UDC 62-83-52.003

# DETERMINATION OF ENGINE PUMP EQUIPMENT STATE USING TAXONOMETRIC METHOD

**Oboronov T.Yu., Fedorus H.O., Poriadina D.S.**
National Technical University of Ukraine
«Igor Sikorsky Kyiv Polytechnic Institute»

The article discusses the issues of determining the main factors affecting the operation of powerful engines. The issue of statistically multifactor data processing is also considered to determine specific indicators of the state of the engines.

**Keywords:** engine, pump installation, indicators of electric power quality, normalization, energy condition, technical condition.

**Formulation of the problem.** The work of pumping plants in the conditions of supply of low-quality electric power leads to lowering of engine power indices and performance of the plant. So, with deviations of electricity quality indicators that exceed the standardized values, the normal operation of the engine, or can only be achieved if there is a significant reduction in the load, or even impossible at all. Reducing the power and technical state of the pump installation occurs even when the electricity quality indicators change within acceptable tolerance standards.

Two options are offered for solution of the problem, namely, the use of modern methods of regulating the quality of electricity through the use of the latest power electronic components or work with a reduced efficiency and the need for more frequent repairs and replacement of equipment.

**Analysis of recent research and publications.** The power and technical state of powerful (more than 100 kW) engines of pumping plants depends on a variety of factors, as evidenced by the experience of the operation of industrial plants [1]. The greatest influence on the power and technical state of the electric drive of the pump plants results in: the quality of manufacturing of the parts of the plants, active and structural materials of the engines; their maintenance and repair; power supply quality; load mode; operating conditions; compliance with application implementation.

**Selection of previously unsettled parts of the general problem.** On the basis of research into the factors of influence on the power and technical state of engines of pump systems with synchronous motors to determine which of them cause the greatest negative impact on the electric drive and their operating modes. Deviation of the parameters causes the deterioration of the energy and technical condition and reduces the resource of the electrical complex. On the basis of definite factors, a taxonomic evaluation of the engines.

**The purpose of the article.** The main purpose of this work is to accomplish taxonomic evaluation of the energy and technical state of the pumping unit engines and the factors that influence them most.

**Presenting main material.** The accuracy and adequacy of the assessment of the impact factors on synchronous pump systems on production depends on the completeness of the consideration of all important indicators that have an impact on this efficiency and reflect the full picture of the diagnosis during operation of the equipment in the production. Therefore, the definition of a sufficiently complete set of output indicators is a fundamentally important and responsible step for further analysis of the energy and technical state of pumping plants.

According to DSTU EN 50006: 2016 it is recommended to use Ishikawa and Pareto diagrams for analyzing energy consumption of electrical engineering complexes, and the volume of the group of experts is recommended from 15 to 25 people (specialists of the energy department of enterprises and scientists in this field). During the analysis of the indicators, experts who were competent in this field, namely, employees, energy, mechanics, deputy directors on technical issues at enterprises of Ukraine who were trained and taught in the field of energy saving, were involved. According to the results of expert evaluation, they determined a set of indicators that are most in line with the task – the determination of the factors influencing the power and technical state of the electric drive of pump systems with synchronous engines.

The consistency of experts' evaluations based on the coefficient of concordation offered by Kendall on the importance of each of the indicators for the task of assessing the current state of the quality of the operation of pumping plants, the analysis of factors influencing the energy and technical state of the electrical complex is given by the formula:

$$W = \frac{12 \cdot D}{m^2\left(k^3 - k\right)}, \tag{1}$$

Where

$$D = \sum_{i=1}^{n}\left\{\sum_{j=1}^{m} x_{ij} - \frac{1}{2}\cdot m\left(k+1\right)\right\}^2$$

sum of squares of differences (deviations);

$t$ – number of experts; $n$ – number of indicators.

Having analyzed the set of selected indicators in the paper [4] it was concluded that the greatest influence on the power and technical state of the piston engines causesdeviation of the supply voltage; load mode; the operation conditions; quality of maintenance and repair; non-sinusoidal voltage supply; quality of active and constructive engine materials; voltage asymmetry.

The basis of the taxonometric method is the choice of the standard and the comparison of the optimal parameters of its vector with the corre-

ТЕХНІЧНІ НАУКИ

sponding parameters of the vectors of all other objects of research (determination of the Euclidean distances, according to which the object is ranked: the smallest distance corresponds to the highest point of the object). The principal difference between this method and the other used to evaluate the status of an object is to provide all statistical data by selected criteria (indicators) in the form of a matrix, where a single line is a vector of a particular object whose coordinates are the values of the criteria (indicators).

The method involves several steps [3; 5]. The main of them is the stage of valuation of the indicators under consideration, due to the fact that they may have different nature and incomparable value between themselves. Indicators, in turn, make up the matrix *P* (*i*-th vector-column of the elements of the matrix *P* is the list of values of the homogeneous *i*-th indicator (the number of indices *n*) for each of the *b* – objects, and the *s*-th vector row of elements – list of heterogeneous values of indicators for *s*-th object ($i=\overline{1,n};\ \ s=\overline{1,b}$). At this stage, normalization occurs according to the following formulas:

$$P'_{s,i}=\frac{p_{s,i}-\overline{p_i}}{\sigma_i},$$

$$\overline{p_i}=\frac{1}{b}\sum_{s=1}^{b}p_{s,i},$$

$$\sigma_i=\sqrt{\frac{1}{b}\sum_{s=1}^{b}p_{s,i}-\overline{p_i}^{\,2}}$$

where $P'_{s,i}$ – the matrix normalized values indicators (*s* 1, *b* ; *i* 1, *n*); $p_{s,i}$ – elements matrix P; $\sigma_i$ – average value *i*-th indicator for all over aggregate the objects;   – average quadratic deviation *i*-th index.

Another important step is to form a «reference» object [2, 6]. For the formation of a «reference» object, with which all the others will be compared, the optimal values of normalized *and* – h indicators for all objects are determined. Accordingly, the maximum values for the resultant sign are chosen [6]. The selected optimal values form a matrix string:

$$Pet_i=\left[\max p_{s,1}\ \max p_{s,2}\ldots\max p_{s,n}\right],$$

where $\max p_{s,1}$ – setting the maximum value *i-th* normalized index for productive the sign.

The next step in the method is to map the values *i*-x values of all the objects under study with their «reference» values. At this stage, the distances are calculated   between *s*-m object and reference, using the following expression:

$$D_s=\sqrt{\sum_{s=1}^{b}p'_{s,i}-p'et_i^{\,2}}$$

Based on the distances defined at this stage   it is already possible to draw a conclusion on which object is the best, that is, to perform the rating of the objects under study. As noted above, we use the matrix:

$$P=\begin{bmatrix}P_{11} & \cdots & P_{1i} & \cdots & P_{1n}\\ \cdots & \cdots & \cdots & \cdots & \cdots\\ P_{s1} & \cdots & P_{si} & \cdots & P_{sn}\\ \cdots & \cdots & \cdots & \cdots & \cdots\\ P_{b1} & \cdots & P_{bi} & \cdots & P_{bn}\end{bmatrix}$$

For the matrix *P the* influence of the quality of the supply voltage on the power and technical state of the piston engines (9) *i*-th vector-column of the elements – a list of values of the homogeneous *i*-th indicator (number of indices *n*) for each of the *b* – installations, and *s*-th element vector row – a list of varied values indicators for the *s* – thinstallation ($i=\overline{1,n};\ s=\overline{1,b}$).

In order to compare the numerical values of indicators among themselves, it is necessary to bring them dimensionless. This is proposed to be done by standardizing the values of indicators [3]. For the numerical value, which will be compared with each indicator, it is convenient to take the norm of the vector – column (the norm of each criterion) for the engines under study:

$$P_i^{norm}=\sqrt{\sum_{s=1}^{b}p_{si}^2},$$

where $p_{s,i}$ – numerical value of the *i*-th indicator ($i=\overline{1,n}$) on the *s*-th installation ($s=\overline{1,b}$);

*n* – the number of indicators being considered;
*b* – the number of plants under investigation.

Thus, the normalized values of the criteria given in the unit are determined by the expression:

$$P'_{s,i}=\frac{p_{s,i}}{P_i^{norm}}$$

where $P'_{s,i}$ – matrix of normalized values of indicators ($i=\overline{1,n};\ s=\overline{1,b}$)

For the formation of a «reference» indicator of the influence of the quality of supply voltage on the NU with SD, which will be compared to all the others, the optimal values of normalized *and* -h indicators for all installations are determined. The maximal values, depending on the influence on the NU, are selected accordingly. The selected optimal values form a matrix string:

$$Pet_i^e=\left[\max p'^e_{s1}\ldots\max p'^e_{si}\ldots\max p'^e_{sn}\right],$$

$\max p'^e_{si}$ – determination of the maximum normalized taking into account the value of the *i*-th factor from the influence on the NU ($s=\overline{1,b};\ i=\overline{1,n}$)

As a result, the ratio for determining the distances between the *s*-m real state and the «reference», on the basis of which the impact on the energy and technical state of the NU from SD is determined, will have the following form:

$$D_s^e=\sqrt{\sum_{s=1}^{b}p'_{s,i}-p'et_i^{e2}}.$$

The influence of the voltage quality is determined on the basis of the above expression – the distance value $D^e_s$ the smaller the negative effect is caused by the indicators of supply voltage on the NU from SD and above its residual resource. The results of the calculations of the influence of the quality of the supply voltage on the total energy of SD NU 1D1250-125 are given on the dendrogram of rice 1.

The combined taxonomic indices of the influence of the quality of the supply voltage on the energy Indexes synchronous engines pump them installations are given in tabl. 1

With the dendrograms, it is evident that there are 2 classes of engine operation, that is, the normal and transient mode of operation. Indicators 14 and 19 correspond to the emergency mode of the engine with a voltage drop of 13%.

**Conclusions and suggestions.** According to Table 1, we can conclude that the greatest negative impact on the energy performance of the ND 1D1250-125 causes precisely the deviation of the quality of the supply voltage. It is also proposed to identify factors that adversely affect the pumping stations through the use of Ishikawa and Pareto diagramsinvolving experts, enabling the identification of key informational factors, such as the quality of supply voltage, load conditions and operating conditions. This method can be used online, and immediately affect the cause of engine malfunction.

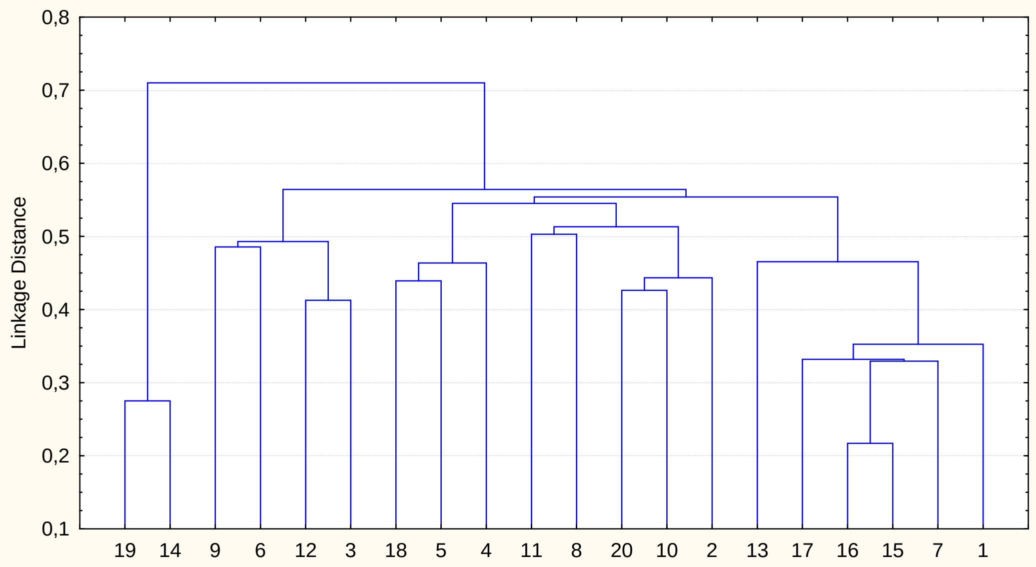


**Fig. 1. Dendrogram of the total influence of the quality indicators of the supply voltage on the total energy of SD NU 1Д1250-125**

Table 1

**Taxonomic Indicator of Impact of Quality of Supply Voltage on Energy Indicators of Pump Station Engines**

| Taxonomic Indicator | SD NU SDV 7200/29 (1000 kW) | SD NU SM 250 (250 kW) | NU 1D1250-125 (630 kW) |
|---|---|---|---|
| Coefficient of performance | 0,357 | 0.561 | 0.781 |
| Full energy | 0.421 | 0.612 | 0.705 |
| Active energy | 0.394 | 0.524 | 0.652 |
| Reactive energy | 0.182 | 0.195 | 0.283 |
| Complete energy loss | 0.467 | 0.689 | 0.846 |

## References:

1. Ромашихин Ю.В. Алгоритмы системы определения параметров двигателей переменного тока / Ю.В. Ромашихин, Д.И. Родькин // Вісник КДПУ. Зб. наук, праць КДПУ им. М. Остроградского. Кременчук: КДПУ им. М. Остроградского, 2010. – Вип. 4(63), ч. 2. – С. 130-134.
2. Калинов А.П. Анализ методов идентификации электромагнитных параметров синхронных двигателей / А.П. Калинов // Зб. наук, праць КНТУ. Техніка в сільськогосподарському виробництві галузеве машинобудування, автоматизація. – Кіровоград, 2004. – Вип. 15. – С. 110-119.
3. Zhezhelenko I.V. Electromagnetic compatibility in electric power supply systems: textbook for institutions of higer education: translation from Ukrainian by S.I. Kostritska and L.O. Tokar / I.V. Zhezhelenko, A.K. Shidlovskiy, G.G. Pivnyak, Yu.L. Sayenko; editorship of the English version and terminology by Professor O.B. Ivanov. – 2nd edition. – D.: National Mining University, 2013. – 239 p.
4. Печеник М.В. Визначення сукупності факторів впливу на енергоефективність насосних установок з синхронними двигунами на цукрових заводах / М.В. Печеник Т.Ю. Оборонов, А.М. Терезюк // Матеріали XXV Міжнародної науково-практичної конференції «Проблеми та перспективи розвитку науки на початку третього тисячоліття у країнах Європи та Азії». Збірник наукових праць. – м. Переяслав-Хмельницький: ДВНЗ «ПХДПУ ім. Григорія Сковороди» – 2016. – С. 256-261.
5. Фокин Ю.А. Вероятностно-статистические методы в расчетах систем электронабжения / Ю.А. Фокин. – М.: Энергоатомиздат, 1985. – 240 с.
6. Белоконов И.В. Статистический анализ динамических систем: Учебное пособие / И.В. Белоконов. – Самара: Самар. гос. аэрокосм. ун-т, 2001. – 256 с.

**Оборонов Т.Ю., Федорусь Г.О., Порядіна Д.С.**
Національний технічний університет України
«Київський політехнічний інститут імені Ігоря Сікорського»

# ВИЗНАЧЕННЯ СТАНУ РОБОТИ ДВИГУНІВ НАСОСНИХ УСТАНОВОК З ВИКОРИСТАННЯМ ТАКСОНОМЕТРИЧНОГО МЕТОДУ

**Анотація**
В статті розглядаються питання визначення основних факторів впливу на роботу потужних двигунів. Також розглядається питання статистичної багатофакторної обробки даних для визначення конкретних показників впливу на стан двигунів.
**Ключові слова:** двигун, насосна установка, показники якості електроенергії, нормування, енергетичний стан, технічний стан.

**Оборонов Т.Ю., Федорусь А.О., Порядина Д.С.**
Национальный технический университет Украины
«Киевский политехнический институт имени Игоря Сикорского»

# ОПРЕДЕЛЕНИЕ СОСТОЯНИЯ РАБОТЫ ДВИГАТЕЛЕЙ НАСОСНЫХ УСТАНОВОК С ИСПОЛЬЗОВАНИЕМ ТАКСОНОМЕТРИЧЕСКОГО МЕТОДА

**Аннотация**
В статье рассматриваются вопросы определения основных факторов влияния на работу мощных двигателей. Также рассматривается вопрос статистической многофакторной обработки данных для определения конкретных показателей влияния на состояние двигателей.
**Ключевые слова:** двигатель, насосная установка, показатели качества электроэнергии, нормирование, энергетическое состояние, техническое состояние.