępu do sieci w odniesieniu do transgranicznej wymiany energii elektrycznej.

9. Rozporządzenie Ministra Gospodarki z dnia 20 grudnia 2004 r. w sprawie szczegółowych warunków przyłączenia podmiotów do sieci elektroenergetycznych, ruchu sieciowego i eksploatacji sieci oraz standardów jakościowych obsługi odbiorców. Dz.U. z 2004 r. nr 2, poz. 5 i 6.
10. Rozporządzeniem Ministra Gospodarki z dnia 4 maja 2007 r. w sprawie szczegółowych warunków funkcjonowania systemu elektroenergetycznego Dz. U. Nr 93, poz. 623 z dnia 29 maja 2007.
11. Rozporządzeniem z dnia 21 sierpnia 2008 r. zmieniające rozporządzenie w sprawie szczegółowych warunków funkcjonowania systemu elektroenergetycznego Dz. U. Nr. 162, poz. 1005 z dnia 9 września 2008.
12. Sagan A., Łapczyński M. 2009.: Techniki segmentacji w badaniach rynkowych. Materiały szkoleniowe StatSoft Polska.
13. Sokołowski A. 1992.: Empiryczne testy istotności w taksonomii. Akademia Ekonomiczna w Krakowie. Zeszyty Naukowe. Kraków.
14. Trojanowska M. 2007.: Analiza statystyczna ciągłości dostaw energii elektrycznej odbiorcom z terenów wiejskich województwa małopolskiego. Problemy inżynierii rolniczej. Nr 3. S. 43-48.
15. Trojanowska M. 2008.: Analiza stanu technicznego sieci niskiego napięcia na terenach wiejskich podkarpacia. MOTROL 10. s. 131-135.
16. Trojanowska M., Nęcka K. 2010.: Identyfikacja wskaźników opisujących niezawodność zasilania energią elektryczną odbiorców wiejskich. TEKA Komisji Motoryzacji i Energetyki Rolnictwa. Vol X. Lublin. s. 475-483.
17. Ustawa z dnia 10 kwietnia 1997 r. Prawo energetyczne. Dz.U. z 1997 r. nr 54 wraz z późniejszymi zmianami.
18. Załącznik nr 9 – Przerwy w dostawie energii elektrycznej i należne odbiorcom bonifikaty. [online]. [dostęp 14–07–2011]. Dostępny w Internecie: http://www.szczecin.uw.gov.pl/ Aktualnosci/Documents/Za%C5%82%C4%85cznik%20nr%209.pdf
http://centrum-energetyczne.pl/o-nas/obszar-dzialania.

ANALIZA CIĄGŁOŚCI DOSTAW ENERGII ELEKTRYCZNEJ NA TERENIE POLSKI

Streszczenie. Przeprowadzono analizę ciągłości dostaw energii elektrycznej odbiorcom zlokalizowanym na terenie poszczególnych Operatorów Systemów Dystrybucyjnych w Polsce. Wykonano również analizę skupień, która doprowadziła do wyodrębnienia Operatorów Systemów Dystrybucyjnych podobnych do siebie ze względu na wartości wskaźników dotyczących przerw w dostawie energii elektrycznej zarejestrowanych w roku 2010 i podzielono je na cztery grupy.

Słowa kluczowe: analiza skupień, ciągłość zasilania, energia elektryczna, Operator Systemu Dystrybucyjnego.