Monitoring and updating of specific electric loads of residential and public buildings

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Abstract. Design organizations use standard specific load values to calculate the power consumed by residential and public buildings. The practice of operating power supply systems has shown that in most cases the actual load is 1.5 – 2.5 times less than the calculated load. The constructed cable networks and transformer substations of 0.4 / 10 kV are actually underloaded. The Association "Roselektromontazh" conducted research of TS loading of 0.4/10 kV in several cities of the Russian Federation, the results of which determined that about 80% of TS work with a maximum load of less than 30% during the year. The capacity of power transformers is selected according to account 70% of the total maximum load in the rated mode. Low load of power transformers leads to an increase in losses in them by comparing those working with a load of 70%; an inefficient use of investments. To solve this situation, it is proposed to monitor electric loads with subsequent updating of standard documents in terms of calculated specific electric loads, which will bring the calculated values closer to the actual ones to increase economic efficiency in the construction and operation of the power grid complex.

1. Introduction
The calculation of the electrical load is the basis of designing the power supply system for any capital construction project. The structure of the system, power and accordingly the cost of the electrical equipment to be installed depend on the size of the electrical load [3-5, 8]. The cost of technological connection to existing electric networks is determined mainly by the value of the power that the consumer requests in their application [6, 7].

Currently, to calculate the loads of residential and public buildings use the normative and technical documents SR 256.1325800.2016 “Electroinstallations of residential and public buildings. Rules for design and installation” [15] and GD 34.20.185-94 “Instructions for the design of urban electric networks” [16]. As shown by the estimates of specialists of the Association “Roselektromontazh” (hereinafter the Association), the standards specified in the normative and technical documents [15, 16] are significantly overstated in comparison with the real values.

From the report on the operation of JSC SO UES in 2019, it follows that the installed capacity of power plants in the Russian Federation is 245.4 GW, and the load of power plants for the annual maximum power consumption is 153.5 GW, i.e. 91.9 GW was not used [18]. Housing and social,
cultural and household facilities account for 20%, including 14.7% of the power consumed by households [20]. Therefore the 91.9 GW of unused capacity (“locked”) - 18.4 GW is accounted for housing and social services.

From 2012 to 2016, the country’s annual growth rate of final electricity consumption was 0.3% [19]. However, the network infrastructure capacities introduced in the same years can cover the load of consumers by 86 GW. The actual unused power (“locked”) was more than 85-88% [19], which is 73.1-75.68 GW.

2. Monitoring and updating of specific electric loads

Figure 1 shows a comparison of the values of the specific design load for SR 256.1325800.2016 and the estimated calculations of the Association "Roselektromontazh", based on monitoring the load in residential and public buildings of the Republic of Tatarstan [1, 2].

Figure 1 illustrates a significant difference between the actual and calculated electrical load, which once again proves the relevance of reviewing the normative values in terms of calculated specific electrical loads [1, 2]. This difference is because the values of specific electrical loads in regulatory documents have not been revised since the last century.

Monitoring of the electrical load with subsequent updating of regulatory documents will bring the calculated values closer to the actual ones, and consequently reduce the cost of construction and operation of electric networks. The housing construction program caused the appearance of regulatory documents. Since 1960, the number of square meters of housing commissioned has increased every
year. Already in 1988, housing commissioning in the USSR amounted to about 125 million square meters [11]. Table 1 presents the history of development of regulatory documents.

| Document | Validity | Document | Validity |
|----------|----------|----------|----------|
| SR 256.1325800.2016 Electrical Installations of residential and public buildings. Design and installation rules | validity: 02.03.2017 - until now | WD 34.20.185-94 Instructions for the design of urban electric networks | validity: 01.01.1995 until now |
| SR 31-110-2003 Design and installation of electroinstallations in residential and public buildings | validity: 01.01.2004-02.03.2017 | DBC 97-83 97-83 instructions for the design of urban and rural electric networks | validity: 01.07.1983-01.01.1995 |
| DBC 59-88 Goskomarhitektury of the Electrical equipment of residential and public buildings. Design standards | validity: 01.07.1989-01.01.2004 | DBC 97-75 Guidelines for the design of urban electric networks | validity: 01.11.1975-01.07.1983 |
| BC 543-82 Instructions for the design of electrical equipment for residential and public buildings of mass construction | validity: 01.07.1982-01.07.1989 | WD 167-61 Guidelines for the design of urban electric networks | validity: 01.10.1961-01.11.1975 |
| DBC 19-74 Instructions for the design of electrical equipment for public buildings of mass construction | validity: 01.04.1975-01.07.1982 |
| BC 544-82 Instructions for the design of electrical equipment for residential buildings | validity: 01.07.1982-01.07.1989 |
| BC 297-64 Instructions for the design of electrical equipment for residential buildings | validity: 01.07.1965-01.07.1982 |

Table 1 shows that the frequency of revision of normative documents was 8-10 years. In modern conditions, when electrical appliances are becoming more energy-efficient every year, updating of regulatory documents in terms of calculated specific electrical loads must be carried out at intervals of 5 years; this need is caused by reduced costs in the construction and operation of electrical networks. The smaller the difference between the estimated and actual load, the greater the economic effect will be obtained. The reliability of the obtained values is proposed to be justified by 5-year monitoring of the electrical load with subsequent statistic processing. Timely updating of existing regulatory documents will significantly reduce the cost of building electric networks, since by 2024 it is planned to increase the volume of housing construction to 120 million square meters. m/year [12]; creation of 8.6 thousand groups of preschool education [12]; creation of 230 thousand new places in General education organizations [12].

In favor of monitoring with subsequent updating of the values of specific electrical loads of consumers with a 5-year periodicity, the following arguments are also given:

- constantly improving the power consumption class of household appliances to A++ (the difference in power consumption between class G and A++ is 75%);
- from 2023, the indicators of specific electricity consumption in apartment buildings should be improved by 40%, and from 2028 by 50% [13], the energy efficiency classes of apartment buildings [14] are presented in table 2;
- implementation of energy service agreements that provide for the implementation of a full range of works on the implementation of energy-saving solutions by a specialized energy service company, this will reduce the consumption of electricity in budget institutions from 40 to 60%.
Table 2. Energy efficiency class

| №   | Class name | The value of deviation of the actual specific annual consumption of energy resources from the base level, % |
|-----|------------|---------------------------------------------------------------------------------------------------|
| A++ | Supreme    | - 60 inclusive or less                                                                               |
| A+  | Supreme    | - 50 up to and including - 60                                                                         |
| A   | Very high  | - 40 up to and including - 50                                                                         |
| B   | High       | - 30 up to and including - 40                                                                         |
| C   | Elevated   | - 15 up to and including - 30                                                                         |
| D   | Normal     | 0 up to and including - 15                                                                            |

To determine the period of monitoring the electrical load of residential and public buildings for the purpose of statistically justified updating of regulatory documents, the influence of the service life on the power consumption of apartment buildings was analyzed, as shown in figure 2 (kWh/ap.).

Figure 2. Dependence of apartment buildings power consumption on the month and year of operation.

Figure 2 shows that power consumption changes not only during the year (the maximum is in the winter months, and the minimum is in the summer months for Kazan), but also from the period of operation. In the first two years of operation, power consumption is very different, so it is necessary to monitor starting from the third year of operation for at least 3 years. Figure 3 shows the power consumption during the year, depending on the year of commissioning.

Figure 3. Power consumption during the year, depending on the year of commissioning.
Figure 3. Electricity consumption during the year depending on the year of commissioning.

Figure 3 shows that electricity consumption varies from the year of commissioning (the older the research object, the greater the power consumption). This is due to changes in the quantitative composition of electric receivers and their characteristics (energy efficiency). Monitoring the electrical load will allow you to correct regulatory documents in a timely manner and will help to obtain the maximum economic effect. Since the longitude time zones of the Russian Federation are 11.4 hours long, and the country is administratively divided into 9 time zones with an average annual temperature range of 36 degrees (from -23 to +13), it is not possible to apply a single document for calculating the electrical load for the entire territory of the country. Differentiation in Federal districts, figure 4 [20], shows that the specific electricity costs increase from the southwest to the North and East. The far Eastern Federal district (1,461 kWh/person per year) is almost twice larger than the North Caucasus Federal district (795 kWh/person per year) and about one and a half time larger than other Federal districts in the European part of the country [20]. Data on individual subjects of the Russian Federation generally show that the maximum per capital electricity consumption is typical for areas with cheap HPP energy (Irkutsk region, Republic of Khakassia, Republic of Dagestan). As well as for areas without developed gas networks (regions of the Far East and North-West, where the population uses electricity in the most energy-intensive household appliance-electric stoves, and often for heat supply) [20, 21]. The regional attribute should be taken into account when monitoring and updating specific values of electrical load [1, 2].

Figure 4. Unit expenditures in the Russian Federation by region [20].
Figure 5 shows a comparison of the specific electrical load of two apartment buildings in Kazan (287 sq. m.) and Magnitogorsk (300 sq.m.).

On figure 5 as the example of Kazan and Magnitogorsk confirms that there are regional differences in terms of electrical loads (for similar apartment buildings, the load has the same form of change, but the level is different). Figures 4 and 5 demonstrate the need for monitoring and subsequent updating of specific electrical loads for each region separately.

Currently, monitoring is facilitated by the adoption of the Federal Law of December 27, 2018. N 522-FL “On amendments to certain legislative acts of the Russian Federation in connection with the development of electric energy (capacity) accounting systems in the Russian Federation”, which States that, starting from January 1, 2022, suppliers and network organizations must provide consumers with electric energy with a minimum set of functions of intelligent electric energy accounting systems, and starting from January 1, 2023. In case of non-compliance with this law, the consumer has the right to demand payment of a fine. The decision of the government of the Russian Federation on approval of rules of provision of access to a minimum set of functions that smart metering of electric energy (capacity) the information about the number and other parameters of the electrical energy includes the volume received and given electric energy, measured at the point of delivery, including tariff zones, and in the cases provided for in hourly or half hour basis.

3. Implementation of research results

Monitoring of electric loads in apartment houses with the subsequent statistical processing in the Republic of Tatarstan partially presented [1, 2] after passing through peer review experts: SAI “Center of energy saving technologies of RT under the Cabinet of Ministers of RT, SAI Directorate of state expertise and pricing Tatarstan for construction and architecture”, SPI “Main investment and construction management of RT”, SUE “Tatinvestgrazhdanproekt” and was reflected in the decree of the Cabinet of Ministers of the Republic of Tatarstan № 805 from 09.09.2019 G. (the decrease in the specific calculated electrical loads of apartment buildings was from 223% to 50%) [17, 1, 2]. Table 3 shows the updated specific electrical load for calculating the declared capacity of apartment buildings, approved by the resolution of the Cabinet of Ministers of the Republic of Tatarstan № 805 [17].

The results of calculations shows that the economic effect of implementing the decree of the Cabinet of Ministers of the Republic of Tatarstan No. 805 of 09.09.2019. [17] for the developer will be about 30 million rubles when entering 95 thousand square meters [1, 2]. In the Republic of Tatarstan in 2019, housing commissioning amounted to 2.675 million sq. m. [10], of which 1.569 million sq.m. fall on the apartment buildings. Thus, the expected economic effect for developers was about 495 million rubles per year. The calculation did not take into account territory released by reducing the number of TS and their protection zone.
Table 3. Specific load of capacity of electric receivers of residential apartments buildings for calculating the declared power, kW / apartment

| №. | Electricity consumer                                      | Specific electrical load for calculating the claimed power of the specific capacity , kW/apartment |
|----|----------------------------------------------------------|--------------------------------------------------------------------------------------------------|
| 1  | 1st group of residential buildings without elevators with gas stoves | 0.53                                                                                              |
| 2  | 2nd group of residential buildings with elevators with gas stoves | 0.61                                                                                              |
| 3  | 3rd group of residential buildings with elevators and electric stoves | 0.81                                                                                              |

For OJSC «Grid company» [9], the reduction of electricity losses due to the solution of the issue with "locked capacity" will amount to about 273 million kWh, which is 17% of the total number of electricity losses for 2018. The estimated economic effect will be about 649 million rubles per year, excluding capital expenditures for the construction and reconstruction of electric networks.

4. Conclusions
The work made the following conclusions:

1. Savings of 1.15 billion rubles per year for the Republic of Tatarstan are associated with a reduction in the cost of technological connection, reduced capacity, number and losses in transformer substations. The economic effect of timely updating of specific design loads in General for the Russian Federation will be at least 100 billion rubles per year.

2. Updating the calculated electrical loads will make it possible to solve the issue related to increasing the load of transformer substations, and, consequently, the trend to reduce the "locked" power will be palpable within 3-5 years.

3. Specific electrical loads should be monitored for regions (groups of regions) and climate zones. The difference in the electrical load of apartment buildings between the cities of Kazan and Magnitogorsk (figure 5) was about 40%.

4. Increasing the energy efficiency of electric receivers, as well as reducing power consumption due to high cost, indicate the need for monitoring with appropriate updating in regulatory documents, which should be reviewed at least every 5 years. This period will allow timely response to the difference between the estimated and actual electrical load of consumers.

5. All conditions are created for monitoring the electrical load, including the possibility of remote reading from the electric meter.

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