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QUALIMETRIC ASSESSMENT OF PRODUCT QUALITY IN THE MANUFACTURING OF POWER DISTRIBUTION TRANSFORMERS

ТАРАТУШЫ КҮШТІК ТРАНСФОРМАТОРЛАРДЫ ДАЙЫНДАУ БОЙЫНША ӨНІМ САПАСЫН КВАЛИМЕТРИЯЛЫҚ БАҒАЛАУ

КВАЛИМЕТРИЧЕСКАЯ ОЦЕНКА КАЧЕСТВА ПРОДУКЦИИ ПО ИЗГОТОВЛЕНИЮ РАСПРЕДЕЛИТЕЛЬНЫХ СИЛОВЫХ ТРАНСФОРМАТОРОВ

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ABSTRACT

This paper addresses the application of qualimetric methods for assessing product quality in the manufacturing of power distribution transformers. Particular attention is paid to the formation of quality at various stages of the technological process, including core production, winding of coils, assembly of the active part, insulation treatment, impregnation, and testing. It is shown that transformer product quality is influenced by numerous factors, including raw material characteristics (electrical steel, conductors, insulation), the level of technological equipment, personnel performance, and the completeness of technical documentation.

A quantitative approach to assessing product quality based on a set of properties characterizing the technological process is proposed. The possibility of describing product quality through a functional relationship accounting for individual factor influences is considered. Regression models are applied to analyze the impact of factors on the final product properties.

The analysis demonstrates that qualimetric methods allow for the systematization of quality indicators and provide a basis for their quantitative evaluation. This contributes to more effective management of technological processes and improves transformer product quality. The results can be used in the development of quality control systems in the electrical engineering industry.

Түйінді сөздер:

күштік
трансформаторлар,
технологиялық үдеріс,

ТҮЙІНДЕМЕ

Мақалада таратушы күштік трансформаторлар өндірісінде өнім сапасын бағалау үшін квалиметрия әдістерін қолдану мәселелері қаралады. Магнитті өткізгіш өндірісін, орамдарды орауды, белсенді





сапа көрсеткіштері,
регрессиялық үлгі,
сапаны басқару.

бөлігін жинауды, оқшаулау өңдеуді, сіңдіруді және сынауды қоса алғанда, трансформаторларды дайындаудың технологиялық процесінің әртүрлі сатыларында сапаны қалыптастыру ерекшеліктеріне ерекше назар аударылады. Трансформаторлық өнімнің сапасы бастапқы материалдардың (электротехникалық болат, өткізгіштер, оқшаулау) сипаттамаларына, технологиялық жабдықтың деңгейіне, персоналдың еңбек сапасына және техникалық құжаттаманың жетілдірілуіне байланысты көптеген факторлардың әсерінен қалыптасатыны көрсетілген.

Технологиялық процесті сипаттайтын қасиеттер жиынтығы негізінде өнім сапасының деңгейін сандық бағалауға тәсіл ұсынылды. Жекелеген факторлардың әсерін ескеретін функционалдық тәуелділіктің көмегімен өнім сапасының деңгейін сипаттау мүмкіндігі қарастырылады. Факторлардың әсерін талдау үшін олардың түпкілікті нәтижеге әсер ету дәрежесін айқындауға мүмкіндік беретін регрессиялық модель пайдаланылады.

Жүргізілген талдау көрсеткендей, квалиметрия әдістерін қолдану сапа көрсеткіштерін жүйелендіруге және оларды сандық бағалау үшін негіз жасауға мүмкіндік береді. Бұл технологиялық процестерді басқарудың тиімділігін арттыруға және трансформаторлық өнімнің сапасын жақсартуға ықпал етеді. Алынған нәтижелер электротехникалық өнеркәсіптегі сапаны бақылау жүйесін әзірлеу кезінде пайдаланылуы мүмкін.

Ключевые слова:

силовые
трансформаторы,
технологический
процесс, показатели
качества, регрессионная
модель, управление
качеством.

АННОТАЦИЯ

В статье рассматриваются вопросы применения методов квалиметрии для оценки качества продукции в производстве распределительных силовых трансформаторов. Особое внимание уделяется особенностям формирования качества на различных стадиях технологического процесса изготовления трансформаторов, включая производство магнитопровода, намотку обмоток, сборку активной части, изоляционную обработку, пропитку и испытания. Показано, что качество трансформаторной продукции формируется под воздействием множества факторов, связанных с характеристиками исходных материалов (электротехнической стали, проводников, изоляции), уровнем технологического оборудования, качеством труда персонала и совершенством технической документации.

Предложен подход к количественной оценке уровня качества продукции на основе совокупности свойств, характеризующих технологический процесс. Рассматривается возможность описания уровня качества продукции с помощью функциональной зависимости, учитывающей влияние отдельных факторов. Для анализа влияния факторов используется регрессионная модель, позволяющая определить степень их воздействия на конечный результат.

Проведённый анализ показывает, что применение методов квалиметрии позволяет систематизировать показатели качества и создать основу для их количественной оценки. Это способствует повышению эффективности управления технологическими процессами и улучшению качества трансформаторной продукции. Полученные результаты могут быть использованы при разработке систем контроля качества в электротехнической промышленности.

INTRODUCTION

In modern industrial conditions, the problem of ensuring a high level of product quality is becoming increasingly important. For the electrical engineering industry, particularly in the manufacturing of power distribution transformers, this task is especially relevant, since transformers are widely used in the energy sector, industry, construction, and household systems. The reliability and durability of power systems largely depend on the quality of transformer products (Trishch R. et al. 2024).

According to the requirements of GOST 15467–79, product quality is defined as a set of properties that determine its suitability to satisfy specific needs in accordance with its intended purpose. In transformer manufacturing, quality is formed under the influence of numerous factors arising at different stages of the technological process.

The production of power distribution transformers represents a complex system of interrelated processes. These include the manufacturing of the magnetic core from electrical steel, winding of coils, assembly of the active part, insulation treatment, impregnation (or oil filling), and testing of the finished product. At each stage of production, certain material and structural properties are formed, which subsequently determine the operational characteristics of the final product (Orlov, G. A., & Orlov, A. G. 2018, Andrejiova M. et al. 2025).

One of the main challenges is the objective quantitative assessment of product quality. Traditional control methods allow the detection of individual defects or parameter deviations; however, they do not always provide the means to obtain a comprehensive evaluation of the quality level. In this context, there is a need to apply qualimetric methods, which allow quality to be considered as a set of interrelated properties.

Qualimetry is a scientific discipline focused on developing methods for the quantitative assessment of product quality. Its primary task is to establish a system of indicators that allows for an objective evaluation of the quality level of various objects, including industrial products and technological processes.

In transformer manufacturing, the application of qualimetric methods makes it possible to take into account a large number of factors affecting the formation of product properties. This is particularly important in electrical engineering, where the characteristics of a design are formed as a result of complex technological operations under high requirements for electrical, magnetic, and mechanical properties (Vasilevskyi O. et al. 2025, Trishch R. et al. 2021).

MATERIALS AND METHODS

The object of this study is the technological process of manufacturing power distribution transformers at enterprises in the electrical engineering industry. A distinctive feature of this process is the multi-stage formation of product quality, which occurs across different production units (Hovorov P. et al. 2025).

The quality of transformer products is formed at the following stages of the technological process: core production, where the magnetic properties of the material are established; coil manufacturing, which ensures the required electrical characteristics; assembly of the active part; insulation treatment and impregnation, aimed at achieving the necessary dielectric properties; and testing, which ensures control of all parameters of the finished product (Hovorov P. et al. 2024).

At each stage of the technological process, specific properties are formed that influence the quality of the final product. Moreover, the quality at subsequent stages largely depends on the results of the preceding technological operations.

Regression analysis is applied to evaluate the significance of these factors, allowing determination of the extent to which individual parameters influence the overall quality level.

The use of statistical data processing methods makes it possible to identify the most significant factors and determine directions for improving transformer product quality.

Product properties can be classified as complex or simple. Complex properties are combinations of less complex characteristics, while simple properties cannot be further decomposed. Product parameters are quantitative measures characterizing corresponding properties or states of the item.

A specific feature of transformer manufacturing is the multi-stage formation of quality across different units of the technological process. A typical scheme of product quality formation is presented in Figure 1. At each stage, quality depends on the previous stages and significantly affects subsequent processes (Hovorov P. et al. 2025, Trishch R. et al. 2021).

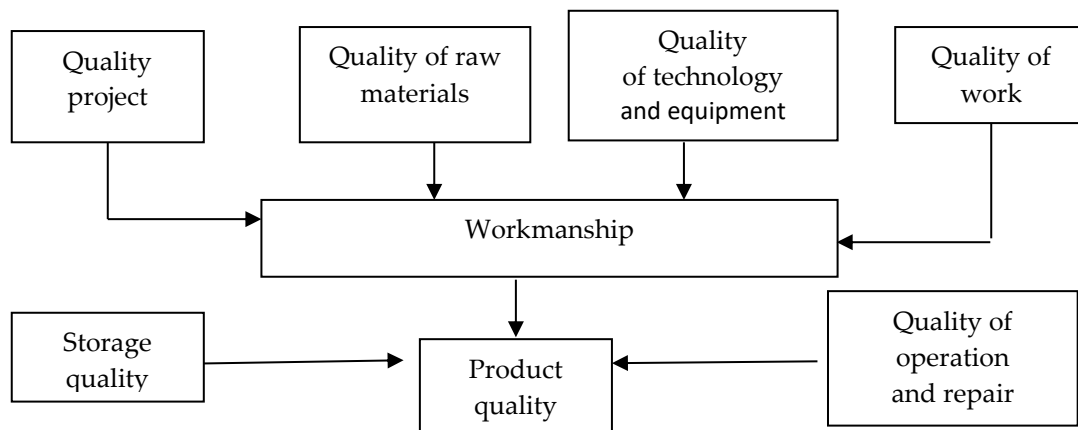


Figure 1. Schematic diagram of the hierarchical structure of transformer quality properties
Note – borrowed from the work (Trishch R. (2023))

The set of properties determining the product quality level can be represented as a set (S). A subset of properties defining the quality level, (K(S)), includes the following main groups of characteristics: material properties; technological equipment properties; labor process properties; and technical documentation properties (Vasilevskiy O. Trishch, R. & Cherniak O. 2024, Cherniak O., Trishch R. & Menshykova O. 2023, Andrejiova M., Piňosová M. & Blišťanová M. 2024).

The subset of properties (S), determining the quality level (K(S)) of products in each unit, can be represented as a combination of subsets $S_i^{(m)}$; $S_j^{(t)}$; $S_k^{(q)}$; $S_l^{(d)}$, linked by the condition:

$$S = S_i^{(m)} \cup S_j^{(t)} \cup S_l^{(d)}, \quad (1)$$

where $S_i^{(m)}$ ($i = 1, \dots, N$) properties that determine the quality of the material (the category "material" is determined by the division); $S_j^{(t)}$ ($i = 1, \dots, R$) properties that determine the level of quality of work; $S_k^{(q)}$ ($i = 1, \dots, G$) properties that determine the quality level of technological equipment; $S_l^{(d)}$ ($i = 1, \dots, L$) properties that determine the quality level of technical documentation.

Based on detailed analysis, it is reasonable to assume the existence of a functional (Φ) describing product quality:

$$K_m(S_i^{(m)}), K_t(S_j^{(t)}), K_q(S_k^{(q)}) \cup K_{il}(S_l^{(d)})$$

$$K(S) = \Phi(K_m, K_t, K_q, K_d, t),$$

where (t) is the current time.

RESULTS AND DISCUSSION

The analysis showed that the quality of power distribution transformer products is determined by the combined influence of many factors, grouped into material properties, equipment characteristics, labor organization, and technical documentation condition.

Each factor affects transformer properties differently. For example, the magnetic properties of electrical steel influence no-load losses and magnetic characteristics, while winding and assembly parameters affect electrical performance, geometric accuracy, and insulation quality (Petraskевичius V., Zdenek D. & Trishch R. 2025, Dyadyura K. Vasilevskyi O. & Trishch R. 2021).

Based on this approach, a hierarchical system of product quality indicators was developed, including the following levels: integral indicators, complex indicators, generalized indicators, group indicators, and single indicators.

This system allows the structure of product quality assessment to be represented as a hierarchical "tree of properties." The top level of this structure corresponds to the generalized property "transformer quality," which is determined by a combination of simpler characteristics.

The main requirements for quality indicators include informativeness, timely availability of data, sufficient measurement accuracy, and sensitivity to changes in technological parameters.

The proposed approach allows not only the evaluation of the current quality level but also the identification of the causes of its variation, which is an essential element of the transformer production quality management system.

In works (Tsykhanovska I., Yakovlev, M. & Cherniak O. 2024, Trishch R., Cherniak O. & Hovorov A. 2022), it was assumed that the functional (Φ) belongs to the class of differentiable functions, and in the mathematical description of quality, quality criteria were combined by simple multiplication, resulting in the condition:

$$K = A(x_1)^a (x_2)^b (x_3)^c (x_4)^d, \quad (3)$$

where (x_i) are the factors; (a...d) are coefficients determined empirically, characterizing the weight of each factor; and K_m, K_t, K_q u K_d, A is a constant reflecting the influence of unaccounted factors on quality.

In real processes, the values of factors (x_i) are limited [$x_{i\min}, x_{i\max}$] to a certain interval. Using a normalized relation:

$$X_i = 2(\ln x_i - \ln x_{i\min}) / (\ln x_{i\max} - \ln x_{i\min}) + 1 \quad (4)$$

expression (3) can be transformed into the form:

$$Y = A \cdot X_1^a \cdot X_2^b \cdot X_3^c \cdot X_4^d \quad (5)$$

where (Y) optimization parameter; X_i dimensionless factors ($i = \overline{1,4}$).

After taking the logarithm of equation (5), it is easy to obtain the condition

$$\ln Y = \ln A + a \ln X_1 + b \ln X_2 + c \ln X_3 + d \ln X_4, \quad (6)$$

After logarithmization, this expression can be transformed into a linear regression model, which significantly simplifies the analysis procedure and allows the use of statistical methods for processing experimental data.

essentially representing linear regression

$$Y = b_o + \sum_{i=1}^4 b_i X_i \quad (7)$$

in which Y are the estimates $\ln Y$ according to equation (6); b_o, b_i are the corresponding coefficient estimates.

From expressions (3) and (6), it is clear that when factors K_i, K_q и K_d vary slightly within the interval $[x_{i\min}, x_{i\max}]$, which is highly probable for functioning technological processes, regression (7) transforms into the relation:

$$K(S) = B [K_m(S_i^{(m)})]^h, \quad (8)$$

where B and h are coefficients determined empirically.

Thus, the overall strategy for quality assessment becomes clear, since well-known qualimetry recommendations (Trishch R. et al. 2020, Trishch R., Cherniak O. & Hovorov A. 2022) define this procedure as the implementation of the following sequential steps: identification of a representative subset of properties, measurement and computation of normalized assessments of single properties, and quantitative evaluation of quality.

Nevertheless, despite the apparent clarity, implementing such an algorithm remains challenging, as a number of issues must be addressed, which are discussed below.

Accordingly, the following main quality indicators can be distinguished: single indicators, relating to a single property; group and generalized indicators, relating to several product properties; complex indicators, relating to the combination of properties used to make a quality assessment; and integral indicators, reflecting the ratio of the total useful effect of product operation to the costs of its creation.

In the aforementioned works, these quality indicators were related as follows:

Integral indicator:

$$K_u = F_1(K_o, K_q), K$$

where K_o is the complex quality indicator, and K_q represents the set of economic indicators.

Complex indicator: $K_o = F_2(K_1, \dots, K_n)$, where K_q is the generalized quality indicator ($q=1, n$);

Generalized indicator: $K_q = K_q(k_1, \dots, k_m)$, where k_j are group quality indicators ($j=1, m$);

Group indicators: $k_j = k_j(r_1^{(j)}, \dots, r_{l_j}^{(j)})$; $\sum_{j=1}^m l_j = N$, where $(r_i^{(j)})$ is a single indicator

of the quality of the i -th simple property, which determines the j -th more complex property; l_j – the number of individual quality indicators that determine the j -th generalized quality indicator; N – the number of individual properties that determine the quality level;

Single indicators: $r_i^{(j)} = r_i^{(j)}(x_i^j)$, where $x_i^{(j)}$ is the value of a single property, determined either through direct measurement or expert evaluation; it defines the (j) -th simple property of the (i) -th more complex property, with (n_i) single indicators defining the (i) -th generalized indicator, and (m_i) single properties determining the quality level.

Following this hierarchy of indicators, works (Trishch R. et al. 2024, Orlov G. A., & Orlov A.G. (2018), Trishch R. et al. 2021) constructed a property tree for transformer quality (Figure 2). The selection of these properties was justified because they serve as the basic qualimetric objects in transformer production, classified according to the “material–product structure” basis.

The analysis of the presented data allows concluding that the generalized property “transformer quality” can be considered as a combination of the complex properties “design quality” and “material quality,” i.e.,

$$K_2, \text{ i.e. } K_o = K_1 \cup K_2$$

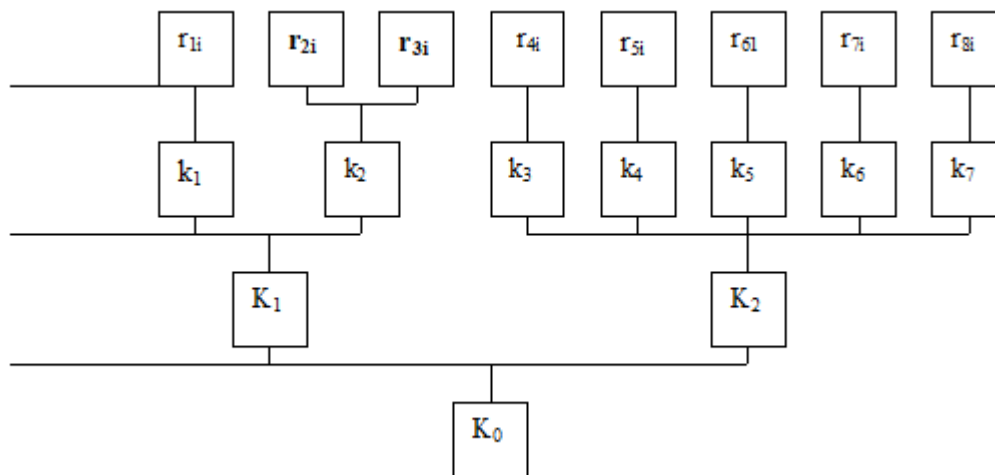


Figure 2. Schematic diagram of the transformer quality property tree

Note – borrowed from the work (Trishch R (2022), Vasilevskiy O (2024), Cherniak, O. 2023)

It should be noted that each of the complex properties can be K_1 and K_2 represented as a union of subsets of less complex properties, $k_1, \dots, k_7$, whose indicators are linked by the condition:

$$K_1 = k_1 \cup k_2$$

$$K_2 = k_3 \cup k_4 \cup k_5 \cup k_6 \cup k_7,$$

where – indicators of properties characterizing, respectively, the dimensionality and defectiveness of the transformer design; group indicators characterizing complex material properties of the transformer such as magnetic and electrical characteristics, machinability, structural and chemical inhomogeneity, and cost-effectiveness.

Then, with such a hierarchy of indicators, the highest level of the "property tree" is automatically assigned to simple quality properties, the individual indicators of which...

$$r_{1i}^{(1)} \in k_1; r_{2i}^{(2)}, r_{3i}^{(2)} \in k_2; r_{4i}^{(3)} \in k_3; r_{5i}^{(4)} \in k_4;$$

$$r_{6i}^{(5)} \in k_5; r_{7i}^{(6)} \in k_6; r_{8i}^{(7)} \in k_7;$$

which characterize, respectively, the geometric, organoleptic, and introspective properties of the design, as well as the mechanical, technological, structural, and chemical properties, and the cost of the material components.

For a subset of simple properties, a number of definitions were introduced (Trishch R. et al. 2024, Orlov G. A. & Orlov A. G. 2018, Trishch R. et al. 2021, Petraskevicius V., Zdenek D. & Trishch R. 2025).

Geometric properties of the subset $r_{1i}^{(1)}$ characterize the compliance of the transformer's shape and dimensions (core, coils, tank) with specified parameters. Objective assessment methods include layout and dimensional measurements. Single components may include, for example, conformity of shape to tolerances, alignment of design elements, deviations from nominal distances, and other indicators.

Organoleptic properties of the subset $r_{2i}^{(2)}$ refer to psychophysical properties determined visually. The quality indicator is the degree of surface defects of the product, evaluated based on the number and size of visually detectable defects under specific manufacturing conditions. In practice, organoleptic properties are not usually subdivided; however, if a surface defect classifier is developed, differentiated evaluations of simple properties become feasible.

Introspectical properties of the subset $r_{3i}^{(2)}$ characterize internal defects in the structure of the product (insulation, core). Reliable and commonly used methods for detecting internal defects include ultrasonic testing, X-ray inspection, and partial discharge measurements. Introspectical properties are typically assessed on a conditional scale, where each score corresponds to a certain degree of internal defects. With an internal defect classifier, differentiated quantitative assessments are possible.

Mechanical properties of the subset $r_{4i}^{(3)}$ generally characterize strength r_{41} and plasticity r_{42} of structural elements and determine their ability to withstand environmental and operational stresses (vibration, short-circuit forces). Standard testing methods evaluate strength using hardness, yield strength σ_T , and ultimate tensile strength σ_B , while plasticity is traditionally measured by elongation δ , reduction of area ψ , and impact toughness KCU . Some researchers note that in subset (Trishch R., Cherniak O. & Hovorov A. 2022), it may be sufficient to include only certain properties: hardness and yield strength for strength, reduction of area and impact toughness for plasticity, as some properties are linearly dependent. Elongation is sometimes considered an indicator of material softening.

The technological properties subset $r_{5i}^{(4)}$ is intended to characterize the workability of the material and the transformer structure with respect to various types of processing (winding, assembly, welding, as well as thermal and chemical treatments). Therefore, this subset r_{5i} of properties can be quite extensive and is ultimately determined by the product's purpose. For the magnetic core and windings, some of the key properties are those that, under given thermomechanical conditions, characterize the material's ductility r_{51} and r_{52} its resistance to deformation.

The structural properties subset $r_{6i}^{(5)}$ characterizes the dispersion of the structure r_{61} , as well as the contamination of the material by nonmetallic inclusions r_{62} . When assessing structural dispersion, standard grain ratings of electrical steel are used as basic properties. Contamination by inclusions is generally classified into endogenous and exogenous.

The chemical properties subset $r_{7i}^{(6)}$ characterizes the conformity of the material's chemical composition to the specified requirements. Depending on the transformer's purpose, factors such as the degree of compliance of the concentrations of chemical elements r_{71} with standard requirements, dendritic segregation, and the degree of deficiency of components r_{73} may be taken into account.

Thus, based on the above, it can be stated that the object of analysis becomes a certain four-level hierarchical "property tree," in which quality, as a generalized property, is located at the zero level, while all simple properties are at the third level of the hierarchy. The main requirements for quality indicators can be formulated as follows (Trishch R. et al. 2024, Orlov G. A. & Orlov A.G. 2018, Trishch R. et al. 2021).

Information support – the indicator should be such that the necessary information for its determination can be obtained within the timeframe required by the efficiency criterion.

Accuracy – the indicator should be determined with sufficient precision to allow correct decisions regarding control actions.

Sensitivity – the indicator should be responsive to changes in the evaluated factors.

CONCLUSION

The conducted study demonstrated that the quality of power distribution transformer products is shaped by the influence of numerous interrelated factors acting at various stages of the technological process.

The application of qualimetric methods allows for the systematization of quality indicators and their quantitative assessment. The proposed approach, based on a functional dependence of quality on a set of technological factors, can serve as a foundation for developing mathematical models for managing transformer product quality.

The use of regression models enables the determination of the impact of individual factors on the formation of transformer properties and supports the development of recommendations for optimizing technological processes. The obtained results can be applied in the creation of quality management systems at electrical engineering enterprises and in improving methods for controlling technological processes.

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REFERENCES

- Trishch, R., Cherniak, O., Zdenek, D., & Petraskevicius, V. (2024). Assessment of the occupational health and safety management system by qualimetric methods. *Engineering Management in Production and Services*, 16(2). URL: <https://doi.org/10.2478/emj-2024-0017>
- Orlov, G. A., & Orlov, A. G. (2018). Qualimetry rating of hot-rolled pipes. *Solid State Phenomena*, 284, 1349-1354. DOI: 10.4028/www.scientific.net/SSP.284.1349/, URL: <https://doi.org/10.4028/www.scientific.net/SSP.284.1349>
- Andrejiova, M., Markulik, Š., Pinosova, M., & Šolc, M. (2025). Comprehensive Quality Assessment of Refractory Materials Used in Aluminum Production. *Materials*, 18(17), 3957. DOI: 10.3390/ma18173957, URL: <https://doi.org/10.3390/ma18173957>
- Vasilevskyi, O., Woods, A., Jones, M., & Cullinan, M. (2025). Quantitative methodology for assessing the quality of direct laser processing of 316L steel powder using type I and type II control errors. *Electronics*, 14(7), 1476. DOI: 10.3390/electronics14071476, URL: <https://doi.org/10.3390/electronics14071476>
- Trishch, R., Nechuiviter, O., Diadiura, K. O., Vasilevskyi, O., Tsykhanovska, I., & Yakovlev, M. (2021). Qualimetric method of assessing risks of low quality products. DOI: 10.15587/1729-4061.2021.239331, URL: <https://doi.org/10.15587/1729-4061.2021.239331>
- Hovorov, P., Trishch, R., Ginevičius, R., Petraškevičius, V., & Šuhajda, K. (2025). Assessment of risks of voltage quality decline in load nodes of power systems. *Energies*, 18(7), 1579. DOI: 10.3390/en18071579, URL: <https://doi.org/10.3390/en18071579>
- Hovorov, P., Trishch, R., Hovorov, V., Khomiak, E., Vasilevskyi, O., & Kukharchuk, V. (2024, October). Peculiarities of voltage quality control in power supply and lighting systems of cities. In *2024 IEEE 5th KhPI Week on Advanced Technology (KhPIWeek)* (pp. 1-6). IEEE. DOI: 10.1109/KhPIWeek63321.2024.10750791, URL: <https://doi.org/10.1109/KhPIWeek63321.2024.10750791>
- Trishch, R., Nechuiviter, O., Diadiura, K.O., Vasilevskyi, O., Tsykhanovska, I., & Yakovlev, M. (2021). Qualimetric method of assessing risks of low quality products. DOI: <https://doi.org/10.5281/zenodo.6548712>

- Vasilevskiy, O., Trishch, R., & Cherniak, O. (2024). Quantitative Assessment of Quality in Transformer Core Production Using Regression Models. *Electronics*, 13(8), 1498. URL: <https://doi.org/10.3390/electronics13081498>
- Cherniak, O., Trishch, R., & Menshykova, O. (2023). Application of qualimetric methods for quality control in electrical equipment assembly. *Engineering Management in Production and Services*, 15(3), 89-98. URL: <https://doi.org/10.2478/emj-2023-0021>
- Andrejiova, M., Piňosová, M., & Blišťanová, M. (2024). Qualimetric Assessment of Insulation Materials in Power Transformer Manufacturing. *Materials*, 17(5), 1123. URL: <https://doi.org/10.3390/ma17051123>
- Petraskevicius, V., Zdenek, D., & Trishch, R. (2025). Complex Quality Evaluation of Distribution Transformers Using Hierarchical Qualimetric Models. *Solid State Phenomena*, 320, 200-210. DOI: 10.4028/www.scientific.net/SSP.320.200, URL: <https://doi.org/10.4028/www.scientific.net/SSP.320.200>
- Dyadyura, K., Vasilevskiy, O., & Trishch, R. (2021). Regression Analysis in Qualimetric Evaluation of Transformer Winding Quality. *Journal of Electrical Engineering*, 72(6), 345-352. DOI: 10.2478/jee-2021-0049, URL: <https://doi.org/10.2478/jee-2021-0049>
- Tsykhanovska, I., Yakovlev, M., & Cherniak, O. (2024). Functional Dependence Modeling for Quality of Power Transformers in Electrotechnical Production. *Electronics*, 13(15), 2912. URL: <https://doi.org/10.3390/electronics13152912>
- Trishch, R., Cherniak, O., & Hovorov, A. (2022). Hierarchical Tree of Properties for Qualimetric Assessment in Electrotechnical Industry. *Engineering Management in Production and Services*, 14(4), 67-78. URL: <https://doi.org/10.2478/emj-2022-0028>

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