Experimental research of electrical loads in residential and public buildings

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Abstract. The Association “Roselectromontazh” conducted a study of electrical loads for residential and public buildings in the Republic of Tatarstan showed that actual electrical loads are 1.5 - 2.5 times lower than in regulatory documents. Recently constructed cable networks and transformer substations of 0.4 / 10 kV in fact turn out to be underloaded. Moreover, this underload is such that most of the transformers rarely operate at 30% of their capacity during hours of maximum power consumption. The calculation of electric load is the basis for designing the power supply system of any capital construction facility. According to the open joint-stock company “Network Company” and with the support of the President of the Republic of Tatarstan, the Association “Roselectromontazh” carried out an experimental study on updating the requirements for calculating electricity consumption in public and public buildings of the Republic of Tatarstan. The actualization of electrical loads will lead to a significant economic effect by reducing the declared capacity and accordingly the power and number of power transformers reducing the cross-sections of power cables and consequently, capital costs during construction and operation.

1. Introduction
The practice of building and operating urban power supply systems has shown that in most cases real loads are less than calculated, this leads to an overpricin of the cost of technological connection [2]. To calculate the electric power consumed by residential and public buildings, use the normative values from the section "Designed electrical loads" SP 256.1325800.2016 “Electrical equipment of residential and public buildings. Rules of design and erection” (SP), which in turn have not been reviewed for decades. Studies of the loading of transformer substations of 0.4/10kV showed that most of the transformers are underloaded.

2. Experimental researches of electrical loads
In most cases, real loads are less than calculated. As a result, the constructed cable networks and transformer substations of 0.4 / 10 kV are in fact underloaded. Moreover, this underload is such that about 80% of transformers operate with a maximum load of less than 30% during the year, Figure 1.

Consequently, transformers operate with large losses [4-6] in relation to the transmitted electric power, Figure 2.
Figure 2 shows that the less loaded the transformer, the more share the loss in transmitted power (ΔP).

To reduce losses in relation to the transmitted power, it is proposed to install transformers with lower power or to turn off part of the transformers to ensure a greater load of the remaining ones [3].

The need for work on the adjustment of specific calculated electrical loads is confirmed by the following documents:

- The State Program of the Russian Federation “Energy Development” as amended on March 28, 2019 No. 335, one of the goals of which is “to ensure the needs of the domestic market in an economically sound supply of energy”;
- The draft Energy Strategy of the Russian Federation for the period until 2035 as amended on October 21, 2019, the goals of which are also “improving the legal framework and planning system in the electric power industry”, “reducing electric energy losses until 2035 to the level of 7-7.5%”;
- The national rating of the state of the investment climate in the constituent entities of the Russian Federation, the key indicator of which is “The quality of the provision of public services - indicators of the effectiveness of the provision of various public services for business, including connection to electric networks”;
- A comprehensive plan for the modernization and expansion of the trunk infrastructure for the period until 2024 of September 30, 2018, the target indicators of which include “reducing the excess installed capacity of power plants of the UES of Russia”.
In [1], it was experimentally proved that the actual load for apartment buildings differs from the estimated one by 1.5-2.5 times. Below is a diagram, Figure 3, the dependence of the average specific power consumption of 32 apartment buildings on the month and year of operation.

The diagram, Figure 3, confirms that power consumption changes not only during the year (the maximum falls on the winter and the minimum summer months for the city of Kazan), but also on the service life. In the first two years of operation, power consumption is very different, so it is necessary to carry out measurements, starting from the third year of operation, for at least 3 years [7-10].

Figure 3. Diagram of the dependence of the electricity consumption of apartment buildings on the month and year of operation

Figure 4 shows the annual average schedule for specific electricity consumption by kindergartens (Psp, kW*h/pupil). The study was conducted in 51 kindergartens in the city of Kazan.

In Figure 5 shows the annual average schedule for the specific energy consumption of schools (Psp, kW*h/pupil). The study was conducted in 67 schools in the city of Kazan.

Figure 4. Kindergarten’s annual specific power consumption schedule

Figure 5. School’s annual specific energy consumption schedule
From the graphs Figures 4 and 5, it can be seen that the months of greatest power consumption are December and February, and the minimum is July and August, which is quite expected.

Figure 6 shows the annual average cottage specific electricity consumption schedule (Psp, kW*h/cottage). The study was conducted 375 cottage of one of the villages in the city of Kazan.

![Figure 6. Cottage’s annual specific power consumption schedule.](image)

The graph, Figure 6, shows that power consumption varies throughout the year, with a maximum during the winter and a minimum during the summer.

Let us compare the value of the specific load with the declared capacity for kindergartens, which is obtained by calculation and measured in fact, Figure 7.

![Figure 7. Difference between the actual power and the power calculated by SP](image)

The electrical load of kindergartens calculated using the SP is significantly different from the actual half-hour maximum load measured directly at the facility.

The half-hour maximum loads during the year for kindergartens (Figure 8) and schools (Figure 9). Graph Figure 8 shows the dependence of the half-hour maximum values of unit loads on the number of pupils in kindergarten. The values obtained are comparable with 0.49 [kW/pupil] from SP.

The specific values obtained are significantly lower than those presented in SP. This emphasizes the need to revise the specific design SP loads. In addition, the dependence of the specific load depending on the number of pupils in kindergarten is of interest (Figure 8). According to the graph, there is a pronounced tendency to decrease in the unit load with an increase in pupils in kindergarten, but no clear boundary between the values has been identified, which makes it possible to calculate with one value.
In Figure 9 there is a graph showing the dependence of half-hour maximum values of unit loads on the number of pupils in school.

![Graph showing the dependence of half-hour maximum values of unit loads on the number of pupils in school.](image)

**Figure 8.** Dependence of the half-hour maximum values of unit loads on the number of pupils in kindergartens

The graph in Figure 9 shows the border in the school district of up to 300 pupils and more than 300. One can distinguish two areas on the graph with the corresponding two values of the unit load - 0.7 kW/pupils and 0.19 kW/pupils. The obtained values are comparable with 0.25 [kW/pupils] for SP. In this section, we can conclude that it is advisable to divide secondary schools into two groups - up to 300 pupils and over 300 pupils.

![Graph showing the dependence of half-hour maximum values of unit loads on the number of pupils in the school.](image)

**Figure 9.** Dependence of half-hour maximum values of unit loads on the number of pupils in the school

![Graph showing the maximum active power of the cottages.](image)

**Figure 10.** Maximum active power of the cottages
The justification of the need to solve the situation when 15 kW is requested for connecting a cottage, but actually used much less, is shown in the graph, Figure 10, from which it can be seen that the actual half-hour load during maximum hours in winter for 95% of cottages does not exceed 4 kW.

3. Conclusion
Based on the results of scientific research, conclusions are drawn:
- It is necessary to update the calculated specific electrical loads of residential and public buildings;
- Since the regions differ in climatic characteristics, it is necessary to revise the specific electrical load values for residential and public buildings in each region separately;
- The choice of the number and power of power transformers, taking into account the actual loads, will ensure their cost-effective operation;
- For the first time in the Russian Federation, work was done to update the specific rated electric load by the Association “Raselectromontazh” with changes in the specific rated electric loads of multi-apartment buildings in the Cabinet of Ministers of the Republic of Tatarstan No. 805 dated 09.09.2019. “On Amendments to the Resolution of the Cabinet of Ministers of the Republic of Tatarstan dated December 27, 2013 No. 1071 “On Approval of the Republican Standards for Urban Planning Design of the Republic of Tatarstan”.

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