SETTING SAIFI AND SAIDI PARAMETERS AND THE ANALYSIS FOR A SPECIFIC CONSUMPTION AREA

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INTRODUCTION

Systematic monitoring of parameters is very significant for the power supply company in order to quantify the status of distribution network and the reliability of power supply to customers.
The overall analysis of the entire distribution system is necessary when directing system development and making proper strategic decisions. For that reason, it is significant to determine the effect that certain parts of the system have on the reliability of customers supply. However, it is also useful to define reliability parameters for minor parts of the system or for minor parts of the consumption area and various customer categories, which is shown in a simple example in further text.
Defining parameters at the feeder level is convenient when planning optimal network development, where it is possible to define borderline reliability parameter values for each feeder or feeder group. Defining parameters for minor parts of the consumption area, at the level of a feeder or the area supplied by one substation can be the basis for signing contracts with customers. This would enable to estimate the costs of customers during power cut as well as customers' participation in investments in the power supply network strengthening. Furthermore, the data on the average number of power cuts and their total duration for a particular consumption area is always useful because it enables insight into justifiability of possible customers' complaints on power supply supposed unreliability.
Dividing the system into smaller parts enables defining different parameter values for different customer categories, where priority customers with more significant installed power could be considered a special category. Population density of the consumption area and distribution module type could be the criteria for adoption of borderline parameter values, which is common in foreign companies with non-regulated power market.

THE EXAMPLE OF PARAMETER DEFINING

Definition of reliability parameters

$SAIFI$ and $SAIDI$ parameters are adopted as relevant reliability parameters. The $SAIFI$ parameter represents the average number of power cuts per customer per year and is defined by the relation (1).

$$SAIFI = \sum_i f_i \frac{N_i}{N} \text{ (/yr)} \quad (1)$$

where:

f_i - breakdown frequency i

N_i – the number of customers without supply within i-cut

N - the total number of customers

The $SAIDI$ parameter represents the average sum of power cut duration per customer per year and is defined by the relation (2).

$$SAIDI = \sum_i D_i \frac{N_i}{N} \text{ (h/yr)} \quad (2)$$

where D_i is the customer's cut i duration in hours

The relative shares of voltage levels (VL) and certain parts of the consumption area are calculated using relations (3) and (4) respectively:

$$SAIFI_{VL}\% = \frac{SAIFI_{VL}}{SAIFI} \cdot 100 \quad (3)$$

$$SAIFI_{N_j}\% = \frac{SAIFI_{N_j}}{SAIFI} \frac{N_j}{N} \cdot 100 \quad (4)$$

$$N = \sum_j N_j \quad (5)$$

where :

$SAIFI_{VL}$ - the share of the part of power supply system

$SAIFI_{N_j}$ - the parameter defined for j -part of the consumption area

N_j - the number of customers of the j -part of the consumption area

The analogous relation is the same for the $SAIDI$ parameter.

Example

The list of labels

A - 110 kV feeder label

B - 110/35 kV substation label

C_i - i - feeder 35 kV label

D_i - i - substation 35/10 kV label

E_{ij} - 10 kV feeder label, where:

i- 35/10 kV substation label and 35kV feeder which supplies the 10 kV feeder

j - 10 kV feeder label

F_{ijk} - 10/0,4 kV substation label, where:

i - 35/10 kV substation label and 35 kV feeder label which supplies 10/0,4 kV substation

j - 10 kV feeder label which supplies 10/0,4 kV substation

k - 10/0,4 kV substation label

G_{ijkl} - LV line label

i- 35/10 kV substation label and 35kV feeder label which supply LV line

j - 10 kV feeder label which supplies LV line

k - 10/0,4 kV substation label which supplies LV line

l - LV line label

f_A, N_A - the number of cuts and the number of cut-off customers due to disfunction of 110 kV feeder

f_B, N_B - the number of cuts and the number of cut-off customers due to disfunction of 110/35 kV substation

f_{Ci}, N_{Ci} - the number of cuts and the number of cut-off customers due to disfunction of i - feeder 35 kV

f_{Di}, N_{Di} - the number of cuts and the number of cut-off customers due to disfunction of i - substation 35/10 kV

f_{Eij}, N_{Eij} - the number of cuts and the number of cut-off customers due to disfunction j - feeder 10 kV

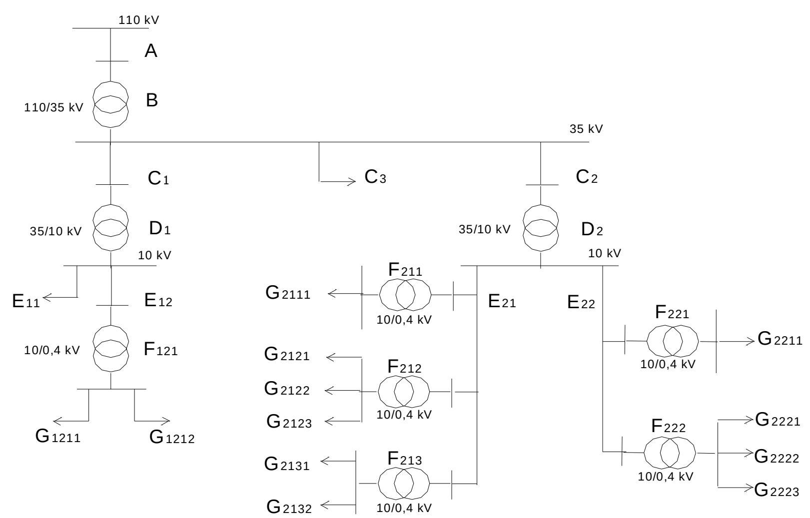
f_{Fijk}, N_{Fijk} - the number of cuts and the number of cut-off customers due to disfunction k - substation 10/0,4 kV

f_{Gijkl}, N_{Gijkl} - the number of cuts and the number of cut-off customers due to disfunction l - LV line

Indexes i, j, k and l range from 1 to n, where n represents the number of power objects.

Example: G_{2223} - represents the third LV line supplied by the second 10/0,4 kV substation, the second 10 kV feeder, the second 35/10 kV substation and the second 35 kV feeder. The total numbers of cuts and customers during one cut are labelled f_{G2223} and N_{G2223} respectively.

The ways of defining $SAIFI$ and $SAIDI$ parameters are shown on a simplified example, for the area shown in picture 1, the obtained shares from certain voltage levels and defining parameters for minor parts of the consumption area. It is supposed that data on the number and duration of cuts are systematically assembled throughout the year. Taking into consideration the fact that that the methodology of defining parameters is of major concern, the practical example is simplified. Furthermore, since the procedures are the same and the relations are similar, only the way of setting $SAIFI$ parameter for the entire area and a few minor parts is shown, whereas the results with the specific values are shown in tables 1 and 2.



PICTURE 1 - The scheme of supply of the analysed area

The voltage level shares of the entire area are calculated using the following relations:

$$SAIFI_{110} = \frac{1}{N} f_A N_A \text{ (/yr)} \quad (6)$$

$$SAIFI_{110/35} = \frac{1}{N} f_B N_B \text{ (/yr)} \quad (7)$$

$$SAIFI_{35} = \frac{1}{N}(f_{C1} N_{C1} + f_{C2} N_{C2} + f_{C3} N_{C3}) \text{ (/yr)} \quad (8)$$

$$SAIFI_{35/10} = \frac{1}{N}(f_{D1} N_{D1} + f_{D2} N_{D2}) \text{ (/yr)} \quad (9)$$

$$SAIFI_{10} = \frac{1}{N}(f_{E11} N_{E11} + f_{E12} N_{E12} + f_{E21} N_{E21} + f_{E22} N_{E22}) \text{ (/yr)} \quad (10)$$

$$SAIFI_{10/0,4} = \frac{1}{N}\big(f_{F121} N_{F121} + f_{F211} N_{F211} + f_{F212} N_{F212} + f_{F213} N_{F213} + f_{F221} N_{F221} + f_{F222} N_{F222}\big) \text{ (/yr)} \quad (11)$$

$$SAIFI_{0,4} = \frac{1}{N}\big(f_{G1211} N_{G1211} + f_{G1212} N_{G1212} + f_{G2111} N_{G2111} + f_{G2121} N_{G2121} + f_{G2122} N_{G2122} + f_{G2123} N_{G2123} + f_{G2131} N_{G2131} + f_{G2132} N_{G2132} + f_{G2211} N_{G2211} + f_{G2221} N_{G2221} + f_{G2222} N_{G2222} + f_{G2223} N_{G2223}\big) \text{ (/yr)} \quad (12)$$

The following relations calculate the $SAIFI$ parameter value for minor parts of the consumption area. When calculating cuts from higher voltage levels, regarding the area of the defined parameter, only the cuts of the power objects which connect the area with the source point are taken into consideration.

The $SAIFI$ parameter is defined for the area supplied by 35/10 kV substation labelled with D_2:

$$SAIFI_{D_2} = \frac{1}{N_{D_2}}\big(f_A N_A + f_B N_B + f_{C2} N_{C2} + f_{D2} N_{D2} + f_{E21} N_{E21} + f_{E22} N_{E22} + f_{F211} N_{F211} + f_{F212} N_{F212} + f_{F213} N_{F213} + f_{F221} N_{F221} + f_{F222} N_{F222} + f_{G2111} N_{G2111} + f_{G2121} N_{G2121} + f_{G2122} N_{G2122} + f_{G2123} N_{G2123} + f_{G2131} N_{G2131} + f_{G2132} N_{G2132} + f_{G2211} N_{G2211} + f_{G2221} N_{G2221} + f_{G2222} N_{G2222} + f_{G2223} N_{G2223}\big) \text{ (/yr)} \quad (13)$$

The $SAIFI$ parameter is defined for the area supplied by 10kV feeder labelled with E_{22}:

$$SAIFI_{E_{22}} = \frac{1}{N_{E_{22}}}\big(f_A N_A + f_B N_B + f_{C2} N_{C2} + f_{D2} N_{D2} + f_{E22} N_{E22} + f_{F221} N_{F221} + f_{F222} N_{F222} + f_{G2211} N_{G2211} + f_{G2221} N_{G2221} + f_{G2222} N_{G2222} + f_{G2223} N_{G2223}\big) \text{ (/yr)} \quad (14)$$

The $SAIFI$ parameter is defined for the area supplied by 10/0,4 kV substation labelled with F_{222}:

$$SAIFI_{F_{222}} = \frac{1}{N_{F_{222}}}\big(f_A N_A + f_B N_B + f_{C2} N_{C2} + f_{D2} N_{D2} + f_{E22} N_{E22} + f_{F222} N_{F222} + f_{G2221} N_{G2221} + f_{G2222} N_{G2222} + f_{G2223} N_{G2223}\big) \text{ (/yr)} \quad (15)$$

Power objects	A	B	C_1	C_2	C_3	D_1	D_2	E_{11}	E_{12}	E_{21}	E_{22}	F_{121}	F_{211}	F_{212}	F_{213}
Breakdown	1	1	2	1	2	1	2	1	10	10	12	1	1	1	0
Customers	464	464	123	340	1	123	340	1	120	150	190	120	60	60	30
Power objects	F_{221}	F_{222}	G_{1211}	G_{1212}	G_{2111}	G_{2121}	G_{2122}	G_{2123}	G_{2131}	G_{2132}	G_{2211}	G_{2221}	G_{2222}	G_{2223}	
Breakdown	1	2	3	2	5	4	1	3	0	1	3	1	0	2	
Customers	100	90	40	80	60	30	10	20	20	10	100	30	40	20	

TABLE 1 **-** The number of cuts and the number of supplied customers

Power objects	Namber of customers	The reletive shares of voltage levels (%)							The reletive shares (%)	SAIFI (/yr)
		110	110/35	35	35/10	10	10/0,4	0,4		
B	464	5,17	5,17	6,52	8,95	55,56	12,26	6,35	100,00	19,33
D2	340	5,04	5,04	5,04	10,07	56,01	5,89	12,89	75,25	19,85
E22	190	4,89	4,89	4,89	9,79	58,76	7,19	9,55	43,26	20,42
F222	90	5,06	5,06	5,06	10,12	60,69	10,12	3,89	19,84	19,77

TABLE 2 **-** Calculation results

THE RESULTS OF BRANCH LESKOVAC ANALYSIS

The area of Branch Leskovac which includes six technical units and the city itself is analysed. There are two distribution systems within the Branch: the urban and the rural distributive models with six technical units. Distributive systems are considered separately due to their different characteristics and in order to be compared with the practical experience of foreign companies. The data shown in tables 3 and 4 are the result of systematic data collection throughout year and include only the cuts caused by breakdowns.

The information on power supply system status are submitted on daily basis in electronic form which contains: the date of power cut, the name and voltage level of power objects, the time of breakdown and the time of voltage establishing at customers, the number of customers without supply, the type of protection which reacted and the reason of its reaction. The data come to the dispatcher centre and are further distributed to the data analysis and processing service.

Consumption area	Number of customers	The relative shares of voltage levels (%)				The relative shares (%)	SAIDI (h/yr)
		0,4	10	35	110		
TJ Grdelica	7.116	7,55	84,73	6,58	1,14	22,59	46,36
TJ Pečenjevac	5.185	0,07	91,32	4,89	3,72	14,60	41,11
TJ Bosilegrad	4.205	0,07	91,44	4,68	3,80	23,49	81,56
TJ Manojlovac	4.917	5,39	79,49	12,94	2,18	17,57	52,18
TJ Vučje	6.000	9,28	79,56	5,68	5,49	8,68	21,13
TJ Turekovac	4.744	2,56	79,26	14,67	3,51	9,90	30,47
grad Leskovac	22.000	0,00	71,43	27,14	1,43	3,16	2,10
Pogon Leskovac	***54.167***	***3,74***	***84,94***	***8,38***	***2,95***	***100,00***	***26,96***

TABLE 3 **-** Relative effect of voltage levels on the $SAIDI$ parameter

Consumption area	Number of customers	The relative shares of voltage levels (%)				The relative shares (%)	SAIFI (/yr)
		0,4	10	35	110		
TJ Grdelica	7.116	12,04	58,05	26,21	3,69	22,52	19,76
TJ Pečenjevac	5.185	0,35	82,08	11,71	5,85	14,18	17,08
TJ Bosilegrad	4.205	0,05	74,92	11,86	13,18	29,80	44,25
TJ Manojlovac	4.917	4,89	78,18	11,36	5,57	10,46	13,29
TJ Vučje	6.000	10,61	48,07	13,77	27,55	6,98	7,26
TJ Turekovac	4.744	5,43	77,86	10,94	5,76	9,09	11,97
grad Leskovac	22.000	0,00	74,24	7,58	18,18	6,98	1,98
Pogon Leskovac	***54.167***	***4,52***	***70,82***	***14,77***	***9,88***	***100,00***	***11,53***

TABLE 4 **-** Relative effect of voltage levels on the $SAIFI$ parameter

Parameters in tables 3 and 4 are defined at the levels of each area, whereas the shares of voltage levels and technical units are presented relatively in relation to the total number of Branch Leskovac customers. It is obvious from the results that 10 kV voltage level cuts which include 10 kV feeders and 10/0,4 kV substations have the most significant effect on $SAIFI$ and $SAIDI$ parameters. The share of 10 kV feeders is predominant, taking into consideration high breakdown frequency and a large number of supplied customers.

Based on obtained results, it is obvious that the parameter values for rural consumption area are significantly higher than the ones in urban area. The $SAIFI$ parameter value for rural power supply system is 18.06 (/yr) and 43.95 (h/yr) for the $SAIDI$ parameter and is defined based on 32,167 customers. For the urban distributive module, the values of $SAIFI$ and $SAIDI$ parameters are 1.98 (/yr) and 2.10 (h/yr). respectively and are defined based on 22,000 customers. To enable the comparison with foreign practical experience, the typical parameter values in some world countries [1] are presented in table 5. The $CAIDI$ parameter in the same table represents the average duration of one power cut and is defined as the quotient of $SAIDI$ and $SAIFI$ parameters.

	SAIFI (/yr)	**SAIDI (min/yr)**	**CAIDI (min)**	**Density (people/mi2)**
Urban Systems				
Finland	0,8	33	41	
Sweden	0,5	30	60	
Denmark	0,3	7	20	
Italy	2,5	120	48	
Netherlands	0,3	15	58	
Rural Systems				
Finland	5	390	78	38,3
Sweden	1,5	180	120	51,2
Denmark	1,2	54	45	313,7
Italy	5	300	60	496,9
Netherlands	0,4	34	79	975,3
Overall				
Norway	2	300	150	34.6
United States	1,3	120	90	73,2
United Kingdom	0,7	67	92	653,4
Netherlands	0,4	27	73	975,3

TABLE 5 **-** Typical parameter values in the world

CONCLUSION

The result of the concrete consumption area analysis is that overground 10 kV feeders are the parts of the power supply system with the most important share in the total value of $SAIFI$ and $SAIDI$ parameters. The necessary measures in order to improve parameters should be focused on this voltage module, and considering the importance of the issue, they should be analysed separately. It is also shown that the parameter values for rural distribution system are far more inconvenient than the parameters for the urban system, and on a global level, more negative than the ones in more developed world countries. In order to improve them, during object exploitation and undertaking some of possible measures, the importance of minimizing the number of customers without supply should be taken into consideration.

To conclude the paper, it can be said that reliability parameters $SAIFI$ and $SAIDI$ have proven to be a good means for forming an active overview on the status in all parts of power supply system. The parameters defined as shown above enable defining priorities and determining the proper dynamics in power systems maintenance. Furthermore, they can be the basis for optimal solutions in designing and planning the development of the supply system.

LIST OF REFERENCES

- 1. Brown R, 2002 „*Electrical Power Distribution Reliability”*, M. Deches, 59