IOP Conference Series: Materials Science and Engineering

Mechanisms of electrical energy management on different tariffs of industrial enterprises

To cite this article: Kh Muratov *et al* 2020 *IOP Conf. Ser.: Mater. Sci. Eng.* **883** 012163

IOP Conf. Series: Materials Science and Engineering **883** (2020) 012163 doi:10.1088/1757-899X/883/1/012163

Mechanisms of electrical energy management on different tariffs of industrial enterprises

Kh Muratov[1], K Kodirov[1] and D Kodirov[2]

[1]"Uzbekenergo" JSC Scientific and Technical Center" LLC, Tashkent, Uzbekistan
[2]Tashkent Institute of Irrigation and Agricultural Mechanization Engineers, Tashkent, Uzbekistan

d.kodirov@tiiame.uz

Abstract. This article addresses the issues of monitoring energy consumption modes to reduce production costs when tariffs that divide consumers' electricity bills by day, weekdays, and seasons. Taking into account the aforementioned issue, the proper use of time-differentiated tariffs has led to some changes in the operating mechanisms of industrial enterprises to monitor their operating modes.

1. Introduction

The efficacy of energy conservation studies conducted at industrial enterprises will depend largely on how much energy balances are detailed. The energy balance determined by all the elements of the power supply scheme makes it possible to quickly identify the wrong energy consumption [1].

Numerous criteria for determining power systems and consumer performance have been proposed [1, 2, 3, 4, 5]. While the overall performance for them all involves the development of the system and the consumer enterprise in different ways, they are based on minimizing development costs. For example, it has been proposed to minimize costs, although foreseeing similar energy effects in determining the development of energy systems.

He also [6], suggested that object refinement be integrated and comprehensive. Integration Defining the main criteria during the activity cycle of the object is based on the integration criteria (integration) at all stages of the activity. That is, it takes into account technological process parameters, operating modes, schemes, equipment, and design.

As a criterion for the efficiency of electric energy consumers, the reduction of energy costs is envisaged by using differentiated tariffs.

Mathematical modeling and formulation of technical and economic indicators of production systems have been reflected in many studies [7, 8, 9, 10].

The classical theory of refinement is based on the use of differential calculations to find the minimum and maximum points in the presence or absence of constraints. The Jacobi method, the Lagrangian multiplication method, and the Kuna-Tucker conditions for the constraints in the form of inequalities are examples of the solution of boundary equations [11].

There is also a dynamic programming method used to improve the computational efficiency of some mathematical programming methods [11, 12, 16].

2. Methods

Consumers are charged with differentiated tariffs to pay for electricity consumed during the "peak", "half peak" and "night" periods. When using differentiated time rates, the main payments for the

IOP Conf. Series: Materials Science and Engineering **883** (2020) 012163 doi:10.1088/1757-899X/883/1/012163

billing periods are made in advance and are as follows:

$$H_{pay.} = a \cdot P_{max.}; \qquad (1)$$

in this: $H_{pay.}$ is the primary billing period,
a is the basic rate of tariff periods, kWh • Soums;
$P_{max.}$ is the rate of payment for the peak periods in the electricity consumption specified in the contract, kWh·uzs.

The value of electricity consumption in "peak" periods is determined by the following expression:

$$P_{max.} = P_{max.}^{uzs} + \Delta P - P_{sub} \qquad (2)$$

in this: $P_{max.}^{uzs}$ is the amount of energy consumed by the power system during the “peak” periods, kW;
ΔP is the power consumption, kWh between the consumer and the electricity grid;
P_{sub} is the sub-consumers who are connected to electric energy on a contract with consumers but not connected to an automated power consumption control system, calculated power consumption during peak periods in the power system.

The total cost of active energy consumed by consumers in differentiated time periods is expressed as follows:

$$W = W_{ae} + \Delta W + W_{сн} - W_{sub}; \qquad (3)$$

in this: W_{ae} is the active energy consumption, kW·h;
ΔW is the electricity Grids line to the next, and transforming the overall network losses (consumers and consumer counters the border points), kW·h;
$W_{сн}$ is the total electricity consumed by the consumer for their own needs and calculated using transformer calculation method (if the frequency is not the energy consumption meter for own needs), kW;
W_{sub} is the total power consumption of consumed sub-consumers not included in the automated system of electricity consumption control, kW

Total energy consumption by time differentiated tariffs system is represented by the following formula:

$$W_{mea.} = W^{n} + W^{sp} + W^{p} \qquad (4)$$

in this: W^{n}, W^{sp}, W^{p} are the total energy consumed during the "peak", "half-peak" and night-time periods, kWh.
W^{n}, W^{sp}, W^{p} are the electricity consumption in "peak", "half-peak" and night-time periods (these periods are determined following the Resolution of the President of the Republic of Uzbekistan dated November 8, 2017 № PP-3379), kWh. [14, 15].

The total volume of electricity consumption calculated using the automated electricity consumption control system is as follows:

$$W = W_{N} + W_{SP} + W_{P} \qquad (5)$$

Taking into account the consumers of industrial enterprises with high energy consumption, the ratio between the measured values of the electricity consumed in the morning and night hours of the power system during the period is:

$$P_{m.p.} \leq P_{e.p.} \qquad (6)$$

Manufacturers are advised to record the daily consumption of electric energy by automated power consumption control systems from the computer to log files. They will be able to make predictions based on daily electricity consumption to meet future consumption.

It is possible to draw the load schedule for the enterprises' electricity consumption. To do this, the maximum computing power of the enterprise should be known R_x. In that case

$$P_n = \frac{n\% \cdot P_x}{100} \quad kvt; \quad (7)$$

in this: P_n is kW at certain times of day;

$n\%$ is the ordinal corresponding to the desired level in the sample graph;

P_x is the company's computing power.

For example, the power consumption of JSC "Quartz" at 9:00 AM on the day of maximum electricity consumption in January 2019 is 80% in the sample program and for the enterprise. P_p=5400 kW if any, 4 p.m. $P_9 = \frac{80 \cdot 5400}{100} = 4320$ kW will be.

Usually $P_{aver.}$ and P_M amount of their great additions for the shift period of time.

The maximum coefficient of the electricity consumption of the industrial enterprises, as opposed to the graph replenishment coefficient, is as follows:

$$K_{Ma} = \frac{1}{K_{Ta}} = \frac{P_M}{P_{Ta}} = \frac{P_M}{P_{aver.}} \quad (8)$$

The value of this coefficient is determined for the high load shifts and belongs to the consumers of the group. If the maximum power is considered to be the computing power,

$$K_{ma} \frac{P_x}{P_{aver.}} \quad (9)$$

This means that the maximum coefficient determines the relationship between the two most important quantities, the estimated and the average load. The K_m coefficient indicates how large the computational power is compared to the average power. It may be equal or larger in size. For consumers (fans, pumps, etc.) with constant load $K_m = 1$, that is $P_x = P_{aver.}$ [13, 17].

The power consumption of the enterprise is mainly concentrated at night, and the enterprise will be completely turned off during the half-time period, which is the main electricity consuming equipment for the day. There is only the personnel department of the enterprise and a large metal-cutting machine, a press-stamping unit for stoves. This represents 3% of the daily electricity consumption of the enterprise.

The monthly results of applying Wangda Metal LLC differentiated tariffs for July 2019, with maximum and minimum electricity consumption are shown in the chart below (Figure 1).

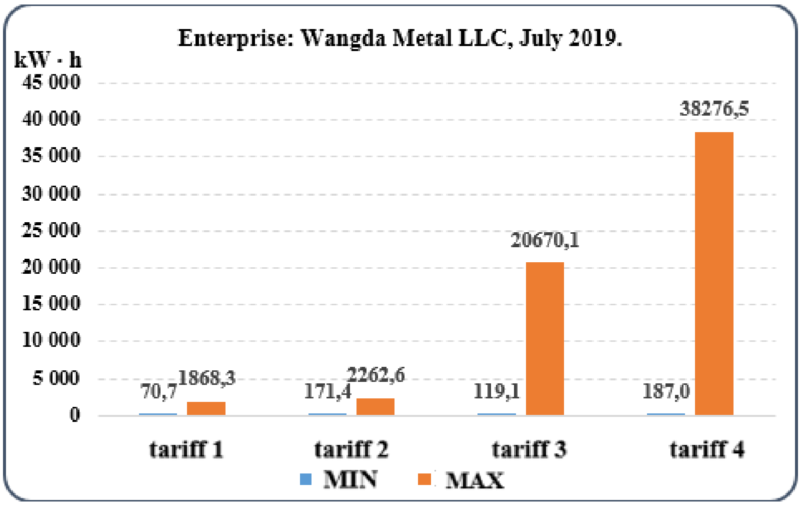

Figure 1. Maximum and minimum power consumption of July 2019 at Wangda Metal LLC

As a result of the use of differentiated tariffs on electricity consumption by the enterprise, the sum of the maximum and minimum payments for electricity consumed by the tariff periods (zones) can be seen in the graph below.

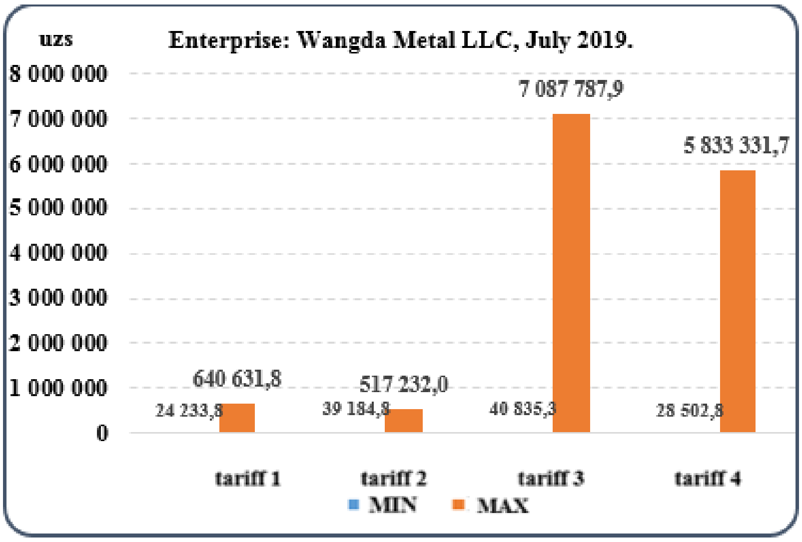

Figure 2. Amount of payment for the maximum and minimum tariff periods (zones) of “Wangda Metal” LLC for July 2019.

The company pays for electricity consumption on a time-varying tariff system. The size of the enterprise's electricity bill is significantly lower than the one-rate tariff system. In this case, the amount of payments made by the enterprise for electricity, in turn, differs by the low cost of production. The company contributes to reducing the load on the power system and reducing power consumption during the daytime due to low power consumption.

As a result of the transfer of electricity to the night-time enterprises, the enterprises will be able to conserve electricity, improve the reliability of the system and the devices available to consumers, and ensure the smooth operation of the electricity at other times of the day. This will ensure the energy efficiency of consumers.

3. Results and Discussions

Studies of processes have shown that the linear programming method is highly effective.

The linear programming method has been developed to solve economically feasible problems in finding more convenient ways of distributing limited production resources. In this method, many mathematical links are expressed linearly. Typical production problems in linear programming include the goal, maximum benefit, or minimum cost. In most cases, the goal can be clarified based on specific circumstances.

A common way to have an exact solution is a common problem of mathematical programming, which is as follows:

$$F_i(x_1, x_2, \dots, x_n) \le b_i \quad (i=1, 2,\dots,n);$$
$$x_j \ge 0 \quad (j=1. 2\dots n); \qquad (10)$$
$$\max (\min)\ Z = f(x_1, x_2, \dots, x_n)$$

Programming issues for solving cost-effective economic solutions are as follows:

Z is the purpose of minimizing the economic system and, accordingly: $(Z = f\ x_1, x_2, \dots, x_n)$ is the target function;

$(x_1, x_2, \dots, x_n)$ is the Indicators of the use of the means of achievement, characterized by the production of products, full utilization of equipment, resource utilization, and so on;

$F_1\ (x_1, x_2, \dots, x_n)$ is the function of expenditure of all means of the i-group, used for the purpose;

b_i - from above F_i (x) Limit group of expenditure on all means.

Bottom in general $F_i\ (x) \le -b_i$, There are also some limitations, which are directly related to the desired level of achievement of the goal, of course.

According to the rules, the actual models of refinement are formed not in the form of general problems of mathematical programming, but various special problems.

f (x) and F_i (x) The general problem of discretionary function (16) is very extreme and can only be solved by a fully structured solution.

$$F_i(x) = b_i \qquad (i=1, 2, \dots, m)$$
$$\max (\min) Z = f(I) \qquad (11)$$

It is much simpler for continuous and differential F_i *(x)* and *f (x)* functions at the point of solving this problem.

The main purpose of parameterization is to minimize the cost of electricity consumption by technological processes using a differentiated tariff system, namely:

$$Z = \sum_{i=1}^{n} C_i E_i \to \min; \qquad (12)$$

in this: E_i is the amount of electricity consumed during the day at different rates, kWh;

C_i is the daily rates, soum / kWh.

or in plain view:

$$Z = C_1E_1 + C_2E_2 + C_3E_3 + \cdots + C_nE_n \qquad (13)$$

Non-negative condition:

$$C_1E_1 + C_2E_2 + C_3E_3 + \ldots + C_nE_n > 0; \qquad (14)$$

The following principles are graphically illustrated (Figure 3).

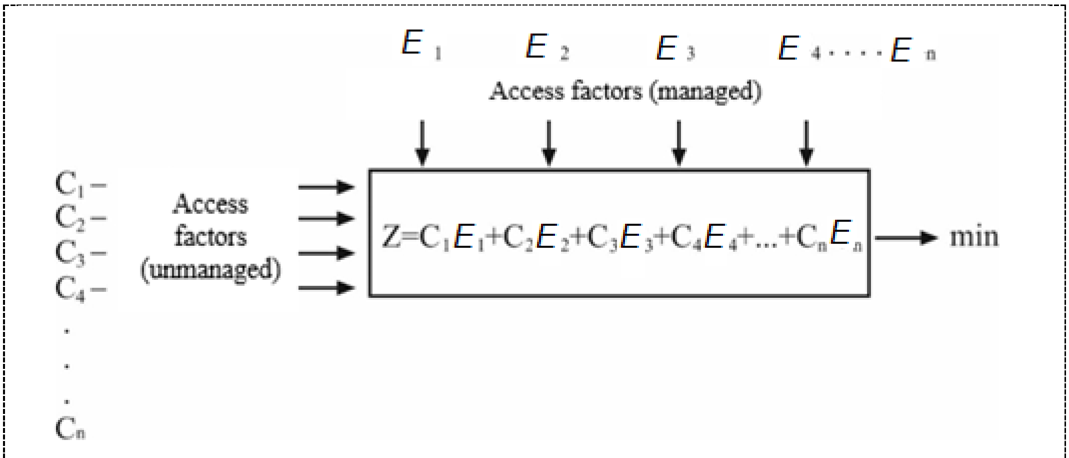

Figure 3. Graphical representation of a formulated principle

in this: $E_1, E_2, E_3, E_4 \dots E_n$ – the factors of the amount of electricity consumed in each cycle, kWh;

$C_1, C_2, C_3, C_4 \dots C_n$ – the factors of the cost of electricity in each period.

As can be seen from the expressions (Formulas 11-14) correspond to the non-standard form of the linear model, for example. Because: the target function must be minimized.

Since there are four variables, the problem is solved by the simplex method.

The process of solving the problem by "simple method" is iterative, that is, until the optimal solution is repeated, the same type of calculations are repeated in a certain order, using a personal computer.

To do this, we define the variables as follows:

$$E_1 \rightarrow X_1; \quad E_2 \rightarrow X_2; \quad E_3 \rightarrow X_3; \quad E_n \rightarrow X_n \tag{15}$$

Wangda Metal LLC was calculated as the month of maximum electricity consumption in April, which is an April ordinary tariff (228.60 soums, as of November 16. 2018).

1 391 304.295 · 228.60 = **318 052 161** soums.

In Wangda Metal LLC, time-differentiated tariffs have been solved by "Simplex-method" of electricity consumption and have been reduced to 312 486 522 sums compared to ordinary tariffs.

Z=26130·342.9+25502·228.6+490975.6·342.9+848695.9·152.4 = **312 486 522**

The problem is solved using the package of economic calculations.

Table 1. The baseline values for the problem are presented

Name of the pointer	Rates in soum / kWh (as of November 16, 2018)			
	C_1	C_2	C_3	C_4
Tariffs for electricity	342.9	228.60	342.9	152.4

The results of the calculation are shown in Tables 4.2-4.10.

Table 2. Initial table

Basis	C (j)	C_1	C_2	C_3	C_4	A_1	S_2	S_3	A_3	B (*i*)	B (*i*) / A (*i, j*)
		342.9	228.6	342.9	152.4	M	0	0	M		
A_1	M	1.0	1.0	1.0	1.0	1.0	0	0	0	100	0
S_2	0	0	0	0	0	0	0	0	0	0	0
A_3	M	100	100	100	100	0	0	-1.0	1.0	0	0
C (j)-Z(j)		342.9	228.6	342.9	152.4	0	0	0	0	0	
*Big M		0	0	0	0	1.0	0	0	1.0	100	

Table 3. Iteration 1

Basis	C (j)	C_1	C_2	C_3	C_4	A_1	S_2	S_3	A_3	B (*i*)	B (*i*) / A (*i, j*)
		342.9	228.6	342.9	152.4	M	0	0	M		
A_1	M	1.0	1.0	1.0	1.0	1.0	0	0	0	100	100.0
S_2	0	0	0	0	0	0	0	0	0	0	0
A_3	M	100	95.0	95.0	25.0	0	0	-1	1.0	0	0
C (j)-Z(j)		342.9	228.6	342.9	152.4	0	0	0	0	0	
*Big M		-101	-96	-96	-26	0	0	1	0	100	

Current amount CA (min)=0+(100 Big M)

The highlighted variable is the input and output variable enter: X_4; exit: A_3.

Table 4. Iteration 2

Basis	C (j)	C_1	C_2	C_3	C_4	A_1	S_2	S_3	A_3	B (*i*)	B (*i*) / A (*i, j*)
		342.9	228.6	342.9	152.4	M	0	0	M		
A_1	M	0	0.05	0.05	0.75	1	0	0.01	-.01	100	133.3
S_2	0	0	0	0	0	0	0	0	0	0	0
X_5	118	1	0.95	0.95	0.25	0	0	-.01	0.01	0	0
C (j)-Z(j)		115	-55	-44	45.5	0	0	1.18	-1.1	0	
*Big M		-0	-.05	-.05	-.75	0	0	-.01	1.01	100	

Current amount CA (min)=0+(100 Big M) enter: X_3; exit: X_4.

Table 5. Iteration 3

Basis	C (j)	C_1	C_2	C_3	C_4	A_1	S_2	S_3	A_3	B (*i*)	B (*i*)
		342.9	228.6	342.9	152.4	M	0	0	M		A (*i*, *j*)
A_1	M	-3	-2.8	-2.8	0	1	0	0.04	-.04	100	2500
S_2	0	0	0	0	0	0	0	0	0	0	0
X_5	75	4	3.8	3.8	1	0	0	-.04	0.04	0	Inf
C (j)-Z(j)		-67	-228	-217	0	0	0	3	-3	0	
*Big M		3	2.8	2.8	0	0	0	-0.4	1.04	100	

Current amount CA (min)=0+(100 Big M) enter: S_3; exit: A_1.

Table 6. Iteration 4

Basis	C (j)	C_1	C_2	C_3	C_4	A_1	S_2	S_3	A_3	B (*i*)	B (*i*)
		342.9	228.6	342.9	152.4	M	0	0	M		A (*i*, *j*)
A_1	0	-75	-70	-70	-75	25	0	1	-1	2500	Inf
S_2	0	0	0	0	0	0	0	0	0	0	0
X_5	75	1	1	1	1	1	0	0	0	100	100
C (j)-Z(j)		158	-18	-7	43	-75	0	0	0	7500	
*Big M		0	0	0	0	1	0	0	1	0	

Current amount CA (min)= 312 486 522 enter: X_2; exit: S_2.

Table 7. Final table (4 iterations total)

Basis	C (j)	C_1	C_2	C_3	C_4	A_1	S_2	S_3	A_3	B (*i*)	B (*i*)
		342.9	228.6	342.9	152.4	M	0	0	M		A (*i*, *j*)
S_3	0	-75	-.01	28.4	0	24	0.1	1	-1	2500	0
X_2	57	0	1	1.40	0	0	.03	0	0	1.13	0
X_4	75	1	0	.40	1	1.0	0	0	0	98.8	0
C (j)-Z(j)		158	0	18.3	0	-75	.04	0	0	7480	
*Big M		0	0	0	0	1	0	0	1	0	

the minimum amount MA= 312 486 522

Table 8. The final table

Variables №	Tariff names	Solution	Double evaluation	Variables №	Tariff names	Solution	Double evaluation
1	C_1	0	158	5	A_1	0	-75.0488
2	C_2	1.1382	0	6	S_2	0	0.0488
3	C_3	98.8618	18.3171	7	S_3	0	0
4	C_4	0	0	8	A_4	0	0

the minimum amount MA = 312 486 522 **Iteration** = 4

Table 9. Stability analysis of target function coefficients

C (j)	Min C (j)	Start	Max C (j)	C (j)	Min C (j)	Start	Max C (j)
C (1)	75.000	233.0000	+ endless	C (4)	57.0000	75.0000	118.0000
C (2)	- endless	57.0000	70.0231	C (5)	75.0000	118.0000	+ endless
C (3)	49.6829	68.0000	+ endless				

Table 10. Stability analysis of part

B (*i*)	Min B (*i*)	Start	Max B (*i*)	B (*i*)	Min B (*i*)	Start	Max B (*i*)
B (1)	1.4054	100.0000	520.0000	B (3)	- endless	0.0000	2579.674
B (2)	100.0000	520.0000	37000.00				

Based on the calculations, the results of the target function definition are presented (Table 11).

Table 11. Results of goal function

№	Tariff cycles	X_1, X_2, X_3, X_4 recommended ratios	Minimum value of target function, soum (UZS / kWh)
1	X_1 = 100%	X_1 – 100% X_2 – 0 X_3 – 0 X_4 – 0	8 959 977 (342.9)
2	X_2 = 100%	X_2 – 100% X_1 – 0 X_3 – 0 X_4 – 0	5 829 757 (228.60)
3	X_3 = 100%	X_3 – 100% X_1 – 0 X_2 – 0 X_4 – 0	168 355 533 (342.9)
4	X_4 = 100%	X_4 – 100% X_1 – 0 X_2 – 0 X_3 – 0	129 341 255 (152.4)
		the minimum amount:	**312 486 522**

The target function for Wangda Metal LLC (13) should be the following:

$$Z=0.02C_1+0.02C_2+0.35C_3+0.61C_4 \quad (16)$$

in this: 0.02; 0.02; 0.35; 0.61 – of monthly electricity consumption by % for each period.

4. Conclusions

Summarizing the research results, we can draw the following conclusions:

- consumption of electricity by consumers was based on indicators of metering devices installed at a normal rate. The dependence of the time differentiated tariff system on the automated control of electricity consumption for the calculation of electricity consumption. As a result, payments for electricity consumed for each period increased the accuracy of computational work.
- developed the program of an electronic computing machine for consumers of electric power of industrial enterprises. As a result, consumers have the opportunity to monitor their daily, monthly, and annual electricity consumption.
- with the help of the developed program, it is possible to predict the daily, monthly and annual electricity consumption by the enterprises in terms of min and max kWh.
- using differentiated tariffs, Wangda Metal's electricity costs are reduced by 312 446 562 sums a month compared to the usual tariffs.

IOP Conf. Series: Materials Science and Engineering **883** (2020) 012163 doi:10.1088/1757-899X/883/1/012163

References

[1] Bolotov V V 1964 The choice of the economic criterion when compiling options for the prospective development of the energy system *Technical and economic issues of designing energy systems and power plants* pp 45-52

[2] Boyarsky V 1970 Criterion for economic evaluation of the development program of the national network, taking into account international interconnections and reliability of power transmission *Symposium on the application of operational research methods for large power systems and the use of computers for this purpose* Varna pp 123-127

[3] Gildbrandt G 1968 Experience in applying the model to optimize the energy sector of the German *Democratic Republic at the VII World Energy Conference* **238** p 12

[4] Klima I, Ireshova A 1970 Economic efficiency criterion for choosing the structure of a developing energy system *Materials symposium on the application of operational research methods for large energy systems and the use of computers for this purpose* Varna pp 67-70

[5] Klima I, Ireshova A 1976 Formulation of the criterion for optimizing the development of production systems // *Proceedings of the Prague Polytechnic Institute* Prague pp 19-22

[6] Klima I, Ireshova A, 1979 Criterion of economic efficiency in the development of electric power systems *Energy* **12** pp 21-25

[7] Kodirov D, Tursunov O 2019 Calculation of Water Wheel Design Parameters for Micro Hydroelectric Powe *E3S Web of Conferences 97 FORM-2019*

[8] Ermoliev Yu M Yastrezhemsky A I 1979 Stochastic models and methods in economic planning *Nauka* p 253

[9] Iozaitis V S Lvov Yu A 1991 Economics-mathematical modeling of production systems *Higher* p 192

[10] Kabulov V K Abdurazzakov V A and Ziyakhodzhaev M Z 1974 Application of economic and mathematical methods in cotton growing Tashkent *Fan* p 143

[11] Anarbaev A, Tursunov O, Kodirov D, Muzafarov Sh, Babayev A, Sanbetova A, Batirova L and Mirzaev B 2019 Reduction of greenhouse gas emissions from renewable energy technologies in agricultural sectors of Uzbekistan *E3S Web of Conferences* **135**

[12] Mathematical modeling of economic processes. Optimization 47 (64). Novosibirsk, 1990. P.-158.

[13] Rant Z 1959 Ekzergija goriv *Strojniski vestnik* **1**

[14] Kodirov D, Tursunov O, Parpieva S, Toshpulatov N, Kubyashev K, Davirov A and Klichov O 2019 The implementation of small-scale hydropower stations in slow flow micro-rivers *A case study of Uzbekistan E3S Web of Conferences* **135**

[15] Taha H 1985 Introduction to Operations Research *In 2 books 2 Trans with eng* p 496

[16] Taslimov A D, Rasulov A N 2013 Sanoat korkhonalalining electro taminoti Toshkent pp 25-28

[17] Rakhmatov A, Tursunov O and Kodirov D Studying the dynamics and optimization of air ions movement in large storage rooms *International Journal of Energy for a Clean Environment* **20(4)** pp 321-338