Analysis of the Causes of Emergency Shutdowns on Electric Networks

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Abstract. The paper analyses the causes of emergency outages on electric networks according to the data of the Pravoberezhny district of Irkutsk for 2008-2017, according to which 82% of failures of elements of the electric network are caused by breakdowns and equipment failure; 9% are due to the influence of external factors; 5% occurred due to natural and climatic reasons, 4% – due to other circumstances. The largest number of outages due to operational reasons occurs due to damage to cable and overhead lines. Accidents caused by the influence of external factors are mainly associated with the negative impact of people, animals and birds. Equipment failures related to natural and climatic factors are mainly due to wind or thunderstorms. Other circumstances, as a rule, include staff errors and unidentified reasons. Calculations of undersupply of electricity and economic losses caused by interruptions in power supply were made. It should be noted that in order to reduce the number of equipment failures, it is necessary to carry out timely maintenance and reconstruction of various elements of electrical networks.

1. Introduction

The electric power system of any country includes a large number of power plants, power transmission lines and transformers that cannot work flawlessly for a long time due to equipment wear, the influence of natural and climatic conditions, personnel errors, etc. At the same time, uninterrupted supply of electricity to consumers is the main task of the functioning of the electric grid complex [1-3].

The analysis of the types and amount of damage in cable and overhead power transmission lines is an urgent problem, the study of which is devoted to the works of various Russian and foreign authors [4-6].

It should be noted that the causes of emergency shutdowns are diverse and depend on the type of electrical networks (cable, air), voltage, the territory where they are located, the degree of wear of equipment, etc. [7-8].

Since the causes of emergency outages depend on the territory where the electrical networks are located, it is necessary to conduct their point analysis on the example of a specific object. The purpose of the work is to analyze the causes of emergency outages on the Southern electric networks of Irkutsk.

The study was conducted on the basis of daily data from the logs of the district electric network of the Pravoberezhny district of Irkutsk for 2008-2017.
2. Results and discussion

There are various qualifications of the causes of emergency shutdowns [9-13], of which the following can be distinguished: operational, natural and climatic, related to the influence of external factors, and others. Emergency shutdowns that occurred due to equipment failure and failure are operational [14]. Among them, the following are distinguished: the burning of fuses, damage to cable and overhead lines, breakdown of equipment of transformer substations. Natural and climatic phenomena that cause unplanned outages are: strong and squally winds, heavy rains, thunderstorms, snowstorms, as well as floods and earthquakes [9, 11, 12, 15-17]. Disconnections often occur due to the negative impact of people (mechanical damage to cable lines and supports, vandalism, etc.), animals and birds, as well as due to falling trees and their branches on cable and overhead lines [12-18]. Others include unidentified causes, fires and outages made at the request of various consumers.

An analysis of the total number of emergency outages by month that occurred in the Pravoberezhny district of Irkutsk showed that in 2008-2010 the largest number of accidents occurred in the winter months (Fig. 1). The main cause of outages in the winter months was the burning of fuses (814 outages in December-February 2008, 504 – in 2009, 312 - in 2010), which indicates an overload of networks during this period associated with a significant decrease in air temperature and insufficient power of transformer substations. The breakdown of the number of emergency shutdowns for reasons showed that 82% of them were caused by breakdowns and equipment failure; 9% – due to the influence of external factors; 5% – occurred for natural and climatic reasons, 4%-due to other circumstances.

![Figure 1. The number of emergency shutdowns by month in the Pravoberezhny district of Irkutsk for 2008-2017.](image.png)

Thus, the majority of failures on electrical networks is equipment failure, which depends on equipment wear, timely maintenance, compliance with operating terms, personnel competence, etc. Among the causes of emergency shutdowns, the following are highlighted: the burning of fuses, damage
to cable and overhead lines, breakdowns of a transformer substation, damage in consumer networks (Fig. 2).

![Graph showing number of emergency shutdowns over years]

**Figure 2.** Causes of emergency shutdowns caused by operational factors.

As noted earlier, in 2008-2010, a significant number of emergency shutdowns occurred due to the combustion of fuses. However, in the following years, there was a decrease in failures for this reason. In general, it is impossible to distinguish a certain trend in a number of equipment failures for operational reasons. At the same time, the number of accidents on cable and overhead lines has a positive trend, despite the fact that in some years this indicator increases, and in others it decreases. It is noteworthy that the growth of emergency shutdowns caused by damage at transformer substations in 2016 almost doubled compared to 2015. Most likely, a large number of outages for operational reasons is associated with equipment wear caused by a decrease in funding for reconstruction and technical re-equipment of networks [19, 20].

Among the reasons caused by external influence, the following are highlighted: wire breakage, downing of a support, mechanical damage to a cable line, fire, animals (rats, cats) and birds (crows, sparrows) getting into a transformer substation, falling of a tree, road accidents and theft.

At the same time, the largest number of accidents is caused by mechanical damage to cable lines (41%), broken wires and fires (12% each), falling trees (10%), knocking down supports and at the request of consumers (9% each). A small percentage of accidents are caused by a ball hitting a transformer substation (3%), animals (3%) and birds (2%).

The main climatic cause of accidents is a strong and stormy wind, which provokes a clash and a break in wires. Moreover, the number of accidents caused by wind in one day can range from 13 to 40, which took place in May 2016. Significantly fewer accidents occur during thunderstorms, snowfall. In addition, natural events such as earthquakes and floods that lead to blackouts are much less common.

These reasons lead to short-term and long interruptions in the power supply. Moreover, not always a large number of failures indicates a significant undersupply of electricity to consumers. According to Figure 3, there were long shutdowns in the period under review. So, in April 2009, the duration of several outages for an unknown reason ranged from 34.83 hours to 17.67, which led to an under-output of 247237 kWh of electricity. In addition, due to the collision of wires, losses amounted to 75715 kWh.
In April 2014 the breakage of the overhead line from the fall of a tree led to an undersupply of 1226032 kWh of electricity, and in August 2016, damage to the cable line caused an undersupply of 283492 kWh.

**Figure 3.** Undersupply of electricity kWh due to emergency shutdowns in 2008-2017.

**Table 1.** Characteristics of losses caused by emergency shutdowns on electric networks.

| Year | Number of shutdowns | Undersupply interruptions, kWh | The electricity tariff, rubles/kWh | Damage from shutdowns, thousand rubles |
|------|---------------------|--------------------------------|-----------------------------------|---------------------------------------|
| 2008 | 1443                | 2626300                        | 0.315                             | 827.3                                 |
| 2009 | 1146                | 2327204                        | 0.392                             | 912.3                                 |
| 2010 | 1123                | 2552708                        | 0.434                             | 1107.9                                |
| 2011 | 825                 | 1693888                        | 0.476                             | 806.3                                 |
| 2012 | 832                 | 2036379                        | 0.504                             | 1026.3                                |
| 2013 | 630                 | 1466746                        | 0.82                              | 1202.7                                |
| 2014 | 813                 | 2716361                        | 0.84                              | 2281.7                                |
| 2015 | 723                 | 1038906                        | 0.92                              | 955.8                                 |
| 2016 | 1027                | 2427609                        | 0.97                              | 2354.8                                |
| 2017 | 903                 | 1483672                        | 1.01                              | 1498.5                                |
Interruptions in electricity supply have negative consequences not only for consumers, but also for energy supply organizations. According to the table, the damage from emergency shutdowns at substations of the Southern electric networks of the Pravoberezhny district of Irkutsk in different years varies from 806.3 thousand to 2.355 million rubles.

It should be noted that in fact, the economic losses of energy supply organizations are much higher, since they include the costs of unscheduled repairs or replacement of equipment, as well as additional costs for generating and transmitting electricity during emergency, post-accident and repair modes of operation of the power supply system [21].

3. Conclusions
1. As a result of the analysis, the following are identified: operational, natural and climatic, related to the influence of external factors and other causes of emergency shutdowns.

2. It was revealed that 82% of failures of electrical network elements are caused by breakdowns and equipment failure; 9% are due to the influence of external factors; 5% occurred due to natural and climatic reasons, 4% due to other circumstances.

3. The main cause of outages for operational reasons is damage to cable and overhead lines. Accidents caused by external influences are mainly associated with the negative influence of people, animals and birds. Despite the fact that the number of failures caused by the influence of natural and climatic reasons is not large, the duration of outages due to wind or thunderstorms in some cases is more than ten hours.

4. Emergency shutdowns, regardless of the cause, lead to a shortage of electricity and significant economic losses. In this connection, timely maintenance and reconstruction of various elements of electrical networks is required in order to prevent equipment breakdowns.

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