A MATHEMATICAL STUDY OF ENERGY EFFICIENCY GROWTH BASED ON DIFFERENTIATED TARIFFS

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Rezume: *This article addresses several key issues, including the role of differentiated tariff systems in enhancing energy efficiency, the application of modern mathematical and analytical accounting methods within electric power systems, the estimation of electricity consumption indicators using the least squares method, as well as approaches to optimize electricity usage and minimize associated costs.*

Keywords: *Electricity tariffs, differential, differentiated tariffs, mathematical and analytical, least squares method.*

INTRODUCTION

In accordance with Resolution No. 348 of the Cabinet of Ministers of the Republic of Uzbekistan dated June 30, 2022, particular emphasis is placed on the implementation of measures aimed at revising the tariff system in the energy sector and exploring opportunities to improve overall system efficiency [1]. In any economic framework, a structured tariff system is applied to regulate financial settlements between energy suppliers and consumers, ensuring proper payment for electricity consumption [1]. This study analyzes the electricity consumption indicators of users supplied through a TM-630/10/0.4 power transformer[2]. The obtained results are presented both graphically and numerically, with analytical interpretations derived from empirical data using the least squares method. [2; 3].

Main part. In single-phase consumers, the main part of consumption fell on the periods of the morning peak from 06:00 to 09:00 and the evening peak from 17:00 to 22:00. Three-phase consumers corresponded to the daytime period from 09:00 to 17:00 (half-day) [2; 3].

Table 1

The ratio of the total consumption by period to the total consumption per day (%)

	1st period	2nd period	3rd period	4th period	5th period
kWh	534 kWh	1510 kWh	1030 kWh	1510 kWh	534 kWh
% of total isomol	10.43%	29.5%	20.14%	29.5%	10.43%
TOTAL:	5118 kWh				

In the process of empirical connections, the connection of indicator values with 5 empirical points was created. The indicators of all consumers in relation to total consumption are based on Table 1, the following points (2; 534), (3; 1510), (5; 1510), (6; 534) and (8; 1030) are formed [3; 4].

Table 2.

Data to construct an empirical function of the index of all consumers relative to total consumption $\mathrm{P}(\boldsymbol{T}) = \boldsymbol{P} = \boldsymbol{aT} + \boldsymbol{b}$

I	regulations for each of the five periods $\mathrm{T_i}$	Every period P_i of har information about the active power consumed per hour	$\mathrm{T_i}^2$	$(P_{i.})\mathrm{T_i}$
1	2	534	4	1068
2	3	1 5 1 0	9	4530
3	5	1 5 1 0	25	7550
4	6	534	36	3204
5	8	1 0 3 0	64	8240
6	24	5118	138	24592

from this table we get this system [3; 4].

$$\begin{cases} a\sum_{I=1}^{6} T_i^2 + b\sum_{i=1}^{6} T_i = \sum_{i=1}^{6} T_i (P_D)_i \\ a\sum_{i=1}^{6} T_i + 6b = \sum_{i=1}^{6} (P_D)_i \end{cases} \begin{cases} 128a + 21b = 24592 \\ 24a + 6b = 5118 \end{cases}$$

uninstall the system $a = 98{,}0952$ and $b = 460{,}6190$. Thus, the desired relationship between T and P is approximately of this form:

$P = aT + b = 98{,}0952T + 460{,}6190.$

Thus, the performance of all consumers in relation to the total consumption is the time dependence points of the power and the empirical function between them

$$P = aT + b = 98{,}0952T + 460{,}6190$$

was formed.

Based on these results, Figure 1 below shows the graph of the load and empirical function drawn based on the indicators of the EX518 brand three-phase balance meter installed on a power transformer of 630 kVA for five periods [4; 5].

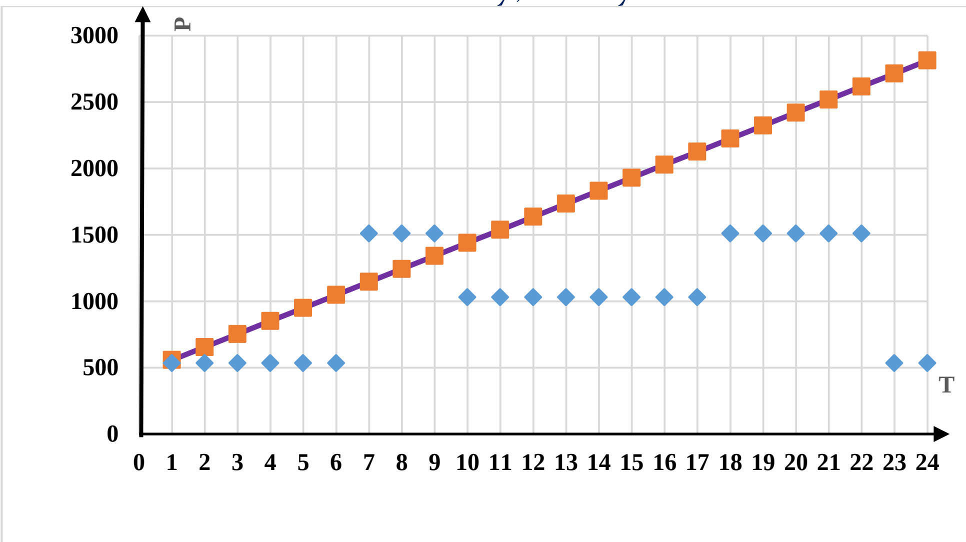

Figure 1. Power to time connection points and they are between empirical function

Based on the above values, $P = \frac{\Delta W}{T} = aT^2 + bT + c$an empirical function was created and the values were calculated [4; 5].

Table 3.

Data are provided to construct the empirical function of the indicator of all consumers in relation to the total consumption .$P(\boldsymbol{T}) = \boldsymbol{aT^2 + bT + c}$

I	T_i	P_i	T_i^2	T_i^3	T_i^4	P_iT_i	$P_iT_i^2$
0	0	0	0	0	0	0	0
1	2	534	4	8	16	1068	2136
2	3	1510	9	27	81	4530	13590
3	5	1510	25	125	625	7550	37750
4	6	534	36	216	1296	3204	19224
5	8	1030	64	512	4096	8240	65920
6	24	5118	138	888	6114	24592	138620

The following system was obtained from the table data : [10, 11, 12].

$$\begin{cases} a\sum_{i=1}^{6} T_i^4 + b\sum_{i=1}^{6} T_i^3 + c\sum_{i=1}^{6} T_i^2 = \sum_{i=1}^{6} T_i^2 + (P_D)_i \\ a\sum_{i=1}^{6} T_i^3 + b\sum_{i=1}^{6} T_i^2 + c\sum_{i=1}^{6} T_i = \sum_{i=1}^{6} T_i + (P_D)_i \\ a\sum_{i=1}^{6} T_i^2 + b\sum_{i=1}^{6} T_i + 6c = \sum (P_D)_i \end{cases} \quad \begin{cases} 6114a + 888b + 138c = 138620 \\ 888a + 138b + 24c = 24592 \\ 138a + 24b + 6c = 5118 \end{cases}$$

uninstall the system

$a = -47{,}8333$, $b = 683{,}111$ and $c = 30{,}1190$

values found. T The desired connection between and is approximately in this form: [15, 16, 17].

$$P=\frac{\Delta W}{T}=-47{,}8333T^2+6831{,}1111T+30{,}1190\,.$$

As a result of the calculations, the indicator of all consumers in relation to the total consumption, the time connection points of the power and the empirical function between them $P=\frac{\Delta W}{T}=-47{,}8333T^2+6831{,}1111T+30{,}1190$ were formed [18, 19, 20].

Brand TM-630/10/0.4 power transformer consumers consumed 5118 kWh of electricity per day, of which 3938 kWh were 1-phase consumers, and 1180 kWh were 3-phase consumers.

Empirical functional bindings directly affect the binding points of given values. As a result, the change in indicators changes the same for all phases and all sequences [22, 23, 25].

The quoted values are obtained from the results of calculations for 5 periods of the day and embodied with the values calculated through empirical connections.

Based on the higher indicators of all consumers compared to the total consumption, the following single-phase transformer indicators are (2; 201.5), (3; 413), (5; 247.5), (6; 67), (8; 81,7) form points [25, 26, 27].

Table 4.

the empirical function of the single-phase transformer indicator in relation to the total consumption of all consumers $P(T)=aT^2+bT+c$.

I	T_i	P_i^{1F}	T_i^2	T_i^3	T_i^4	$P_i^{1F}T_i$	$P_i^{1F}T_i^2$
1	2	201,5	4	8	16	403	806
2	3	413	9	27	81	1239	3717
3	5	247,7	25	125	625	1238,5	6192,5
4	6	67	36	216	1296	402	2412
5	8	81,7	64	512	4096	653,6	5228,8
6	24	1010,9	138	888	6114	265627,7	18356,3

From this table we get this system: [28, 29, 30].

$$\begin{cases} a\sum_{i=1}^{6}T_i^4+b\sum_{i=1}^{6}T_i^3+c\sum_{i=1}^{6}T_i^2=\sum_{i=1}^{6}T_i^2+(P_D)_i \\ a\sum_{i=1}^{6}T_i^3+b\sum_{i=1}^{6}T_i^2+c\sum_{i=1}^{6}T_i=\sum_{i=1}^{6}T_i+(P_D)_i \\ a\sum_{i=1}^{6}T_i^2+b\sum_{i=1}^{6}T_i+6c=\sum(P_D)_i \end{cases} \quad \begin{cases} 6114a+888b+138c=18356{,}3 \\ 888a+138b+24c=265627{,}3 \\ 138a+24b+6c=1010{,}9 \end{cases}$$

remove the system $a=-8323{,}6793, b=72817{,}742$ and $c=-99657{,}4023$.

T and P took approximately this form [33, 34, 35].

$$P=\frac{\Delta W}{T}=-8323{,}6793T^2+72817{,}7420T-99657{,}4023\,.$$

An empirical function of the power-to-time connection points and between them $P=\frac{\Delta W}{T}=-8323{,}6793T^2+72817{,}7420T-99657{,}4023$ was generated. also, based on the above indicators, the three-phase transformer $(2;65{,}5)$created $(5;54{,}3)$ the $(6;22)$ points $(3;22)$ $(8;47)$ [36, 37].

Table 5

Data for the construction of the empirical function of the three-phase transformer performance of all consumers in relation to the total consumption $P(\mathbf{T})=\mathbf{a}\mathbf{T}^2+\boldsymbol{bT}+\boldsymbol{c}$

I	T_i	P_i^{1F}	T_i^2	T_i^3	T_i^4	$P_i^{1F}T_i$	$P_i^{1F}T_i^2$
0	0	0	0	0	0	0	0
1	2	65.5	4	8	16	131	262
2	3	22	9	27	81	66	198
3	5	54.3	25	125	625	271,5	1357,5
4	6	22	36	216	1296	132	792
5	8	47	64	512	4096	376	3008
6	24	210,8	138	888	6114	976,5	5617,5

From this table we get this system: [7; 8; 9].

$$\begin{cases} a\sum_{i=1}^{6}T_i^4+b\sum_{i=1}^{6}T_i^3+c\sum_{i=1}^{6}T_i^2=\sum_{i=1}^{6}T_i^2+(P_D)_i \\ a\sum_{i=1}^{6}T_i^3+b\sum_{i=1}^{6}T_i^2+c\sum_{i=1}^{6}T_i=\sum_{i=1}^{6}T_i+(P_D)_i \\ a\sum_{i=1}^{6}T_i^2+b\sum_{i=1}^{6}T_i+6c=\sum(P_D)_i \end{cases} \qquad \begin{cases} 6114a+888b+138c=5617{,}5 \\ 888a+138b+24c=976{,}5 \\ 138a+24b+6c=210{,}8 \end{cases}$$

uninstall the system $a=-1{,}17, b=12{,}6$ and $c=11{,}8$. Thus, T the desired connection between $P=\frac{\Delta W}{T}=-1{,}1797T^2+12{,}6119T+11{,}8202$ and is approximately in this form:

Thus, the indicator of all consumers in relation to the total consumption is the time connection points of the power and the empirical function between them $P=\frac{\Delta W}{T}=-47{,}8333T^2+6831{,}1111T+30{,}1190$ was formed [38]. Empirical values determined by the method of least squares from the given square function were expressed in the electric load graph, where the difference between the maximum and minimum values of the indicators had a very large change, as a result, the view in Figure 2 appeared [39, 40].

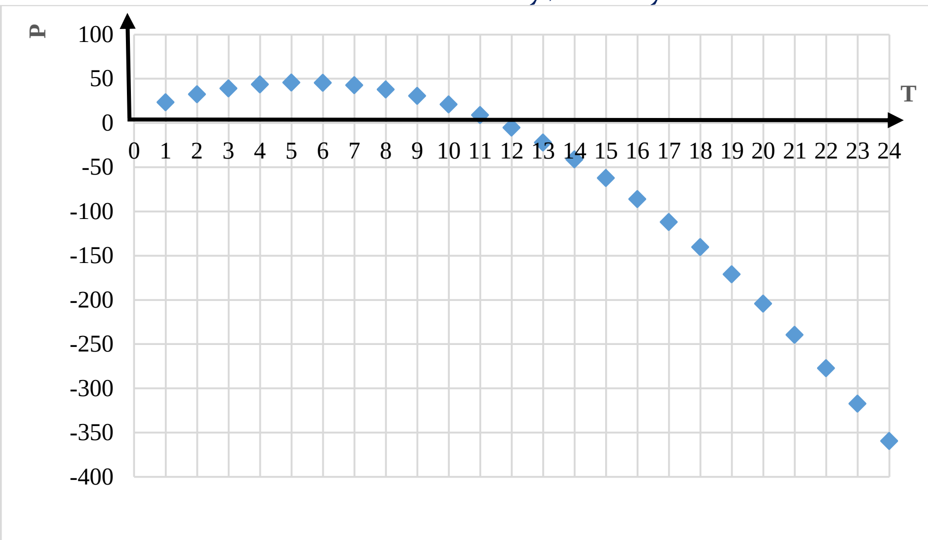

Figure 2. Empirical functional change graph for the consumption indicator

in 5 periods of the day .

Conclusion: Electricity is consumed differently at different times of the day. And this provider transformers and cable to the lines negative effect shows. Consumption indicators energy to the minimum times of consumption relatively raise opportunity create is an urgent issue. Differentiated tariffs system the need empirical functional connections graphics and the most small squares method according to mathematician account books enough light up gave.

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