Calculation of electrical loads of residential and public buildings based on actual data

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Abstract. Design organizations use normative specific load to calculate the power consumed by residential and public building. The practice of construction and operation of urban power supply systems has shown that in most cases real loads are less than calculated ones by 1.5–2 times. A revision of the standard load values is needed based on experimental measurements of power profiles. The newly built cable networks and transformer substations of 10/0.4 kV in fact turn out to be underloaded. Moreover, this underloading is such that transformers rarely operate at 50\% of their capacity during hours of maximum power consumption. The death of investments for power grid companies is obvious, since after the nearest site development, it becomes almost impossible to connect a new consumer.

1. Introduction
Calculation of electrical load is the basis for designing power supply system of any capital construction object. The system structure, power, and, correspondingly, the cost of installed electrical equipment depend on electrical load. The cost of technological connection to the existing electrical networks is determined mainly by the value of power that consumer writes in his application.

Currently there are two regulatory and technical documents (RTD) regulating load calculation for residential buildings SP 256.1325800.2016 “Electrical installations of residential and public buildings. Design and installation rules”, and RD 34.20.185-94 “Instructions for design of urban electrical networks”, where the same specific loads are used as in SP 256.1325800.2016 [1, 2, 3]. As the estimates conducted the Association specialists show, the standards indicated in these RTD are significantly overestimated in comparison with the real values. Measurements on transformer substations (TS) and distribution points (RP) are presented in Figure 1.
It is seen from Figure 1, that more than 73% of TS and DP are less than 30% loaded. Over the past decade, the consumption of household appliances has increased due to the use of new technologies. All modern household appliance are necessarily designated by the category of its energy saving. And the higher is the class, the more competitive the device is [4, 5]. This trend will be preserved among manufacturers of household appliances [6]. In addition, LED lamps are increasingly being used to illuminate streets and courtyards, energy-saving lamps are used in apartments, the cost of 1 kWh is increasing, and residents actually save electricity [7]. It is also worth noting that every year a large amount of new housing is commissioned, therefore, the specific population density (people/m²) is reduced [4, 8].

The above factors have an impact on reduction of the actual value of specific load (kW/m²) [5, 9]. Therefore, there appeared a situation when the energy consumption standards given in the current regulatory and technical documentation do not reflect reality and their values are significantly overestimated.

The specialists of the Association analyzed the information on electricity consumption by multi-apartment residential buildings (MRB) in the cities of St. Petersburg, Kazan, Chelyabinsk, Almetyevsk, and Magnitogorsk in 2017 and carried out estimated research calculations, Figure 2.
The diagrams from Figure 2 show that there are regional differences in terms of power consumption and this is a prerequisite for development of regional standards for specific loads for MRB, Figure 3.

If one does not address the issues of intra-house electrical networks design, then for the task of adequate selection of urban power supply system (substations, cable electrical networks), it is sufficient to correctly calculate the MRB technological connection capacity, which includes both apartments itself and the general house loads.

For further estimates, the city of Kazan was chosen. The analysis of MRB types showed that houses in Kazan are represented mainly by economy class and superior comfort class. There is practically no information about houses of business and elite class, these houses cannot be systemized and require an individual approach to design.

The calculation results confirmed that MRB power consumption essentially depends on the type of stove for cooking, but, moreover, on the presence or absence of an elevator, which naturally correlates with the number of floors in the building, Figure 4.

Thus, it was proposed to categorize MRB into the following groups, Figure 4:
1. Low-rise houses up to five floors with gas stoves;
2. Houses of 7 - 10 floors with elevators and gas stoves;
3. Houses of 12 floors and more with elevators and with electric stoves.
Further calculations showed that the actual values of power consumption during periods of maximum load are lower than the values given in SP 256.1325800.2016 by 30 - 223%.

Figure 5 presents a comparison between specific load set according to SP 256.1325800.2016 and that calculated by the Association “Roselectromontazh”.

Figure 5.
Comparison between specific load set according to SP 256.1325800.2016 and that calculated by the Association “Roselectromontazh” (a – MRB up to 5 floors; b – MRB of 7 – 10 floors; c – MRB of 12 floors and more).
For an example Fig. 6 shows the results of survey in Moscow, Khimki, provided by the “Foresight” Strategic Energy Development Fund.

**Figure 6.** Estimated and actual load of a 25-storey building.

The materials presented in Figure 5 and 6, have a common feature: a significant difference between the actual loads and those calculated according to the current regulatory documents.

The economic efficiency of updating the specific power consumption standards of MRB is determined by a decrease in their declared power, and accordingly, the power (quantity) of power transformers of urban transformer substations, a decrease in power supply cable sections, and, consequently, capital expenditures during construction and operation [9,10].

For the investor-developer, the main benefit of updating the unit loads is reduction of the declared power, and, consequently, reduction of payment for technological connection [11, 12, 13].

Figure 7 presents power profile of three MRBs in Kazan. Analysis of power profiles for other MRBs showed that their character is qualitatively the same and there is a steady maximum load in the evening hours, and the increase beyond the recommended value of 0.35 for reactive power factor takes place at the time intervals for minimum load [14,15].
Figure 7. Two days-measurements of 11-14 floors MRB (1 - MRB for 82 apartments; 2 - MRB for 94 apartments; 3 - MRB for 106 apartments)
a - specific power profile Psp, Qsp; b - reactive power factor, tg φ.

Figure 8 presents a reduced daily schedule of pre-school and MRB, from which it can be seen that profile for the same categories of power consumers varies according to one law, and the hours of maxima for the various categories are shifted.

Figure 8. Daily schedule of pre-school and MRB.

For the city of Kazan, the specialists of the Association analyzed several options for MRB construction using the standards SP 256.1325800.2016 and the actual values obtained experimentally, the 2nd and the 3rd quarters of the “Salavat Kupere” residential complex, Figure 9.
Figure 9. The quarters 2nd and 3rd of the “Salavat Kupere” residential complex.

Calculation results for two variants are presented in Table 1.

| Name                        | Method of the “Roselectromontazh” Association | Calculation according to SP 256.1325800.2016 | Difference       |
|-----------------------------|------------------------------------------------|-----------------------------------------------|------------------|
| Required capacity           | 3 045.9 kW                                      | 5 593.1 kW                                    | 2 547.2 kW       |
| Required transformer substations 0.4/10kV, piece. | 3 045.9 kW/1.3= 2342 kW | 5 593.1 kW/1.3= 4302 kW | 2 pieces        |
|                             | We choose 2 TS of 1200 kVA                      | We choose 4 TS of 1200 kVA                    |                  |

The results of calculations showed that the economic effect from the implementation of the proposed methodology will be more than 19 million rubles. Designing using actual values can significantly reduce the budget costs for the electrical part of the input buildings. For the Republic of Tatarstan, the expected economic effect will be more than 1 billion rubles per year.

2. Conclusions
Firstly, one should not expect that universal standards can be obtained that are suitable for any region of the country.

Secondly, it is necessary to carry out research works on the gathering information and statistical processing of electrical loads in various residential buildings in different cities, taking into account their geographical location and employment.

Thirdly, it is necessary to approve recommendations for design institutes on specific load values at regional levels.

Fourthly, it is necessary to develop a method for selecting the power of transformer substations of a distribution electric network based on the formed base of electrical loads.

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