Policy service design of elements and rural distribution mains of 10 Kv on the results of technical position diagnosis

L M Rybakov, N L Makarova, A O Zakhvataeva, A N Basov, D V Rukavishnikova
Mari State University, Yoshkar-Ola, Russia
E-mail: diagnoz@marsu.ru

Abstract. This article considers questions of overhead high-voltage lines working capacity and ways of its improving reliability. Influence of different factors especially climatic on overhead line condition is shown. Zoning plan of the Russian Federation on annual average duration of thunderstorms in hours is presented. Also, it shows data on numbers of thunderstorm activity intensity on the territory of the Republic of Mari El over a period of observation from 2007 to 2016 years. Statistic data on number of overhead line shutdowns in thunderstorm periods from 1985 to 2010 years. For estimation of working capacity of device and elements of distribution mains weather two-factor models are presented. Key reasons of damage of overhead electric lines elements are shown, besides, data on shutdown of overhead lines because of pin-insulators damages and cords on the territory of the Republic of Mari El over a period from 2007 to 2016 years are illustrated. Maintenance work system of overhead lines that accepted in operation are considered. On the results of reasons of overhead lines breakdown analysis it was found that most of overhead lines emergency shutdowns are caused by nature and climate effects that depend on conditions of usage, high quality conduction routine-preventive repairs, consequently on technical staff qualification etc. Service policy considering nature and climate factors influence, material-and-technical support by modern instruments and equipment, rational service and timely preventive measures implementation was designed.

1. Introduction

Electric energy distribution is based on overhead lines (OHL) with voltage of 6–10–35 kV that general length is more 1 mio. km. Overhead transmission lines are more injured electric installation of electrical mains because of their length and location on open countries that’s why they are subjected to climatic effect influence. Overhead line failure rate is sequence higher than failure rate of transformers and switches.

In the operating process different climatic and operational factors influence on overhead lines. Prime climatic factor influencing on accident-free operation of overhead lines are atmospheric overvoltage, icing, wind, air temperature.

Security of service of electricity transmission lines depends on a lot of factors designing quality, construction and installation operations, bringing into action and proper operating in different states and atmosphere and climatic conditions.
2. Research Method
Failure insulating elements analysis of power distribution zone of 10 kV shows that most number of shutdown of distribution networks of Mid-Volga region is connected with loose of function of insulating elements. Main part of shutdowns are accrued to summer period that is explained by intensive thunderstorm activity and internal over-voltages.

Thunderstorm activity intensity is characterized by average number of thunderous hours per year. According to chapter 2.5 Electrical Installations Code [1] comprehensive map of thunderstorm activity intensity of RF presents in the Figure 1. As it can be seen Republic of Mari El is IV region of thunderstorm season with duration of 40-60 hours per year.

Table 1 illustrates received average rates of number of thunderstorm hours by month of the year over last 10 years in the Republic of Mari El (2007-2016 years).

| Months | April | May | June | July | August | September | October |
|--------|-------|-----|------|------|--------|-----------|--------|
| Number of thunderstorm hours, [h] | 0.1   | 2.5 | 7.6  | 13.1 | 6.7    | 1.2       | 0      |

Figure 2 presents bar chart of distribution of shutdowns of overhead lines in thunderstorm period over a period of 1985-2010 years.
Long-term operating analysis shows that equipment and distribution main elements depend on a seasons. For example, period from December to February is a period of most number of failures caused by cords failures, period from March to November because of insulator failures [2–4]. Among these months there is a period of most emergency shutdowns caused by equipment damage and distribution mains elements that is from April to October.

Prime factor of cord damages is its break from wind actions and gust and gaze influences. Cord break intensity is high over all period of a season, however exceedance of failures caused by its failures falls on winter period because of high wind force, ice loads and snow. That’s why it’s taken a period of December-February for cords.

Figure 3 shows distribution of number of bar chart of cord damages by months of the year for period of observation 2007–2016 years on the sample of production department Yoshkar-Ola electrical mains of the Republic of Mari El.

Most common cause of insulators failure is mechanical damage from one-side influence in cases of cord break in span because of high temperature cause by covering with electric arc and electrical breakdown caused by lightning strike or surge voltages [5–7]. Figure 4 shows bar chart of distribution of number of shutdowns caused by pin-insulators by months over observation period 2007-2016 on the sample of production department Yoshkar-Ola electrical mains of the Republic of Mari El.

On the base of experimental researches weather two-factor models were made for estimation of working capacity of pin-insulators presented on the Figures 5 and 6 [8, 9].

![Figure 3. Bar chart of distribution of number of cord damages by months of the year over a period of observation 2007-2016 years on the sample of production department Yoshkar-Ola electrical mains of the Republic of Mari El.](image1)

![Figure 4. Bar chart of distribution of number of shutdowns caused by pin-insulators by months over observation period 2007-2016 on the sample of production department Yoshkar-Ola electrical mains of the Republic of Mari El.](image2)

![Figure 5. Weather two-factor model (temperature (x) and thunderstorm(y)) for estimation of working capacity of pin-insulators of rural distribution mains.](image3)

![Figure 6. Weather two-factor model (wind (x) and thunderstorm(y)) for estimation of working capacity of pin-insulators of rural distribution mains.](image4)
Figure 7 illustrates prime causes of damages of distribution lines elements of 10 kV. Table 2 illustrates data on distribution of number of distribution mains elements damages of 10 kV of the Republic of Mari El serviced by production department Yoshkar-Ola electrical mains of the Republic of Mari El over last 10 years (given average rates by months of the year for researching 10 years) because of which failures happened.

Figure 7. Prime causes of damages OHL elements, where 1 is carrying capacitance, wear, corrosion; 2 is gust-and-glaze loading; 3 is insulation pollution; 4 is vandalism; 5 is design fault, building and assembly faults; 6 is defects of production; 7 is reasons are not found out; 8 is process defects; 9 is off-design condition of main (internal overvoltage); 10 is atmospheric overvoltage.

3. Results and Discussion
Overhead transmission lines because of their big length have determined number of identical elements that have own reliability index. As it was established weather factors influence on proper overhead transmission lines functioning and failure rate of overhead transmission lines elements depends on features of construction, operation conditions and outside environment. It’s revealed that key reasons of overhead transmission lines basic elements failures are atmospheric, natural and climatic and other effects. Generally, proper overhead transmission lines functioning depends on quality preventive maintenance, early diagnostics and forecasting of researched object [10–12]. Currently, designing, operation and diagnosis of overhead transmission lines are conducted in accordance with such normative documents as GOST839-80, GOST 6490-93, GOST 18322-2016, GOST 25866-83, GOST 26656-85.

In operating practice use following systems of holding maintenance works overhead transmission lines preventive maintenance, that are conducted after the expiry of operation definite period. Such method is not always optimal as it tends to unjustified shutdowns of working items. Emergency recovery repairs and repairs on the results of technical diagnosis when it is necessary to know real state of researched object. Solving problems of technical diagnosis it is possible to support normal functioning and in particular cases improve overhead transmission lines reliability that more over liable to nature and climatic effects. Necessity of moving to maintenance system appears. Herewith, scope and terms are determinate by real state of electric equipment that necessitates creation of effective diagnostic system of overhead transmission lines [13–15].

Using of means of technical diagnosis of overhead transmission lines that function in a real time makes it possible to increase essentially reliability of functioning of overhead lines owing to early defects detection, take-down for repairs, failure inhibition.

Reliability of overhead lines is determined by using conditions, their timely and right accounting bring about change of reliability index.

On the results of calculations statistical model that is dependence of mathematical expectation failures of distribution mains from time by months during a year was received. Received model is presented as a graph on the Figure 8.
4. Conclusion

On the results of reasons of overhead lines breakdown analysis it was found that most of overhead lines emergency shutdowns are caused by nature and climate effects that depend on conditions of usage, high quality conduction routine-preventive repairs, consequently on technical staff qualification etc. Service policy considering nature and climate factors influence, material-and-technical support by modern instruments and equipment, rational service and timely preventive measures implementation on the base of recommendations [16].

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