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To cite this article: I Bakhadirov *et al* 2020 *IOP Conf. Ser.: Mater. Sci. Eng.* **883** 012121

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INTERNATIONAL OPEN ACCESS WEEK
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Differentiated tariffs of electricity for the improvement of steelmaking Uzbekistan

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Abstract. The article outlines options to improve the organization of steel production in the Republic of Uzbekistan in terms of any contractual relation, tariffs with the unified energy system. The agreed “flexible”, differentiated by time of day (multi-fare) tariffs allow not only to produce high-quality steel but also to organize an economically profitable “associated” production. Combined production is optimized by the criterion of maximum capital productivity at all its stages and areas. It also addressed the constraints preventing the intensive use of high-performance equipment and presented the increased tariff for consumed electricity as a criterion factor. As a result of the application of the nonlinear programming method by composing the Lagrange function, the income function of the main and auxiliary industries is maximized. Given the validity of costs, their content is disclosed. Taking into account the importance of energy resources, in a competitive market, they are considered as the most important components of production. The goal of achieving the lowest costs and maximum profits is achieved by the presence of a procedure for manipulating resources. For steelmaking production, the economically most advantageous tariff curve in the demand function $T = f(c)$ is recommended, which will ensure uniformly elastic demand across the entire range of tariffs. This curve means a uniformly elastic demand in the whole range of tariffs, i.e. equal to proportional across the entire range of tariff reduction in the face of rising demand for products, which confirms the perfect representation of the tariff curve as a function of demand in the form of a decaying exponent. The elements of optimization are investigated, in particular, based on relative Lagrange increments. Special attention is paid to the exponential scale of electricity tariffs, providing a kind of “equally proportional” reduction of the tariff with increasing demand for manufactured products. The replacement of an exponential continuous scale of tariffs with a more convenient graded scale is also decided from the standpoint of economic tolerances, where, in the process of monitoring demand, the values of maximum tariffs can be further changed. It has been established that, at the same time, the use of an exponential scale of tariffs at enterprises with a continuous production pattern, in particular steel-smelting sections, makes it possible to ideally solve the problem of optimizing co-production.

1. Introduction



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It is known that an important direction of increasing the efficiency of already certain rational use of energy resources in the conditions of application of multiple tariffs for electricity is the optimization of steelmaking production, in which there is a certain criterion of quality of management in a certain period of time, reaching the appropriate limits of its minimum or maximum value [1].

It is to the complex production systems consisting of interconnected subsystems, united by a common purpose of functioning and having a large number of indicators that characterize their condition, are metallurgical enterprises, as well as their energy components [2].

The part of indicators referring to different subsystems can have opposite tendencies of changes in the course of system operations.

Providing, as a result, the increase of production efficiency and reduction of costs, the multi-criteria of the metallurgical production causes a natural tendency to find such technological, technical, and organizational solutions, which would provide a purposeful change of several indicators simultaneously [3].

Calculations with consumption for electricity, which can be supplied directly from the electrical networks of enterprises, and through the electrical networks of consumers or sub-consumers, is made on the basis of contracts of power supply companies at the appropriately approved tariffs.

Monthly, within five days after the end of the settlement period, all electricity consumers (except for household consumers), together with the enterprises of territorial electric networks, are obliged to draw up a statement of mutual settlements for electricity used.

Consumers with a connected capacity of 750 kVA and higher shall make settlements for electric energy at a differentiated tariff. Moreover, payment for electricity consumed during the hours of the maximum load of the unified electric power system is made with the use of an increased coefficient 1.5 times more than the established tariff, and during the hours of maximum load - with the use of a reduction factor of 1.5 times less than the established tariff. Payment in the half-peak period is carried out according to the established tariff [4].

Taking into account the fact that the steelmaking industry in Uzbekistan is one of the most energy-intensive consumers, the requirement for the most efficient use of each kilowatt-hour of electricity is extremely urgent. There is the way of a solution to this problem with the help of multiple tariffs for electricity is considered below in the proposed article.

The purpose of the article is to organize the management of steelmaking production in Uzbekistan by comparing the costs and results obtained at each main and auxiliary production site. As well as considering the potential introduction of "flexible" (differentiated by time of day) tariffs.

The object of research is enterprises with an attached capacity of 750 kVA or higher.

The subject of the study is the existing electricity tariffs, as well as the process of power consumption of the main equipment of steelmaking production.

The research objectives are:

1. Analysis of the current state of use of the exponential scale of tariffs for industrial enterprises, in private steelmaking.
2. Develop the principles of combining the main and auxiliary production for the production of final products.
3. Develop a mathematical apparatus for nonlinear programming that allows you to get the minimum costs in the production of products.
4. Study of the demand for steelmaking sites for a set of tariffs that will be fully demanded by all-electric consumers of the site.

2. Methods

Modern production equipment on steelmaking sites makes it possible to produce a wide range of quality products, and at the same time to be an integral part of several technological processes. Naturally, it is quite natural to tighten requirements to the quality of finished products at the enterprises with a continuous nature of production, in particular at steelmaking sites. It is clear that a

low load factor in the operation of high-performance equipment that creates high-quality products can negate all expected benefits from the introduction of new technologies.

Let's consider the limitation that prevents the intensive use of high-performance equipment under consideration. Such a limiting factor may be a high tariff on electricity consumed. It is obvious that the solution to this problem lies in the economic plane. For steel-melting production, revenues (I) have two main components: revenues from main production (rolling mill) (I_{mp}) and revenues from auxiliary production (compressed air, propane, oxygen, welding, repair shops, industrial warehouses of finished parts, etc.) (I_{axp}):

$$I = I_{mp} + I_{axp} \quad (1)$$

Based on the fact that industrial enterprises strive to maximize their income: $I \rightarrow \max$, the objective of our research is to determine the optimal balance between main and auxiliary production, ensuring the achievement of a possible maximum of expression (1).

With the help of the non-linear programming method [5-7] and making up the Lagrange function, we can maximize the function of two variables, defined as follows:

$$L = I + \lambda W \quad (2)$$

Where: λ is an indefinite factor, a W is Lagrange auxiliary function.

As an auxiliary function of the Lagrange, let's take the difference between the annual present Z costs and their limit value Z_{pr} , which is a finite value, which is due to the principal limitation of all types of resources:

$$W = Z - Z_{pr} \quad (3)$$

Let's disclose the content of these costs, taking into account their dual belonging: ensuring the operation of technical means of main production (Z_{mp}) and auxiliary production (Z_{axp}):

$$Z = Z_{mp} - Z_{axp} = k_n F_{mp} + R_{mp} + k_n F_{axp} + R_{axp} \quad (4)$$

where: F is fixed assets (capital expenditure), respectively:

F_{mp} is a technical means of the main production;

F_{axp} is a technical means of auxiliary production;

R is annual operating costs:

R_{mp} is for the operation of main production equipment;

R_{axp} is for the operation of auxiliary production equipment.

K_n - normative coefficient of economic efficiency.

The expanded Lagrange function (2) looks like:

$$\begin{aligned} I &= I_{mp} + I_{axp} + \lambda(k_n F_{mp} + k_n F_{axp} + R_{mp} + R_{axp} - Z_{pr}) = \\ &= I_{mp} + I_{axp} + \lambda(F_{mp}^n + F_{axp}^n + R_{mp} + R_{axp} - Z_{pr}) \end{aligned} \quad (5)$$

$$F_{mp}^n = k_n F_{mp} \quad \text{and} \quad F_{axp}^n = k_n F_{axp}$$

where the summands F_{mp}^n and F_{axp}^n are called normalized funds.

To determine the condition for obtaining the maximum of joint income, let's take private derivatives from expression (5) and equate them to zero:

$$\begin{cases} \frac{\partial L}{\partial I_{mp}} = 1 + \lambda \left(\frac{\partial F_{mp}^n}{\partial I_{mp}} + \frac{\partial R_{mp}}{\partial I_{mp}} \right) = 0 \\ \frac{\partial L}{\partial I_{axp}} = 1 + \lambda \left(\frac{\partial F_{axp}^n}{\partial I_{axp}} + \frac{\partial R_{axp}}{\partial I_{axp}} \right) = 0 \end{cases} \quad (6)$$

Having decided on the obtained system (6) regarding the uncertainty of the Lagrange multiplier, we obtain:

$$\lambda = \frac{-1}{\frac{\partial F_{mp}^H}{\partial I_{mp}} + \frac{\partial R_{mp}}{\partial I_{mp}}} = \frac{-1}{\frac{\partial F_{exp}^H}{\partial I_{exp}} + \frac{\partial R_{exp}}{\partial I_{exp}}}. \quad (7)$$

Let's take advantage of denominator equality:

$$\frac{\partial F_{mp}^H}{\partial I_{mp}} + \frac{\partial R_{mp}}{\partial I_{mp}} = \frac{\partial F_{exp}^H}{\partial I_{exp}} + \frac{\partial R_{exp}}{\partial I_{exp}} \quad (8)$$

Expression (8) permits two equivalent transformations, each with its economic meaning. Let us consider them.

First of all, we should take into account that [8, 9] is equal to the efficiency of the main and auxiliary production – the guarantee of the high efficiency of joint production.

Separately, let us group normalized funds and costs:

$$\frac{\partial F_{mp}^H}{\partial I_{mp}} + \frac{\partial F_{exp}^H}{\partial I_{exp}} = \frac{\partial R_{mp}}{\partial I_{mp}} + \frac{\partial R_{exp}}{\partial I_{exp}}. \quad (9)$$

The consequence of market manipulation of resources in the process of achieving minimum production costs is the economic interpretation of the expression (9): the difference in increments (with a different sign) of annual operating costs [8,9].

Second, let's return to the presentation of annualized reduced costs in a summarized form (4). In this case, the expression (8) will get a simplified form:

$$\frac{\partial Z_{mp}}{\partial I_{mp}} = \frac{\partial Z_{exp}}{\partial I_{exp}} \quad (10)$$

Obviously, it's fair to say the opposite:

$$\frac{\partial I_{mp}}{\partial Z_{exp}} = \frac{\partial I_{exp}}{\partial Z_{exp}} \quad (11)$$

The above expressions represent a clear economic interpretation of the incremental revenue per soum (rouble, dollar, euro, etc.) of the incremental costs of both primary and secondary output production should be the same. This conclusion corresponds to the fundamental position of the economic theory [8] - the condition of achieving maximum income, as well as the maximum profits of enterprises.

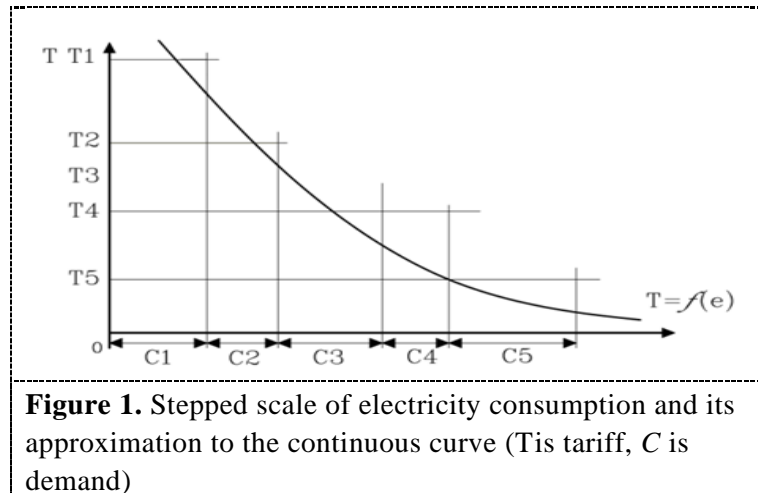
3 Results and Discussion

The above expressions represent a clear economic interpretation of the incremental revenue per soum (rouble, dollar, euro, etc.) of the incremental costs of both primary and secondary output production should be the same. This conclusion corresponds to the fundamental position of the economic theory [8] – the condition of achieving maximum income, as well as the maximum profits of enterprises.

It is established that manipulation in the production sphere can be affected by such factors of production as the quality of raw materials, climatic conditions, as well as various production, technological, and many other factors. In other words, it is possible to increase the cost of improving auxiliary production until it generates the same income (per unit of expenditure) as the main production.

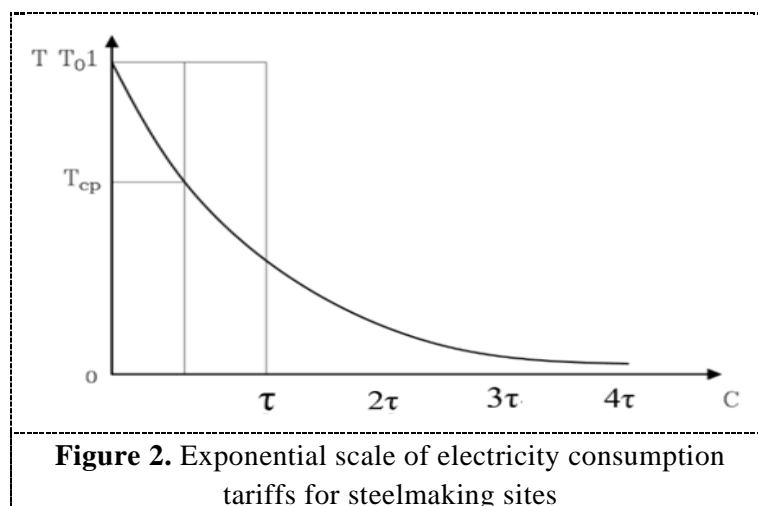
It is known that the more equipment is loaded, the more revenue it can generate. Thus, a fuller load can be achieved by increasing the amount of electricity consumed, especially during the period of minimum power consumption by the energy system. At the same time, there is a stimulation of

demand from the energy system in the conditions of the reduction of electricity tariffs. The way of applying multistage tariffs for electricity consumption in the world is shown in Figure 1.



Multiple tariffs allow to find consumers at any level - from the maximum to the minimum tariff even in the most "inconvenient" periods of the day.

For enterprises with a continuous nature of production, in particular, steelmaking sites, it is obvious that a set of tariffs will be required, which will be fully (without deductions) in demand by all electricity consumers of the site. The most economically advantageous for these production enterprises is the type of tariff curve in the function of demand - $T=f(c)$, which will ensure the inelastic demand in the whole range of tariffs.



Diversified demand means a constant demand ratio, i.e. a constant demand ratio.

$$E = \frac{\Delta C}{\Delta T} = const$$

the constancy of the inverse value is also evident:

$$\frac{1}{E} = \frac{\Delta T}{\Delta C} \approx \frac{\partial T}{\partial C} = \text{const} \quad (12)$$

The tariff curve in the demand function is nothing but an exponent. This leads to the idea that the rate of change of one parameter is constant when the other parameter is changed and interpreted by the derivative (12). The proof is obtained by taking the following analytical form of the tariff curve:

$$T = T_0 l^{-(c/\tau)} \quad (13)$$

where T_0 is the initial maximum tariff from the whole proposed range of tariffs; c - the current value of demand corresponding to the current value of the tariff T ; τ - some constant of demand characterizing the range of demand on the borders of which the tariff differs in "e" times. By expression (13), let's define a derivative of the tariff on-demand:

$$\frac{\partial T}{\partial C} = \frac{\partial}{\partial C} (T_0 l^{c/\tau}) = (-T_0 / \tau) l^{c/\tau} \quad (14)$$

If we compare the initial tariff curve $T=f(c)$ and the curve equivalent to the elasticity of demand

$$\frac{f(c)}{\partial T / \partial C} = \frac{T_0 l^{-(c/\tau)}}{-\frac{T_0}{\tau} l^{-(c/\tau)}} = \text{idem} \quad (15)$$

we find their similarity [10] with a linear and constant similarity coefficient

$$P = -\frac{1}{\tau} = \text{const} \quad (16)$$

Condition $P=\text{const}$, as well as the constancy of a kind of "logarithmic decrement of demand"

$$\ln e^{-(c/\tau)} = -\frac{c}{\tau} = \text{const} \quad (17)$$

which means "equally proportional" across the entire range of tariff reductions with increasing demand for products, indicates the ideal representation of the tariff curve in the demand function in the form of fading exhibitors.

Representation of a service related to the calculation of potential incomes of enterprises in continuous production, using a continuous scale of tariffs, changing according to the exponential law. Thus, in Fig. 2, the maximum tariff is adopted for that. In this case, the income of enterprises in the case of submitted tariffs will be equal to the area of a curvilinear figure, limited by the axes of coordinates and exponent.

$$S = \int_0^{\infty} T_0 l^{-(c/\tau)} dc = T_0 \left(\frac{1}{-1/\tau} \right) \left| l^{-(c/\tau)} \right|_0^{\infty} = -T_0 \tau (l^{-\infty} - l^0) = -T_0 \tau (0 - 1) = T_0 \tau \quad (18)$$

Let us introduce the concept of a "weighted average" tariff, i.e. such a tariff that would divide the total area (possible income) calculated by (18) into two equal parts:

$$S_{0.5} = \frac{S}{2} = \frac{T_0 \tau}{2} = T_0 \frac{\tau}{2} \quad (19)$$

The ordinate corresponding to this area, i.e. the required weighted average tariff T_{av} (see Fig. 2), can be calculated by expression (13) if set by abscissa $c = 2$:

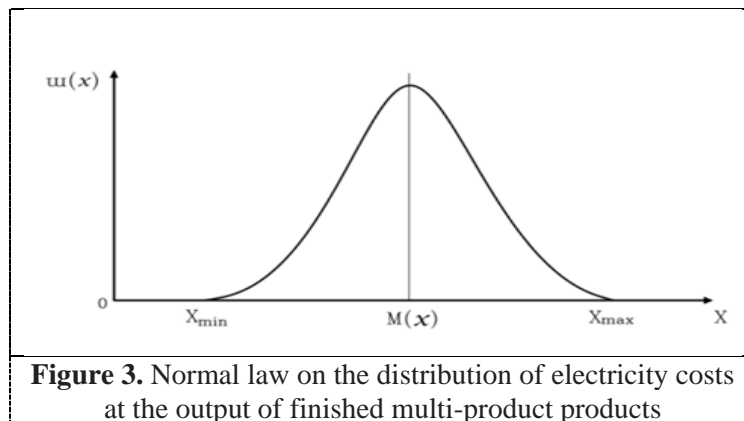
$$T_{cp} = T_0 l^{-(c/\tau)} T_0 l^{-(\tau/2\tau)} = T_0 l^{(1/2)} = \frac{T_0}{\sqrt{l}} \approx 0.606 T_0 \quad (20)$$

Let us analyze the demand for (the legitimacy of) the proposed "equal-proportional, mathematically ideal tariff scale, its use in the range from the minimum to the maximum tariff. Taking into account the significant number of steel producers' sites and auxiliary production, the most isomorphic object

will be the normal law of probability distribution used for this production of energy inputs (in monetary terms):

$$\omega(X) = \frac{1}{\sqrt{Dx}\sqrt{2\pi}} e^{-\frac{|x-M(x)|^2}{2D_1}} \quad (21)$$

where $M(x)$ is a mathematical expectation of expenses and Dx is its dispersion. The graph of this dependence is shown in Figure 3.



It is known that the area under the curve $\omega(x)$ in the range from the minimum to the maximum value of the unit tariff fee in the production of finished products is equal to one:

$$S = \int_{X_{\min}}^{X_{\max}} \omega(X) d(X) = 1 \quad (22)$$

At the same time, the above-mentioned area corresponds to the total revenues of the power system for the analyzed period (estimated period). Therefore, if we equate the weighted average tariff for the production of a unit of output of the T_{av} , obtained in terms of (20) – the mathematical expectation of electricity consumption per unit of output received from the schedule (Fig. 3), then it is possible to obtain a correspondence between the income (supply) of the energy-saving firm and the costs (demand) of electricity consumers. As a result, there will be a balance between demand (legitimacy) and supply: satisfied demand with a fully resourced supply [11-16].

Taking advantage of the condition:

$$M(x) = T_{cp} = 0.606 T_0 \quad (23)$$

we have an opportunity to find the maximum tariff T_0 , which can be offered and will be demanded by enterprises:

$$T_0 = \frac{M(x)}{0,606} \approx 1.65 M(x) \quad (24)$$

It becomes obvious that the statistically represented periods for which the curves in Figures 2 and 3 are drawn should be the same [17-22].

To construct a certain exponential scale of tariffs, apart from that, it is necessary to know the constant demand, which we will find as follows: we will determine the incomes of enterprises with a continuous nature of production (consumption of electricity) for the output of finished products for a certain statistical period:

$$I = \int_{X_{\min}}^{X_{\max}} X\omega(x)dx \approx \int_0^{X_{\max}} x\omega(x)dx \quad (25)$$

We equate them to the value received by the expression (18) through the maximum tariff T_0 :

$$I = T_0\tau \approx 1.65 M_x\tau \quad (26)$$

where we're looking for a constant demand:

$$\tau = \frac{I}{1.65 M_x} \quad (27)$$

The replacement of an exponential continuous tariff scale with another, a more convenient step-by-step scale should be decided on the basis of the economic tolerances for such replacement and requires further study. In the process of changing the results of the demand monitoring in the future, the values of maximum tariffs may be changed (if the identified regularities are preserved), while ensuring the legitimacy of the scale, which will ensure the economic continuation of the output of final products at steel-making production.

4 Conclusions

1. It is theoretically substantiated that the use of an exponential tariff scale makes it possible to ideally solve the problem of optimizing steel production.
2. It was established that one should only strive for it since, in reality, only a discrete scale with approximate possible sections is feasible.
3. It has been established that by focusing on a detailed consideration of joint ventures, it is always possible to improve it in such a way that the joint capital productivity will be increased.
4. The principles of combining the main and auxiliary production for the production of final products have been developed, which ensured the receipt of maximum income and profits.
5. A mathematical apparatus for nonlinear programming using Lagrange multipliers have been developed, which allows, through market manipulation of resources, to obtain minimal costs in the production process.
6. It is shown that for enterprises with a continuous nature of production, in particular steel mills, obviously, a set of tariffs will be required that will be fully (without deductions) demanded by all-electric consumers of the site. The most economically advantageous for these manufacturing enterprises will be such a type of tariff curve as a function of demand - $T = f(c)$, which will ensure uniform elastic demand in the entire range of tariffs.

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