Technical science and innovation

Volume 2019 | Issue 4 Article 2

12-12-2019

# DEVELOPMENT OF CORRELATION AND REGRESSION MODELS OF ELECTRIC ENERGY INDICATORS OF THE EQUIPMENT WITH CONTINUOUS NATURE OF PRODUCTION

I.U. Rakhmonov
*Tashkent State Technical University*

N.N. Niyozov
*Tashkent State Technical University*

К. Ли
*Chungnam National University*

UDK 621.365

# DEVELOPMENT OF CORRELATION AND REGRESSION MODELS OF ELECTRIC ENERGY INDICATORS OF THE EQUIPMENT WITH CONTINUOUS NATURE OF PRODUCTION

**I.U. Rakhmonov**[1], **N.N.Niyozov**[1] , **К.Ли**[2]
[1]*Tashkent State Technical University.*
[3]*Chungnam National University.*

**Abstract**

*The article presents an analysis of the use of correlation-regression analysis, which is based on the methods of mathematical statistics and probability theory in the study of the power consumption of enterprises with equipment of continuous production. On the basis of the annual power consumption schedule of the electric steel-smelting shop in a monthly time section, mathematical models have been developed for the power consumption parameters. And also, on the basis of statistical data with the use of a mathematical method, mathematical expressions were obtained for the electric power consumption and the specific consumption for the main equipment of the electric steel-smelting shop. In order to assess the adequacy of the developed mathematical models, mathematical models of the total and specific consumption of their power consumption are compared with actual data. The comparison results show high reliability of the power consumption modes of the main equipment of the facility in question. The analysis of the values of forecast errors with low error rates determines the adequacy of the developed mathematical models of the parameters of power consumption in terms of power consumption and specific consumption for the main equipment of the electric steel-smelting shop. In this regard, they can be used to determine the predicted values of the parameters of power consumption in electric steelmaking equipment.*

**Key words:** *specific consumption, electricity consumption, correlation analysis, statistical data, power consumption..*

Correlation analysis is one of the widely used methods of statistical analysis in determining the correlation between two or more random factors. The indicated method is used for initial observation data that are random and selected from the general population distributed according to the multidimensional normal law. The purpose of correlation analysis is to provide information about one variable using another variable. In cases of achieving the goal, the variables are correlated [1-4].

For a particular metallurgical production, which in our case JSC "Uzmetkombinat", the most appropriate way to study the modes of power consumption is to use the correlation-regression analysis, the analysis of which is based on the methods of mathematical statistics (MS) and the theory of probabilities [5,6].

Statistical analysis of power consumption includes the following five main steps [7-9]:

1. Research planning, in particular, the method of obtaining samples and the number of observations of indicators of energy consumption parameters.
2. Concretization, which is the formulation of a mathematical-statistical description, as well as the creation of a research model.
3. Evaluation of power consumption parameters that make up the model and the derivation of sample distributions.
4. Analysis of the correspondence between the model and the observations.
5. A real solution to the problem through parameter estimates and significance criteria.

The method of correlation and regression analysis has become convenient for revealing the nature of relations between variables and constant parameters of technological processes of smelting. The correlation dependencies method allows to simplify the determination of the total and specific electricity consumption taking into account the installed capacity of the equipment and construction of correlation dependencies [10].

As studies have shown the formation of the electrobalance of the considered industries, the most acceptable and more fully reflecting the real relationship of the parameters is the calculation and statistical research method [11-13]. It is known that the specific energy consumption d is determined by the ratio of consumed electricity W to the amount of output P.

In similar cases to the above cases, a linear dependence uniquely determines the observed process of the relationship of one variable from another. With numerous experimental data, using the least squares method (least squares) you can get the desired equation [14].

The regression line is denoted as a function Y, defined by the variable argument X, has the form

$$\beta_0+\beta_1 X \quad (1)$$

Then the linear model can be represented as follows:

$$Y=\beta_0+\beta_1 X+\varepsilon \quad (2)$$

so that for a given X the corresponding value of Y consists of β0 + β1X plus the addition of ε, taking into account which any individual function Y gets the opportunity not to be on the regression line. In equation (2), the quantities β0, β1, and ε are unknown, and the quantity ε will in fact be difficult to investigate, since it changes upon observation. But β0 and β1 remain constant and we will find them only after studying the possible combinations of Y and X using the information contained in n observations [15].

To obtain β0 and β1, the equation is represented as:

$$\overline{Y}_i = \beta_0 + \beta_1 X_i \ , \quad (3)$$

where Yi is the predicted value of Y for a given Xi. i = 1, 2,. . . , n.

The values β0 and β1 are determined for all ratios Y and Xi that are included in equation (3), which can be used as a predictive equation; setting the value of Xi into it allows us to predict the “systemic” average value of Yi for a given Xi. Therefore, the standard error (deviation) from the “true” line is

$$S = \sum_{i=1}^{n} \varepsilon_i^2 = \sum_{i=1}^{n} (Y_i - \beta_0 - \beta_1 X_i)^2 , \quad (4)$$

In the theory of correlation, a special place is occupied by linear regression or the linear form of the relationship between random variables [62, 65]. With this form of connection) (xY is a linear function of X, i.e.

$$\overline{Y}(x) = \beta_0 + \beta_1 X , \quad (5)$$

where β0 and β1 are the regression coefficients;

X is an independent random variable.

Linear regression is determined by the two-dimensional normal distribution of the argument and function (X, Y). The regression coefficients are determined by the least-squares method [16].

The values of the norms of specific energy consumption (ERE) for each brand of products are determined by the most probable values, differentiated norms using the above method as follows.

The value of electricity consumption for the period in question is determined as follows:

$$W = \sum d_i \varPi_i , \quad (6)$$

where di - URE per unit of output products of the i-th brand;

Пi– productivity by the i-th type of products for the period under review.

If such equations are compiled from monthly data for several years, taking into account that there was no change in technology and equipment replacement, then the most probable values are determined from the condition of the standard deviation deviation

$$\sum_{i}^{n}(W_{действ}-\sum_{i}^{n}d_i П_i)^2=\sum_{i}^{n}R^2, \qquad (7)$$

reaching the smallest value.

Differentiating this expression with respect to unknowns di and equating the derivative to zero, we arrive at a system of linear equations called the system of normal Gauss equations:

$$d_1\sum П^{i}{}_{1}П^{i}{}_{n}+d_2\sum П^{i}{}_{2}П^{i}{}_{n}+...+d_n\sum П^{i}{}_{n}П^{i}{}_{n}+П_n\sum W_n П^{i}{}_{n} \qquad (8)$$

The solution of system (7-8) by the linear algebra method makes it possible to determine the values of unknown di-SEM for each type of manufactured products and steel grade, provided that the actual energy consumption is minimized from the calculated values.

Using formula (8), we pass from the correlation equation of the first order to equations of higher orders. In such calculations, the criterion of the correlation equation was εh1 to determine the calculation order at higher orders, determined by the expression [17]:

$$\varepsilon_{h1}=\varepsilon_{h-1}-\frac{D_{h1}^{(h)^2}}{D^{(h-1)}D^{(h-1)}} \qquad (9)$$

The main error is defined as follows:

$$\sigma_{\varepsilon_{h1}}=\sqrt{\frac{\varepsilon_{h1}}{n}} \qquad (10)$$

$$\varepsilon_i=\sum_{j=1}^{k}P_{\frac{(j)}{0}}^{1}*(r^{2}{}_{\frac{(j)}{0}})-(r^2{}_{\frac{i}{1}}) \qquad (11)$$

If the value of the criterion εh1 turns out to be sufficiently small compared to its main error σεh1, then we can stop on the hi-order correlation equation [18-19].

The use of correlation and regression models based on the study of the power consumption modes of existing equipment allows us to obtain the necessary calculation formulas that take into account the influence of the main technological and energy factors for analysis and forecast estimates [10].

Consider the mathematical models of the parameters of the power consumption of the main equipment of the electric furnace shop (ESPC).

As initial information for constructing energy characteristics for each equipment and assessing the dependence of the specific consumption of electrical energy for 300 protocol melts conducted in a DSP-100 furnace.

In fig. Figure 1 shows the monthly power consumption schedule of ESPC in a monthly time section, which is a linear functional dependence with stable coefficients and one variable reflecting the general trend of uniformity of power consumption as a whole.

Model of monthly electricity consumption of the enterprise for 2017-2018 described by the following expression:

$$W(t) = -0{,}082x + 51{,}25 \qquad (12)$$

Models of monthly power consumption of the enterprise in annual terms:

$$W(t)=-0{,}816x+55{,}22; \qquad (13)$$

$$W(t) =-0{,}152\,x +51{,}51 \qquad (14)$$

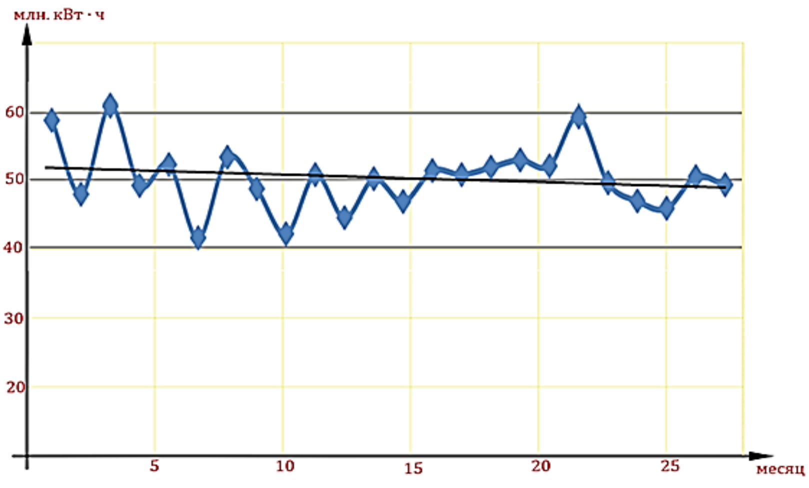
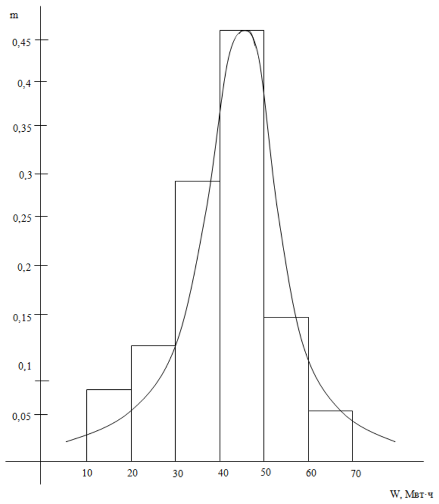



**Fig. 1.** Schedule of monthly power consumption ESPTS overall for 2017-2018

The stability of the coefficient under the variable is that the power consumption for the months of 2017 and 2018. almost do not change, which is characteristic of the level of production of Uzmetkombinat JSC.

The change in the coefficient in 2018 is associated with the gradual increase in the enterprise's production capacities. The trends associated with the seasonal component were not identified.




As a result of the analysis of the workshop performance indicators, it was established that the absolute (W) and specific (d) power consumption of the workshop are subject to the law of normal distribution. The hypothesis of the normality of the distribution of the above values was tested using the values of the measure of inertness and the measure of coolness of the histograms constructed from actual data. In fig. 2, histograms and the theoretical distribution curve of the energy consumption in the DSP-100 furnace are shown as an example.

**Fig. 2.** A histogram of the normal distribution of energy consumption in steelmaking

According to the calculation results and according to Fig. 2 it is seen that the obtained values of the measure of inertness and measure of coolness of a given distribution are within the limits of their twofold basic errors. This means that this distribution can be considered normal.

The number of necessary measurements with a confidence probability of P0 = 0.95 for the development of mathematical models W = f (P) and d = f (P) is determined by the formula:

$$N = \frac{t^2 \cdot \sigma^2}{a^2}, \qquad (15)$$

where t is the student coefficient; σ is the mean square error; and - the set error.

To assess the effect of the power consumption values of each ESPC equipment on the total

plant-wide power consumption, we will construct the corresponding dependencies for each object, expressed by a linear dependence using the mathematical method and in order to obtain the equation for electric power consumption and specific consumption.
Based on statistical data using the mathematical method, equations are obtained for the energy consumption and specific consumption of DSP-100.

$$W_{ДСП} = 0{,}335 \cdot П_{ДСП} + 1844 \tag{16}$$

$$e_{ДСП} = 0{,}335 + \frac{1844}{П_{ДСП}} \tag{17}$$

Based on statistical data using the mathematical method, equations are obtained for the energy consumption and specific consumption of the integrated steel processing unit (AKOS) [11-14].

$$W_{АКОС} = 0{,}019 \cdot П_{АКОС} + 619 \tag{18}$$

$$e_{АКОС} = 0{,}019 + \frac{619}{П_{АКОС}} \tag{19}$$

On the basis of statistical data using the mathematical method, equations are obtained for the energy consumption and specific consumption of the continuous casting section (UNRS) [11-14].

$$W_{УНРС} = 0{,}019 \cdot П_{УНРС} + 371{,}45 \tag{20}$$

$$e_{УНРС} = 0{,}019 + \frac{371{,}45}{П_{УНРС}}, \tag{21}$$

On the basis of statistical data using the mathematical method, equations were obtained for the energy consumption and specific consumption of lime calcining section (IOU) [11-14].

$$W_{ИОУ} = 0{,}0208 \cdot П_{ИОУ} + 55{,}457, \tag{22}$$

$$e_{ИОУ} = 0{,}0208 + \frac{55{,}457}{П_{ИОУ}}, \tag{23}$$

Using (22), the calculated power consumption data of the IOU are determined [20].

In order to assess the adequacy of mathematical models, we simulated the process of total and specific consumption of electric power and compared them with actual data. The results characterize the high reliability of the power consumption modes of the main equipment of the ESPC (DSP-100, AKOS, UNRS, IOU). The degree of adequacy of the developed models is justified by low absolute and relative errors between the actual and calculated data. We consider in detail the forecast error on total power consumption for ESPC equipment: for DSP-100, the maximum deviation of the forecast is within 4.8%, for AKOS - 6.8%, for UNRS - 6%, for IOU - 5%), and also specific electricity consumption for DSP-100 - 1.7%, for AKOS - 7.2%, for UNRS - 7%, for IOU - 7%. An analysis of the values of forecast errors shows that a low percentage of error determines the adequacy of the developed mathematical models of power consumption parameters. In this regard, they can be used in determining the forecast values of the parameters of power consumption at the enterprises of ferrous metallurgy, in particular in electric steel production.

**Reference**

1. Zarubin V.S. Matematicheskoe modelirovanie v texnike. / Pod red. B.C. Zarubina, A.P. Krishenko. - 2-e izd., stereotip. - M.: Izd-vo MGTU im. N.E. Baumana, 2003. - 496 s.
2. Minashkin V.G., Shmoylova R.A. i dr. Teoriya statistiki. Uchebno-metodicheskiy kompleks.: YeAOI, 2008, — 296 s.
3. Kalinina V.N., Pankin V.F. «Matematicheskaya statistika», uchebnoe posobie, 2002. - 340 s.
4. Svetozarov V.V. Osnovi statisticheskoy obrabotki rezul'tatov izmereniy. Uchebnoeposobie. – M.:Izd. MIFI, 2005. - 40 s.
5. Allaev K.R. Elektroenergetika Uzbekistana i mira. T.: Fan vatexnologiya, 2009. - 463 s
6. Kononov Yu.D. Puti povisheniya obosnovannosti dolgosrochnix prognozov razvitiya TEK – Novosibirsk: Nauka, 2015. – 147 s.
7. Bokun I.A., Temichev A.M.; «Prognozirovanie i planirovanie ekonomiki», MN., 2002 g. 282 s.
8. Gorodjiy A.V., Zotova S.A., Matveeva T.A., Svetlichnaya V.B. Primenenie teorii korrelyasii na praktike // Mejdunarodniy studencheskiy nauchniy vestnik. 2015. № 3-4.
9. Smit G., Dreyper N. Prikladnoy regressionniy analiz. Tret'e izdanie – M.: Vil'yams, 2016. - 912 s.
10. Kudrin B.I. Elektropotreblenie v elektrometallurgii // Elektrika, 2003. №9. S.35-45
11. Rakhmonov I.U. Regulation of energy consumption in the iron and steel mills // Scientific journal «European Science review». Austria, Vienna, 2018. №5-6 May-June. PP. 327-329.
12. Rakhmonov I.U., Niyozov N.N. Analysis of existing methods of electric consumption // Scientific journal «European Science review». Austria, Vienna, 2018. №9-10 September-October. PP. 209-211.
13. Rakhmonov I.U. Existing Methods and Approaches to Forecasting Electric Consumption at Industrial Enterprises // International Journal of Advanced Research in Science, Engineering and Technology. India, 2019. – Vol. 6, Issue 2, February, 2019. ISSN: 2350-0328. PP. 8183-8185.
14. Xoshimov F.A., Raxmonov I.U. Metodika opredeleniya optimal'nix predelov parametrov elektropotrebleniya oborudovaniya predpriyatiy chernoy metallurgii // Nauchno-texnicheskiy jurnal FerPI. Fergana, 2019. Tom 23 - №3. S. 147-150.
15. Hoshimov F.A., Rasulov A.N., Taslimov A.D., Rakhmonov I.U. The current state of electrometallurgy in Uzbekistan: Monograph, "East West" Association Studies and Higher Education GmbH.– Vienna, Austria, 2017. – 84 p.
16.Xoshimov F.A., Raxmonov I.U. Razrabotka metodov snijeniya energozatratov v elektrostaleplavil'nix pechax chernoy metallurgii Uzbekistana: Monografiya, Moya stroka - Rossiya, Sankt-Peterburg, 2017. – 116 s.
17.Hoshimov F.A., Rahmonov I.U. Rationing of electricity production in the rolling of ferrous metallurgy // Scientific journal «European Science review». Austria, Vienna, 2014. - №11-12 November-December. PP. 56-59.
18. Raxmonov I.U., Niyozov N.N. Analiz proizvoditel'nosti kompressornix stansiy na promishlennix predpriyatiy i usovershenstvovanie ix rascheta. Jurnal «Vestnik TashGTU». Tashkent, 2018. - №4. S. 72-76.
19.Rakhmonov I.U., Niyozov N.N. Modeling power consumption modes in industrial facility. International Conference "Bridge to science: research works". San Francisco, California, USA. April 15, 2019. – 37-40 pp.
20. Raxmonov I.U., Rasulov A.N. Analiz vibora stupeney moshnosti pechnogo transformatora dlya dugovoy pechi DSP-100 // «Promishlennaya energetika». Rossiya, Moskva, 2017. - №6 Iyun'. – S. 16-17.