Journal of Modern Energy Research
Vol. 2, No. 1, Jul 2024, pp. 16-23
ISSN: 3078-3534, DOI: 10.56947/jmer.v2i1.6

Enhancing Reliability of Electricity Supply of City Electric Networks Cities

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Article Info

Article history:

Received Feb 25, 2024
Revised Apr 13, 2024
Accepted Jun 17, 2024

Keywords:

Cable and overhead lines
Transformer substations
Reliability of power supply
Failure flow
Power consumption
Mathematical model

ABSTRACT

The article is devoted to the urgent problem of a method for increasing the reliability of a city electric network. Based on a statistical analysis of the outage accident rate of electrical equipment of the city distribution networks of Dushanbe for the periods of 2022-2023 and due to damage reasons leading to these outage trips, factors were identified that affect the distribution of damage leading to outages. This factor includes increases in electrical load and changes in climatic and meteorological conditions in Dushanbe. Taking into account the identified factors, the electricity consumption prediction equations are proposed taking into account the terrain of the city of Dushanbe, which allows us to propose a way to control the operating parameters of the electric network, thereby increasing the reliability of the city electric network in Dushanbe based on the recommendation of electricity consumption standards. The implementation of the control of the proposed method for improving the reliability of power supply to the city electric grid is proposed based on the functionality of modern smart electricity metering using the control algorithm. This algorithm allows you to maintain energy consumption standards, thereby controlling the operational parameters of the city electric network and will reduce the likelihood of an increase in the distribution of damage leading to emergency outages. To implement the control algorithm, a schematic design of the reception and transmission of information from smart electricity metering to the information collection center is proposed.

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1. INTRODUCTION

The effectiveness of any electrical networks, including city networks, is ensured by maintaining the allowable specific loads, both at maximum hours and throughout the day and month. Exceeding specific loads from the normative leads to a deterioration in the reliability of the power supply system [1]–[8]. The efficiency of the power supply system depends on the correct forecast of power consumption. Under the concept of efficiency is understood - the reliability of power supply. In turn, the reliability refers [7]–[13]:

- power quality;
- service life of electrical equipment;
- lack of electricity supply.

The increase in electrical load is associated, in particular, with the climatic and meteorological conditions of the area and in the absence of warm-hot water supply for urban consumers, this factor may be the main reason for the increase in electric load, which subsequently can lead to a violation of the quality of

electric power and the life of electrical equipment and undersupply of electricity. It should be noted that consumers in Dushanbe, like the whole Republic of Tajikistan, are deprived of other sources and the entire load lies on the shoulder of electricity.

To increase the reliability of Dushanbe city networks, it is necessary to identify factors affecting damage to the main elements of the power supply system with the aim of proposing a method and method of increasing the reliability of power supply to the city electric network using the example of Dushanbe.

Assessing the performance of electrical equipment of urban electric networks is the main criterion for the reliability of power supply [14]–[24]. Therefore, in order to increase the reliability of power supply to urban electric networks, it is necessary to analyze the operation and dynamics of damage, taking into account the factor dependencies on damage for the electrical equipment in question.

2. STATEMENT OF THE PROBLEM

To assess the reliability of power supply to the city electric network in Dushanbe according to damage data for the periods of 2022-23.

Damage dynamics were constructed based on months, ambient temperature and air humidity.
In Figures 1-2 show the dynamics of damage to overhead lines, overhead lines and transformer substations with a voltage of 6-10 kV for months for the period 2022-2023.

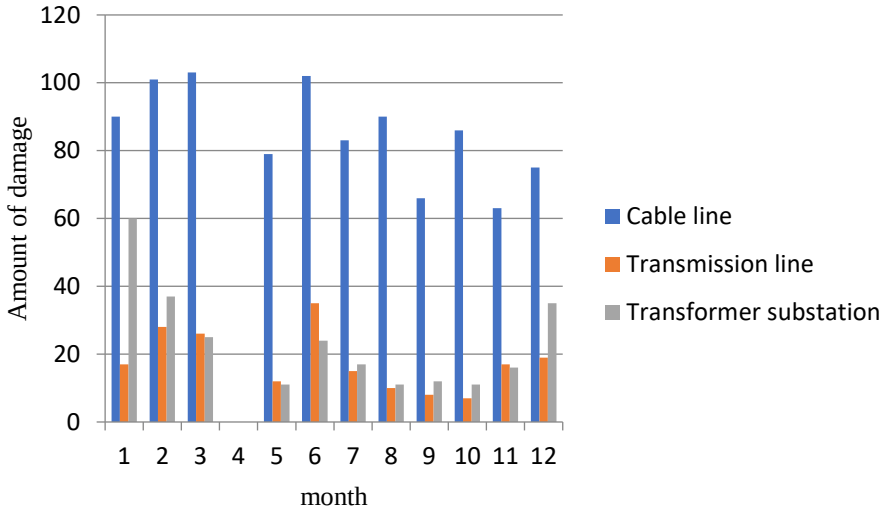


Figure 1. Dynamics of damage to cable lines, overhead lines and transformer substations with a voltage of 6-10 kV for 2022

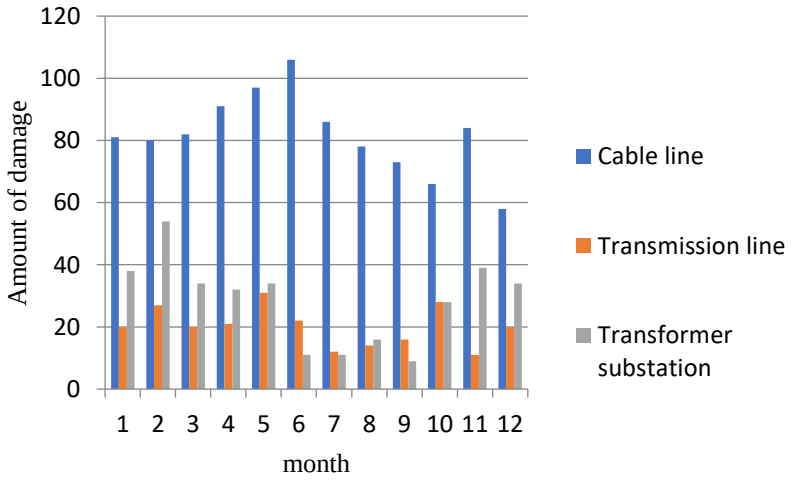


Figure 2. Dynamics of damage to cable lines, overhead lines and transformer substations with a voltage

of 6-10 kV for 2023

To assess the dependence of the ambient temperature and air humidity on damage to the cable lines, overhead lines and transformer substations for 3 months, the dynamics of damage for the electrical equipment under consideration was built in Figures 3-4.

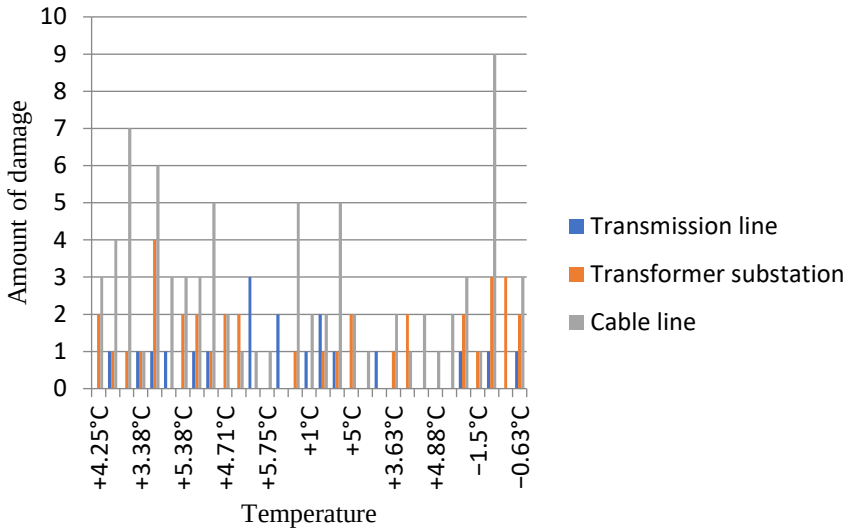


Figure 3. Dynamics of damage to transmission lines, cable lines and transformer substations depending on the ambient temperature by days in the month of January

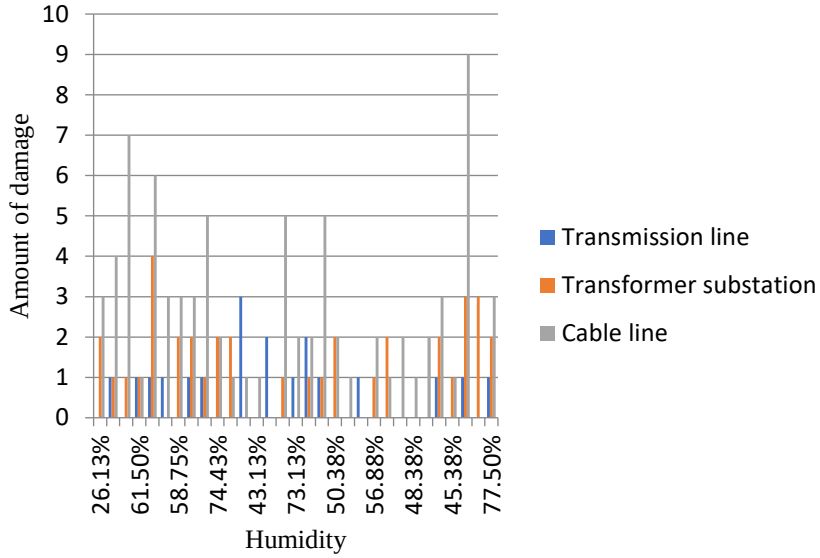


Figure 4. Dynamics of damage to transmission lines, cable lines and transformer substations depending on air humidity by days in January

The purpose of assessing the dependence of climatic factors on damage was to identify the main factors on damage to the electrical equipment of urban electric networks in Dushanbe to further recommend measures to improve the reliability of power supply. When assessing damage, cable lines (CL) of 6-10 kV, transmission lines (TL) of 6-10 kV and urban transformer substations (TS) of 6-10/0.4 kV will be considered.

3. METHODOLOGY

The main criterion for the efficiency of urban electric networks is the reliability of power supply, which in turn can be expressed through the lack of electricity supply depending on the flow of failure and the recovery time of damaged electrical equipment.

$$\Delta W = W_{consumption} \cdot \omega^* \cdot (\frac{t_{recovery}}{T_{year}}), \quad (1)$$

According to the current document in the Republic of Tajikistan (RT) RD 34.20.801-90 "Instructions for the investigation and registration of technological violations in the operation of power plants, networks and power systems" all damage is classified into:

1) Technical (technological);
2) Organizational.

From the above expressions (1), the technical (technological) causes of damage include the flow of failures - ω^* and for organizational reasons, recovery time - $t_{recovery}$. In this article we will focus on reducing technical (technological) damage.

Therefore, to reduce technical (technological) damage, it is necessary to reduce the flow of failures - ω^*. Given that one of the main factors affecting the increase in failure flows is the increased electric load and the power consumption depending on it [9]–[22] when recommending a mathematical model to improve the reliability of power supply in urban electric networks of the Republic of Tajikistan in particular, Dushanbe, we will focus on this factor.

4. RESEARCH RESULTS AND DISCUSSION

The dependence of the failure flow on power consumption can be represented as a linear dependence and according to our study [25]–[34], the main time interval at which the probability of damage increases is the maximum load time. In Figure 5 shows the relative dependence of the flow of failure - ω^* from power consumption during peak hours - $W^*_{maximum\ load\ time} \cdot \omega^*_{standart}$. We attach this dependence in the form of the following mathematical expression (2).

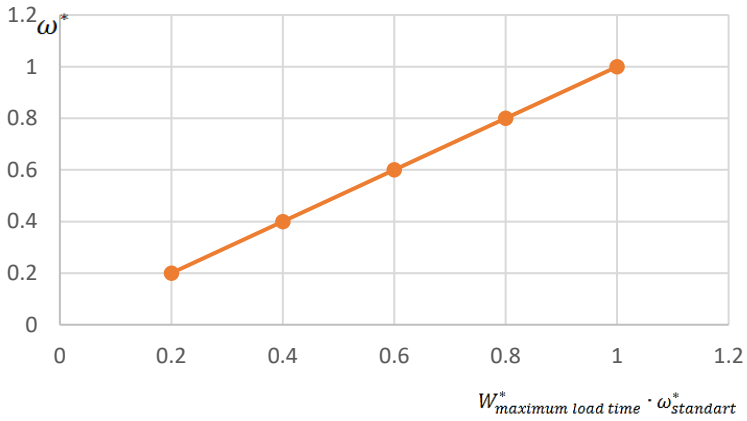


Figure 5. Relative dependence of the flow of failures on power consumption during hours of maximum loads

From Figure 5 it can be seen that if the power consumption is met corresponding to the specific power consumption standards, the relative probability of the flow of failure will slowly tend to 1. Whereas if the power consumption exceeds the specific power consumption standards, the probability of damage increases sharply.

$$\omega^* = f\ (W^*_{maximum\ load\ time} \cdot \omega^*_{standart}\ ), \quad (2)$$

Where: $W^*_{maximum\ load\ time} = \frac{W_{maximum\ load\ time}}{W_{recommended}}$, $\omega^*_{standart}$ - standard failure molasses for the considered electrical equipment according to [35]–[40].

We will represent power consumption during hours of maximum loads in the form of expression (3):

$$W_{maximum\ load\ time} = P_{allowed} \cdot t_{maximum\ time\ per\ day} \cdot \alpha_{maximum\ load\ time}, \quad (3)$$

Where: $P_{allowed}$ - permitted power provided by the electricity supply organization 8-10 kW, $t_{maximum\ time\ per\ day}$ - maximum load time during the day, hours, $\alpha_{maximum\ load\ time}$ - maximum load time factor.

To test the proposed mathematical model for increasing the reliability of power supply of the city electric network in Dushanbe according to the predicted power consumption schedules for the winter and summer months, Figure 6, 7 the dependences of the relative failure flow on power consumption during hours of maximum loads Figure 8. The rate of specific power consumption during hours of maximum loads for winter and summer and the norms of failure flows are given.

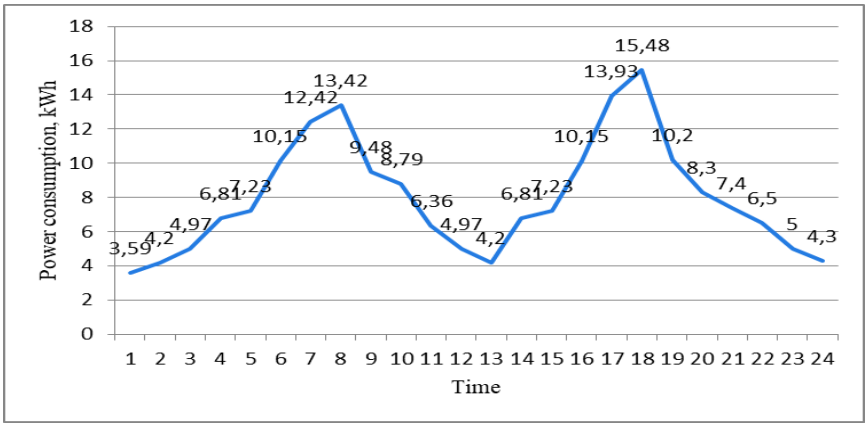


Figure 6. Winter hourly energy consumption schedule in Dushanbe

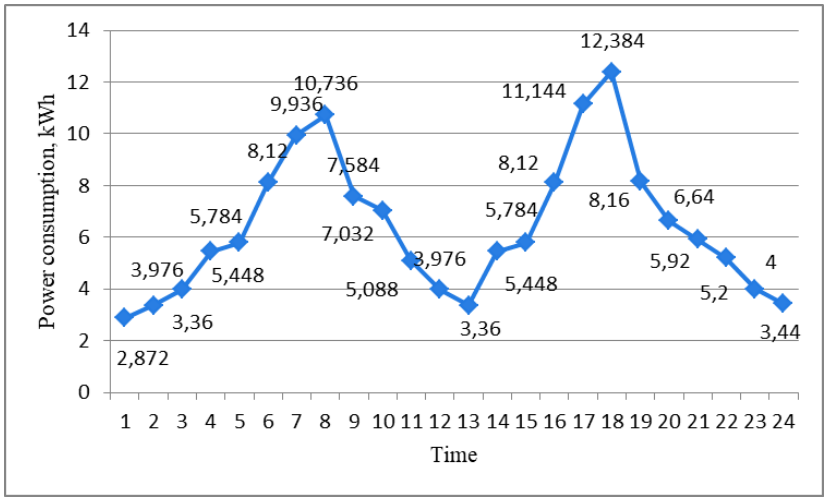


Figure 7. Summer hourly energy consumption schedule in Dushanbe

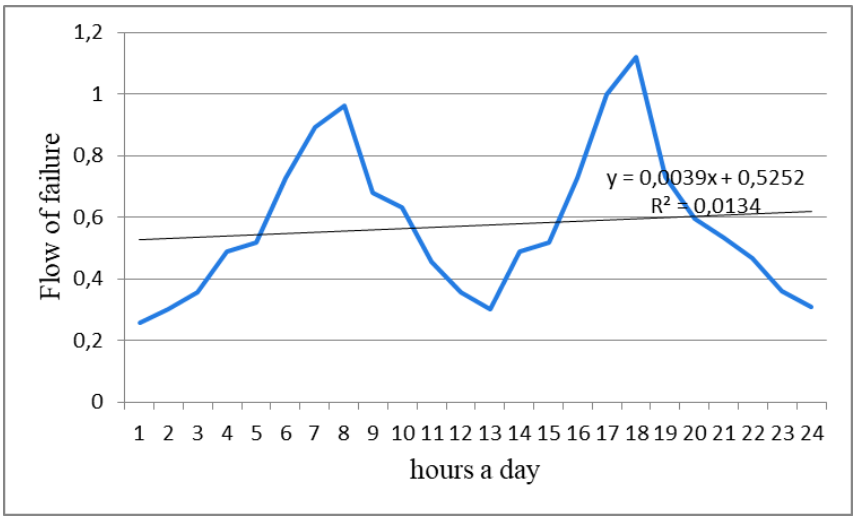


Figure 8. The dependence of the relative probability of the flow of failure on the time of maximum loads during the day

From Figure 8 shows that with increasing power consumption and exceeding specific norms of power consumption during hours of maximum loads, the probability of damage increases sharply. This shows a linear relationship between power failure flows. Based on the foregoing, we can conclude.

5. CONCLUSIONS

According to a statistical analysis of the outage occurrence of electrical equipment in urban distribution electric networks in Dushanbe for the periods of 2022-2023 and for reasons of distribution damage resulting in outage shutdown data, factors have been identified that affect the reliability of power supply to the electrical network in Dushanbe. Taking into account the identified factors, the electricity consumption prediction equations are proposed taking into account the terrain of the city of Dushanbe, the introduction of which into the control algorithm based on the functionality of smart electricity metering, it is possible to maintain operational parameters of the electric network thereby increasing the reliability of the city electric network of Dushanbe.

A specific feature of the obtained mathematical model, which makes it possible to increase the reliability of power supply in distribution networks, is that, using the predicted power consumption schedules obtained by us during peak hours (morning and evening), taking into account climatic factors, damage to the considered electrical equipment can be predicted in advance.

Since it is known that the main time between failure and the first damage is observed during peak hours. However, the existing forecast methods are made according to the monthly and annual power consumption, which does not always coincide with the climatic factor.

ACKNOWLEDGEMENTS

Author thanks and acknowledgements.

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