Reactive power compensation for sustainable development of power grids in cities of Uzbekistan

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Abstract. The article deals with relevant and much needed at this stage problems of reconstruction and modernization of urban power supply systems and issues of energy saving in urban power grids. For the first time, it is proposed to carry out energy saving in the residential and public sectors of the residential zone of cities on the basis of reactive power compensation. There are given an analysis of experimental studies and measurements of power consumption and based on them recommendations and ways of energy saving in urban power grids.

1 Introduction

Currently, special attention is paid to improving energy efficiency, energy saving and rational power supply to consumers in cities. If earlier electricity consumption in cities for household needs was 11%, then due to the rapid construction of housing and communal facilities in cities, electricity consumption in 2022 increased to 40% of all usefully supplied electricity. One of the important problems of urban power supply is the use of reactive power compensation in urban networks. Due to the fact that the small-motor load has increased and the power factor *cosφ* has decreased. As a result, the consumption of reactive power increased, and the losses of electricity increased. To solve this problem, it is necessary to install multifunctional meters at each transformer station (TP) and, depending on the amount of reactive power consumed, calculate the necessary automated installations of capacitor banks [1-4, 6].

2 The current state of the investigated problem

The task of calculating the mode of urban electrical networks can be formulated as follows: it is necessary, as accurately as possible, to determine the maximum (calculated) load of the same type, each individual consumer and the total total load of consumers included in this electrical network, to reduce to a possible minimum the loss of electrical energy (which depends on many factors and therefore have different meanings) in the transmission and distribution of given flows of active and reactive power, provided that the established quality of electricity is ensured and reliability requirements are met, while using a new patented method for determining the total design load and choosing the optimal number and power of the district heating substation [5, 7-13, 16].

Consider the energy saving and energy efficiency of low- voltage urban electrical networks based on reactive power compensation (using the example of power supply to consumers in a microdistrict) [14, 15].

At present, due to the growth of the well-being of the population, an increase in the number of and power of household electrical appliances, the consumption of active electricity and the consumption of reactive energy increases, since the small- motor load of household electrical appliances and fluorescent LED lamps have a low Cos φ, this leads to additional losses on reactive power. In this regard, the governmental inspection “Uzenergoinspection” adopted *cosφ* =0,85. Therefore, the time has come to apply reactive power compensation in urban electrical networks and reduce electricity losses in low-voltage networks by installing compensating devices at urban transformer substations and large utility power consumers.

Based on the measurements of daily power consumption regimes and technical and economic calculations, the following results were obtained:

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Table 1. Comparative table of loads determined by the new method and after reactive power compensation [17]

TP	Load determined by the new method			Load determined after compensation			Difference		
	P, MVt	Q MVar	S MVA	P MVt	Q MVar	S MVA	P MVt	Q MVar	S MVA
Total	3,03	1,96	3,72	3,03	0,93	3,18	0.0	-1,03	-0,54
TP1	0,58	0,36	0,68	0,58	0,21	0,61	0.0	-0,15	-0,07
TP2	0,61	0,38	0,7	0,61	0,18	0,63	0.0	-0,2	-0,07
TP3	0,76	0,47	0,89	0,76	0,2	0,79	0.0	-0,27	-0,1
TP4	0,4	0,25	0,47	0,4	0,098	0,41	0.0	-0,15	-0,06
TP5	0,39	0,24	0,46	0,39	0,14	0,41	0.0	-0,1	-0,05
TP6	0,43	0,27	0,51	0,43	0,09	0,44	0.0	-0,18	-0,07

In the general case, for a microdistrict, a decrease in active energy consumption due to an increase in cosφ [2].

$$\Delta W_{hc} = \left\{\left[{}^{1}/_{cos^2\varphi_1} - {}^{1}/_{cos^2\varphi_2}\right] / {}^{1}/_{cos^2\varphi_1}\right\} \cdot K_p \quad (1)$$

Where with $cos\varphi_2$ – before compensation (0.85) ;
$cos\varphi_2$ – after compensation (0,95) ;

The relative active component of the current (coinciding in phase with voltage) will be taken equal to unity.

Relative full current is before implementations:

$$I_1 = 1/0{,}85 = 1{,}176\ A$$

Relative full current is after implementations:

$$I_2 = 1/0{,}95 = 1{,}052\ A.$$

Energy savings from reactive power compensation at one transformer substation amounted to 21040,2 kWh, current reduction by 10-13 %, line capacity increases and TP by 3-6 %, there is an increase *cosφ* up to standard, reduction of electricity losses, saving of non-ferrous metal and transformer power.

Table 2. Results of measurement and calculation at a transformer substation

Time	Before compensation				After compensation			
	RU- 10kV f-r Bakhor1 RP Dagestanskaya 10kV Assets	RU- 10kV f-r Bakhor -1 RP Dagestan Skye 10 kV reagent	RU- 0,4 kV input T-2 TP – 2280 Assets	RU- 0,4 kV T-2 input TP- 2280 Reactive	RU- 10kV f-r Bakhor-2 RP Dagestanskaya10 kV Assets	RU- 10kV f-r Bahor RP Dagestan 10kV Reagent	RU- 0,4 kV input T- 2 TP-2280 Active	RU- 0,4 kV T-2 input TP- 2280 Reactive
00:00	115,03	56,57	108,80	41,43	108,73	15,13	103,42	4,71
00:30	106,20	56,83	100,00	40,17	100,20	15,00	95,56	4,44
01:00	99,86	56,23	94,00	39,89	94,27	15,53	89,56	4,76
01:30	93,86	55,89	87,94	39,83	89,20	15,80	84,67	3,69
02:00	88,54	55,63	83,03	39,66	83,13	14,80	79,02	3,51
02:30	85,89	54,43	80,51	38,97	79,93	14,27	75,96	3,38
03:00	84,26	54,69	78,80	39,49	78,00	13,87	73,56	3,20
03:30	83,40	54,51	77,89	39,71	76,67	14,13	72,89	3,64
04:00	82,03	55,03	76,63	39,71	76,13	14,13	72,04	3,29
04:30	81,51	54,43	76,06	39,26	75,07	14,40	71,24	3,16
05:00	79,89	54,09	74,57	38,91	74,60	13,53	71,02	3,47
05:30	80,14	53,66	74,80	39,09	74,93	14,60	71,29	3,38
06:00	81,51	53,83	76,00	38,74	74,87	13,60	71,06	3,47
06:30	72,86	45,51	68,17	29,94	75,47	12,40	70,97	4,09
07:00	69,77	41,49	64,74	22,29	54,67	9,60	51,52	5,23
07:30	71,06	40,54	66,34	20,86	59,93	28,00	57,08	15,33
08:00	74,14	34,89	69,37	22,23	64,40	27,40	61,25	15,87
08:30	68,83	35,74	64,29	23,49	65,47	28,87	62,28	15,96
09:00	66,69	34,63	62,06	23,09	67,27	26,47	63,94	16,93
09:30	66,26	33,60	61,77	21,31	68,73	27,20	65,20	15,07
10:00	69,94	32,91	65,49	22,06	70,47	25,73	66,62	14,84
10:30	70,03	33,17	65,71	23,20	74,20	22,60	70,67	12,97
11:00	71,57	33,86	67,00	24,51	78,67	22,87	74,98	15,33
11:30	66,60	35,91	61,89	25,37	78,60	23,20	75,16	13,32
12:00	70,71	38,06	63,37	26,29	79,53	22,13	75,87	13,33
02:30	69,51	39,00	63,77	27,37	78,87	21,53	75,07	14,38
13:00	72,26	40,11	64,29	26,57	79,07	23,73	75,60	15,56
13:30	71,31	37,37	63,09	25,60	80,67	23,00	76,76	15,02
14:00	70,97	38,06	65,71	25,89	79,80	20,27	76,22	12,84
14:30	70,89	36,86	65,49	26,29	77,93	20,33	74,09	14,76
15:00	73,97	36,77	67,26	25,77	79,53	20,93	76,09	12,52
15:30	74,49	37,54	69,43	26,11	80,93	21,93	76,93	13,82
16:00	76,46	36,69	71,54	25,89	80,93	20,47	77,16	13,60
16:30	78,86	37,46	72,29	26,51	83,33	20,67	79,47	14,02
17:00	81,86	37,71	74,97	27,09	85,80	22,33	81,87	15,42
17:30	88,03	40,29	81,37	29,71	90,40	22,20	86,58	14,67
18:00	96,34	41,23	88,11	29,14	99,33	24,33	95,07	17,24
18:30	107,57	41,74	99,66	30,46	107,93	23,60	103,64	18,1
19:00	135,34	52,89	127,09	41,20	134,53	24,27	129,02	12,53
19:30	148,71	63,26	140,46	48,17	139,47	20,93	133,64	9,82
20:00	148,54	61,54	140,23	46,40	137,73	18,60	132,22	8,13
20:30	147,00	58,54	139,54	44,51	135,40	17,73	129,60	5,73
21:00	146,66	58,11	139,54	44,00	135,20	15,07	129,51	6,18
21:30	144,94	57,43	137,09	43,94	132,80	14,73	127,38	6,18
22:00	141,34	57,94	134,11	42,91	130,87	14,93	125,38	5,73
22:30	137,49	56,57	130,40	42,69	125,60	14,67	120,09	5,29
23:00	131,06	57,43	124,29	42,80	119,73	14,53	114,76	4,89
23:30	121,54	56,57	114,69	41,31	113,67	14,13	108,44	4,67

The widespread use of multifunctional "smart" meters ASKUE allows you to automate the whole process of calculating and consuming electricity. The use of capacitor banks at the TP of the microdistrict to compensate for reactive power, as studies have shown, has saved 52,73 million sums, while the payback period for invested money was less than 2 years. Due to the increase in the consumption of reactive energy in the residential and public sectors, it is currently necessary to installation in all transformer paragraphs or large consumers of automated capacitor banks for reactive power compensation [5. 16].

The economic effect from the introduction of an automatic capacitor plant consists of the following components: savings on losses and due to the rational control of reactive power.

Consider economic component work, compensating installation on the example of a microdistrict of the city.

Before implementation automatic condenser installations $cos\varphi$=0,85.

After implementation automatic condenser installations $cos\varphi$=0,95.

In Uzbekistan and in Tashkent city, with the support of IFIs were implemented Automatic metering systems – AIM, with the extensions. On the basis of an investment projects, the reconstruction and modernization of 0,38,6-10 kV electrical networks, including in the city of Tashkent, began in the cities of Uzbekistan. When processing experimental studies, the Fisher criterion and its special cases - Student's criterion, as well as statistical and regression analyzes of natural measured data were applied [7]. A comparison of the options for the proposed method for calculating electrical loads and the standard one (according to KMK 2017 - 2019) showed that the difference in electrical loads is 21,6%, the proposed new method is more accurate, this saves electricity, transformer power, reduces electricity losses, reduces losses voltage and power, and meets the energy-saving program.

3 Conclusion

Measurements and analysis of electricity consumption in the residential and public sector showed that the calculation of the load using the new methodology saves 21,6%.

Savings due to the use of automated condenser units for our experimental microdistrict in monetary terms amounted to 52,25 million sums

The use of AIM in urban electrical networks made it possible to reduce the balance difference and saves 8÷12%.

Carrying out a number of organizational and technical measures in urban low-voltage networks will reduce electricity losses and solve the issue of energy saving.

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