Analysis of the interruptions in a section of power distribution network medium voltage 20 kV

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***Abstract* — The analysis of the interruptions in a section of the power distribution network of medium voltage 20 kV - "Okolite" power line is given in the report. In 2017, new equipment was installed on the power line to locate the damaged sections more quickly and to switch them off. A classification of the reasons for the power line offs has been made before and after the modernization. The average duration of interruptions is determined. The SAIFI and SAIDI electricity continuity indicators for the period from 2012 to 2018 are determined.**

Keywords — interruptions, continuity of power supply, power line, medium voltage.

I. INTRODUCTION

Reducing the time of power supply interruptions is one of the most essential components for supplying high-quality electrical energy to the consumers [8]. This can be achieved by modernization and better management of the medium voltage (MV) distribution network [1, 2, 4].

Improvement of the MV distribution network can be achieved by:

- use of a large number of short controllable sections - this way only the section, in which failure has occurred or repairs are being done, is left without power supply, and the rest of the power line remains supplied;
- operating reserve, by connecting the power line with other power lines. If the main power source fails, it is possible to supply the power line from another location;
- using secure (reliable) equipment - reliable and secure switchgear and electrical equipment. This is achieved through regular preventive maintenance and timely troubleshooting and repair.

The management of the MV distribution network includes fault indication, remote control, and automation.

The paper presents an analysis of the interruptions in a section of medium voltage power distribution network 20 kV - "Okolite" power line. In 2017 a modernization of the power line was made, and new equipment was installed on the power line to locate the damaged sections more quickly and to switch them off. A classification, of the reasons for the power line turn-offs, has been made and the average duration of interruptions before and after the modernization has been determined. The indicators, of the continuity of electrical power supply SAIFI and SAIDI for the period from 2012 to 2018, are determined [1, 5, 6].

II. CHARACTERISTICS OF THE EXAMINED SECTION FROM THE MEDIUM VOLTAGE DISTRIBUTION NETWORK

The 110/20 kV "Samokov" substation is supplied with three high voltage 110kV overhead power lines - "Sokol" power line from "Kazichene" substation, "Belchin" power line from "Marek" substation and "Yastrebets" power line from HPP "Beli Iskar". The substation is equipped with two power transformers, the rated parameters of which are given in Table I. The substation has 18 outgoing power lines with rated voltage 20kV. They are constructed mainly as overhead power lines.

TABLE I. RATED PARAMETERS OF THE POWER TRANSFORMERS

	Transformer 1	**Transformer 2**
Rated primary voltage U_{1R}, kV	110	110
Rated secondary voltage U_{2R}, kV	20	20
Rated apparent power S, MVA	40	50
Relative short-circuit voltage u_K,%	14,6	12
Winding vector group	YNyn0	YNyn5

The object of research is one of the medium voltage power lines 20 kV - power line "Okolite". This power line (Figure 1) provides power supply for a part of the town of Samokov, and it also crosses and supplies the villages Dragoshinovo, Shiroki Dol, Zlokuchene, Gorni Okol, and Dolni Okol. The number of transformer stations 20/0.4 kV connected to the power line is 48 and the total installed power of the transformers in the transformer stations is 11.2 MVA. The customers, powered by the power line under consideration, are about 4500 - mainly households. The total length of the power line is 49 980 m, of which 6125 m are constructed as cable line, and 43 855 m are constructed as an overhead power line. The cable lines are used only in separate branches from the power line in the direction of the transformer stations. The main line of the power line is constructed as an overhead power line with aluminum-steel conductors with a cross-section of 70 mm2 (Al/steel 70). The type of conductors and their length for the rest of the power line are shown in Table II.

The beginning of the "Okolite" power line is located in a flat part and thus continues to about the middle of its mainline. Physically it passes meters away from the road and can be reached relatively easily and quickly if necessary.

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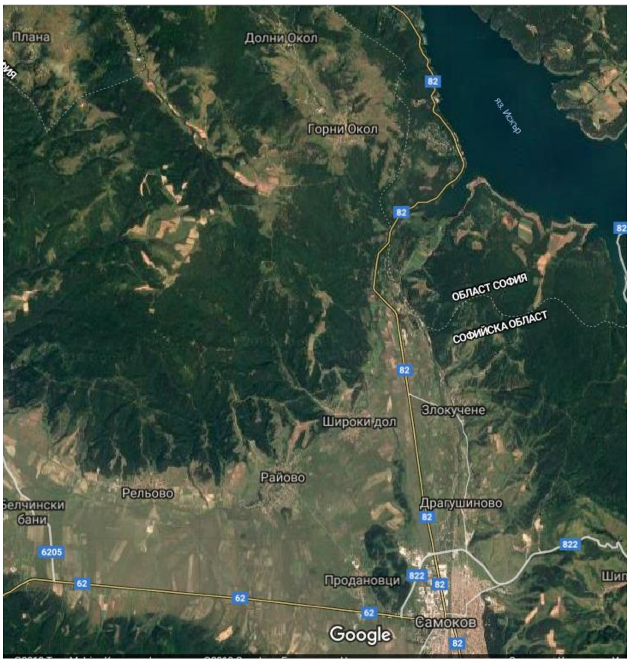
a) view in GIS



b) view in Google Maps

Fig. 1. Location of the "Okolite" power line.

TABLE II. TYPE AND LENGTH OF THE SECTIONS OF THE POWER LINE „OKOLITE“

Type of conductor	Length, m	Total, m
Overhead power line		
Al/steel 35	2443	43855
Al/steel 50	27042	
Al/steel 70	14370	
Cable power line		
(N)AKBA 50	848	6125
(N)A2XSY 70	662	
(N)A2XSY 95	1812	
(N)A2XSY 185	2803	

The access to the rest of the power line is not that easy. It passes through higher and somewhat hard-to-reach parts of the mountain. In case of a failure, especially in the winter and in bad weather conditions, when it is to be discovered by visual inspection through the length of the power line, this may take hours. During this time, many users are left without power supply, which is not advisable, and for users with zero and first category on power supply reliability, this is unacceptable. These power supply interruptions lead to both consumer dissatisfaction and losses for the electric power supply company from non-supplied electrical energy [2, 4, 7].

III. ANALYSIS OF THE INTERRUPTIONS

The time required to locate and reach the damaged area of the power line has the largest share of the total interruption time [1, 2, 3]. The power supply interruption time can be reduced to the minimum by controlling the 20 kV MV network by means of automation, remote control and installation of modern equipment.

In 2017, the following equipment was installed on the "Okolite" power line:

- One remote-operable three-pole, two-position circuit breaker - recloser;
- Two remote-operable power disconnectors;
- Three short-circuits annunciators with remote data transmission.

The main purpose for installing this equipment is to locate the faulty sections of the power line more quickly and, if possible, to disconnect them, thus to reduce the power supply interruption time.

Summary data, for interruptions for the year before (2016) and the year after (2018) the automation and modernization with the new equipment of the "Okolite" power line, are given in Table III.

TABLE III. SUMMARY DATA FOR THE INTERRUPTIONS OF "OKOLITE" POWER LINE

Indicator	For 2016	For 2018
Total number of users powered by the power line, number	4505	4532
Total number of users affected by power supply interruption, number	46 266	13 652
Non-supplied electrical energy, kWh	111 622	88 044
Total power supply interruption time for: - planned interruptions, min - unplanned interruptions, min	 7700 2811	 4980 1020
Total number of interruptions - planned interruptions, number - unplanned interruptions, number	 62 39	 53 44

The total number of interruptions in the power line in 2016 is 101 and in 2018 it is 97. The planned interruptions in 2016 are 62, with a total duration of 128 hours and 20 minutes, and in 2018 the interruptions are 53 with a total duration of 83 hours.

Unplanned interruptions in 2016 are 39, with a total duration of 46 hours and 51 minutes, and in 2018 the interruptions are 44 with duration of 17 hours. The average duration of unplanned interruptions in 2016 is 72 minutes and in 2018 is 23 minutes.

The failures in the power line are due to line to line short circuits and/or ground faults, with occurring of which the power supply is interrupted by the action of the protective and automatic devices.

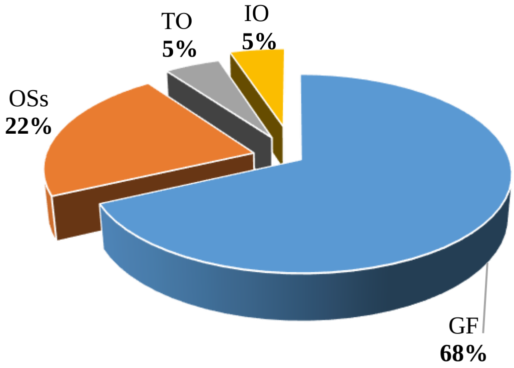


Fig. 2. Reasons for unplanned interruptions in 2016

A classification of the reasons for unplanned interruptions in 2016, in percent, is shown in Fig. 2. The highest number of interruptions is due to the action of the ground fault protection (GF) - 68%, on the second place, are the interruptions due to power supply turn-offs under operational switchovers (OSs) - 22%. Interruptions due to the action of instantaneous overcurrent protection (IO) are 5% and are mainly caused by lightning. Interruptions resulting from timed overcurrent protection (TO) are also 5% and are mainly caused by overloading in the MV network.

The reasons, for power line turn-offs due to the triggering ground fault protection in 2016, are shown in Fig. 3. It is easy to see that the highest percentage of turn-offs of 38% is due to accidents caused by weather conditions, that is to say falling branches and trees, storms, strong winds, rains, and snowfalls. The remaining turn-offs are: 10% of power line faults, 10% of successful auto-reclosing (AR), 5% of excavation work, and 5% of birds.

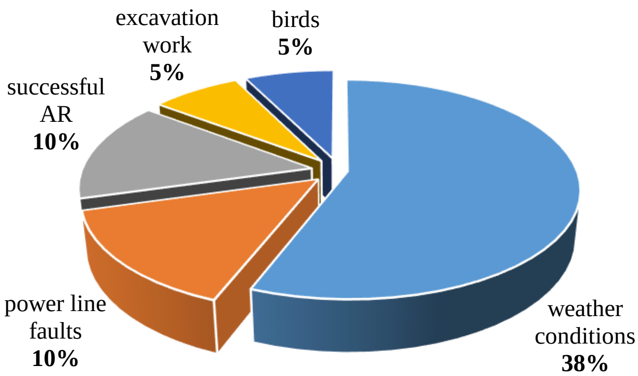


Fig. 3. Reasons for turn-offs due to ground fault protection in 2016

Fig. 4 shows the reasons for the unplanned interruptions for 2018, after installing the new equipment, in percent. Here again, the highest number of interruptions - 75% are caused by the triggering of the ground fault protection. Interruptions resulting from operational switchovers are 15%. Interruptions after TO triggering are 5% and are mainly caused by overloading in the network. The turn-offs after triggering of the instantaneous overcurrent protection are also 5% and are mainly caused by lightning.

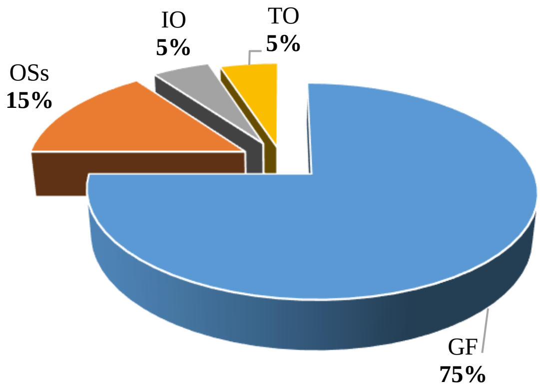


Fig. 4. Reasons for unplanned interruptions in 2018

The reasons, for turn-offs of the power line due to the triggering of ground protection in 2018, are shown in Fig. 5. They are due to faults caused by a successful auto-reclosing (35%), severe weather conditions (30%) - falling branches and trees, storms, strong winds, rains, snowfalls, and power line faults (10%).

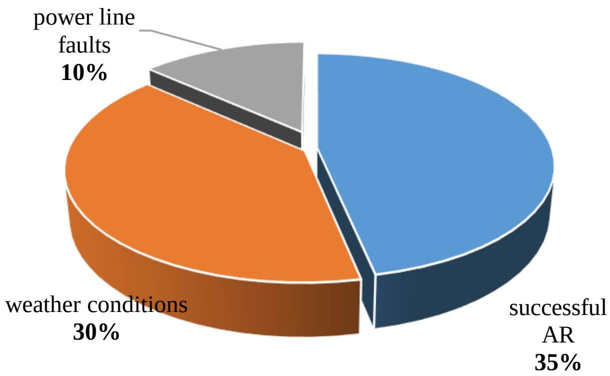


Fig. 5. Reasons for turn-offs due to ground fault protection in 2018

The indicators, for the continuity of the power supply for the examined power line, have been determined. Reference values for the indicators of the continuity of the power supply at the medium voltage level are specified in [1, 5, 6]:

- System Annual Interruption Frequency Index (SAIFI);
- System Average Interruption Duration Index (SAIDI).

The acquired values are given in Table IV.

TABLE IV. SAIFI AND SAIDI VALUES FOR THE „OKOLITE“ POWER LINE

Indicator	For 2016	For 2018
For planned interruptions: SAIFI, number per year. SAIDI, min	 0,0137 1,7092	 0,0116 1,0988
For unplanned interruptions: SAIFI, number per year. SAIDI, min	 0,0086 0,6239	 0,0097 0,2250

The SAIFI data and values show that the number of interruptions is almost the same over the two years under consideration, but the duration of the interruptions SAIDI varies considerably.

After the installation of the new equipment on the "Okolite" power line, the average duration of the interruption of the power supply is reduced three times compared to the period prior to their installation. There is also an increase in the number of successful ARs after a fault occurring, in which practically the users aren't left without power. Therefore, the automation of the medium voltage distribution network with the installation of remote-controlled devices and devices for data acquisition has a significant impact on the customers' power supply, and therefore the reduction of the non-supplied electrical energy to the customers of the power supply company.

Data on planned and unplanned interruptions of the "Okolite" power line from 2012 to 2018 are presented in Table V.

TABLE V. DATA FOR THE "OKOLITE" POWER LINE FOR THE YEARS FROM 2012 TO 2018

Year	Total number of users, number	Total number of users affected by power supply interruption, number	Non-supplied electrical energy, kWh	SAIFI planned, number per year	SAIFI unplanned, number per year	SAIDI planned, min	SAIDI unplanned, min
2012	4567	245 852	44 136	0,0219	0,0188	1,9400	0,8150
2013	4553	157 395	49 940	0,0193	0,0037	2,7037	0,8150
2014	4520	169 750	50 314	0,0039	0,0143	0,0745	2,9025
2015	4516	305 383	142 872	0,0211	0,0136	1,4231	0,7120
2016	4505	46 266	111 622	0,0137	0,0086	1,7092	0,6239
2017	4510	93 243	46 919	0,0330	0.0159	3,6465	0,5957
2018	4532	13 652	88 044	0,0116	0,0097	1,0988	0,2250

The diagrams, that present the summarized results for the indicators SAIFI and SAIDI for the period 2012 to 2018, are shown in Fig. 6 and Fig. 7.

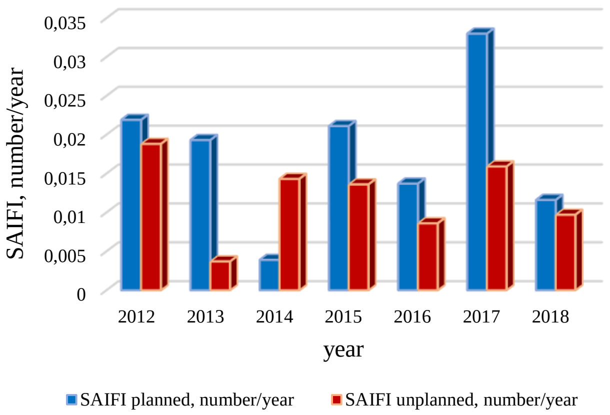


Fig. 6. SAIFI in the period from 2012 to 2018

As shown in the figures, when there are planned interruptions for work on the network - regular preventive maintenance and repairs, trees around the power lines are cut, etc., the unplanned interruptions are less. When there are few planned interruptions and no repairs are done as it was in 2014, unplanned interruptions are dramatically increasing. In 2017, planned interruptions are the most on number and longest on duration for the period under consideration, some of which are due to the installation of the new equipment. In 2018, the best results were recorded, especially for the interruption duration - SAIDI indicator.

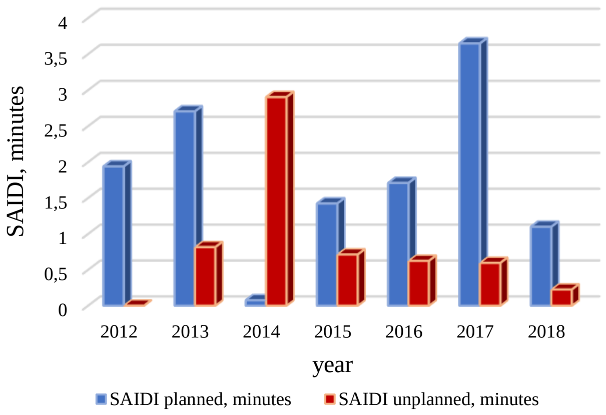


Fig. 7. SAIDI in the period from 2012 to 2018

CONCLUSION

From the research and analysis of the "Okolite" power line, it can be seen that the installation of remote-controlled devices and devices for data acquisition results in the following benefits:

- The localization of the damaged section of the medium voltage distribution network is facilitated;
- The time for locating the faulted section and eliminating the fault, of the power distribution network, is being reduced;
- The duration and number of interruptions are being reduced;
- Decreasing the amount of non-supplied electrical energy to customers and hence increasing the profit of the power supply company.

It is expedient and advisable for power supply companies to invest more in network automation, which will improve all the power quality indicators and better meet the customer's electrical energy needs.

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