International Journal of Advanced Research in Science, Engineering and Technology

ISSN: 2350-0328

Vol. 13, Issue 1, January 2026

Effect of Existing Conventional Repair Process of Substation Electrical Equipment on Operational Reability

Mavlonov Jonibek Ashurovich, Sayidov Muzaffar Karimtoshevich

Candidate of technical science, Navoi State Mining and Technology University, Navoi, Uzbekistan
Senior teacher, Navoi State Mining and Technology University, Navoi, Uzbekistan

ABSTRACT: The article analyzes the traditional schedule system for the operation and repair of electrical equipment at substations of mining and metallurgical enterprises. It is noted that changes in load, temperature, and the state of contact connections can cause repair stages to lag behind the real technical condition. The process of transmitting electrical energy to consumers through functional connections at the substation is considered as a single technological chain. It shows that in current preventive maintenance, decisions are made mainly based on calendar intervals, and periodic inspections do not fully reflect the real dynamics of defects and wear.

KEY WORDS: substation, electrical equipment, operation, repair, plan-schedule (preventive) system, technical condition, reliability, defects, wear, diagnostics, condition-based maintenance, mining and metallurgical industry, contact connections, load, temperature effect.

I. INTRODUCTION

Traditional approaches to repairing electrical equipment are often based on the rich experience and unique practical methods of craftsmen accumulated over the years.These approaches are aimed at ensuring the reliability of electrical equipment, extending its service life and increasing operational efficiency through proper maintenance. In the mining and metallurgical industry, the operation and repair of electrical equipment of substations is carried out mainly based on traditional approaches[1-2]. These processes are based on the general structure of the substation, the main electrical equipment and their interconnection, and the repair process is regulated by many years of practical experience and regulatory documents[3]. The structural connection diagram of the substation is shown in Figure 1. This diagram shows the main functional connections between the high-voltage side and the step-down side of the power transformer[4].

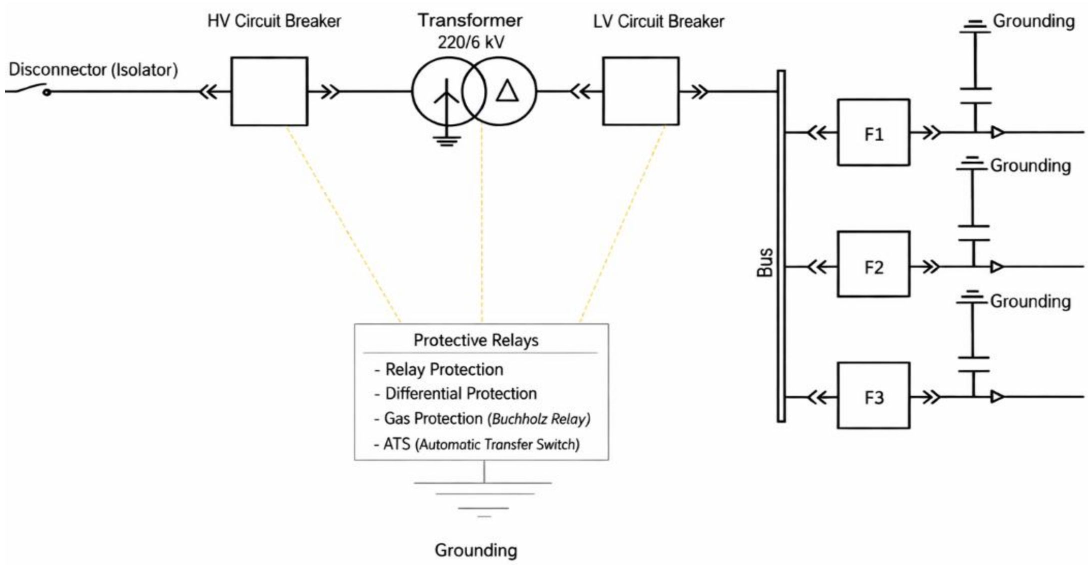

Figure 1. Structural connection scheme of the substation

International Journal of Advanced Research in Science, Engineering and Technology

ISSN: 2350-0328

IJARSET IMPACT FACTOR 7.150

Vol. 13, Issue 1, January 2026

The transformer includes the process of switching devices and the transmission of electrical energy to subsequent consumers through buses to the step-down part. The traditional repair process is focused on these elements as a single technological chain. Of course, their technical condition is assessed not from the point of view of a separate part, but from the point of view of the overall operational function. The process of repairing and maintaining the electrical equipment of the substation at the mining enterprise is carried out on the basis of a traditional plan - schedule[5].

II. RELATED WORK

The logical sequence of this process is detailed in Figure 2, which reflects the process from the commissioning of electrical equipment to the next scheduled repair measures. At the initial stage of the process, electrical equipment is put into operation and operated in the specified operating modes. During this period, the equipment operates under load, and its commissioning and daily operation are regulated by current technical standards. The next stage is scheduled inspections, which examine the external condition of electrical equipment. This includes checking the integrity of housings, insulators, fasteners, contact connections, and mechanical parts. Scheduled inspections are usually carried out without a complete shutdown of the equipment or with short-term interruptions, or with partial interruptions of the substation process[6-7].

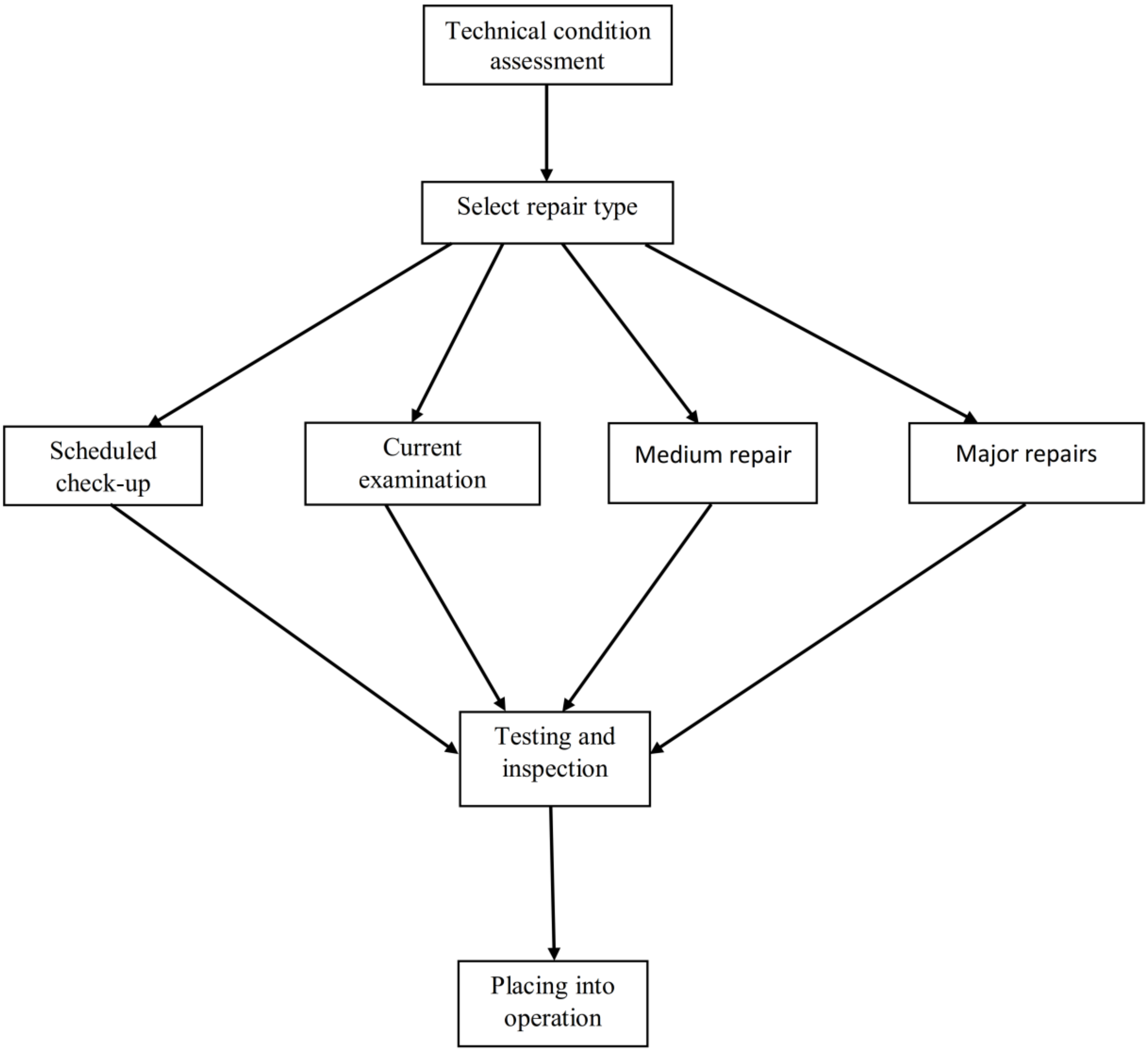

Figure 2. Functional scheme of the electrical equipment repair process

International Journal of Advanced Research in Science, Engineering and Technology

ISSN: 2350-0328

IJARSET IMPACT FACTOR 7.150

Vol. 13, Issue 1, January 2026

Thus, this process, carried out on the basis of a traditional plan - schedule, is aimed at maintaining the overall operability of the substation electrical equipment, which ensures the sequential and systematic implementation of operational and maintenance work [8]. However, the organization of a repair system based on such a schedule has a number of methodological and practical limitations. As we know, this process is based primarily on the results of periodic inspections and inspections of the technical condition of electrical equipment at specified intervals. This limits the possibility of fully reflecting the dynamic development of defects and wear processes occurring in electrical equipment [9].

The planned preventive approach is not always sufficient for the effective organization of the repair process due to external uncertain influences and limited possibilities of efficiency control. Therefore, it is necessary to deeply analyze and evaluate the current operational reliability of substation electrical equipment such as transformers, circuit breakers, power transmission lines, electrical devices in the main circuit of electrical installations, cable systems, electrical equipment intended for domestic needs, contact connections, current and voltage transformers, and measuring devices [10]. In the traditional maintenance cycle, we know that decision-making processes are mainly performed on calendar time intervals. However, in real operating conditions, defects and wear processes occurring in electrical equipment are not evenly distributed over time. Therefore, the risk of failure of electrical equipment does not remain at the same level over time, but changes dynamically [11].

III. SIGNIFICANCE OF THE SYSTEM

However, decision-making in this scheme is mainly based on calendar time, and the continuous and uneven changes in the technical condition of electrical equipment are not sufficiently taken into account. In real operation, the technical condition does not change at the same rate over time as a result of the wear process, load changes, temperature effects and deterioration of the contact condition. Therefore, the stages of repair provided in the functional scheme often lag behind the real technical condition (Table 1) [12].

Table 1

Changes in the technical condition of electrical equipment in the traditional repair cycle

No.	Operating period (years)	Repair phase	Technical condition / risk level	The content of the technical condition	Critical commentary
1	0 – 1	Operation (without maintenance)	Low	The unit is started, wear starts	Risk is not monitored
2	1	Technical inspection (TC)	Low → medium	Visual and external control only	Hidden defects are not detected
3	1 – 3	Operation	Medium	Load and environmental impact increases	The risk begins to accumulate
4	3	Current Maintenance (JT)	Medium → high	Minor faults are eliminated	Influence the effect, not the cause
5	3 – 6	Operation	Up	The aging process is accelerated	The repair cycle is behind
6	6	Next JT	Up	Partial restoration	The risk reduction is temporary
7	6 – 10	Operation	Up → dangerous	Insulation aging, contact heating	The risk of an accident increases
8	10	Medium maintenance (MT)	Dangerous	Deep technical intervention is necessary	Repairs are delayed.
9	10 – 16	Operation	Dangerous → critical	Resource depletion stage	Risk grows out of control
10	16	Overhaul (CT)*	Critic	The resource is almost exhausted	CT is a delayed measure
11	16 – 20	Operation	Medium	Partial recovery after repair	The cycle repeats itself

The table shows that in the traditional repair cycle, the technical condition continuously deteriorates, and repair measures are carried out mainly after reaching high or critical risk levels. This indicates that the repair process is not preventive, but reactive in nature [13]. Conditional wear index as a general indicator of the technical condition of electrical equipment$W(t)$is entered [14]. This index expresses the degree to which the electrical equipment's efficiency is lost and can be given as follows:

$$0 \le W(t) \le 1, \qquad W(t) = 0, \qquad \frac{W(t)}{dt} > 0 \tag{1}$$

Here$W(t) = 0$It means the state of an electrical device that is new or fully functional, and the state where its resource is almost exhausted [15]. The process of obsolescence is expressed as a simple, but physically valid value, as follows:$W(t) = 1$

$$W(t) = 1 - e^{-kt} \tag{2}$$

where k is the coefficient of wear rate depending on operating conditions, which includes factors such as load level, temperature effects, environmental conditions and quality of service. In traditional repair systems, this coefficient is usually taken as constant, which leads to the fact that the variability of wear rate in real operation is not taken into account.

IV. METHODOLOGY

One of the important indicators for assessing the reliability of electrical equipment is the intensity of the risk of failure$\lambda(t)$is considered It is defined according to classical reliability theory as follows:

$$\lambda(t) = \frac{f(t)}{1 - F(t)} \tag{3}$$

here$f(t)$ $-$density function of failure distribution, distribution function. This expression describes the degree of tendency of electrical equipment to fail at a certain time. In practice, especially for substation electrical equipment, it is desirable to use the intensity function based on the Weibull distribution due to its sensitivity to wear processes:$F(t) -$

$$\lambda(t) = \frac{\beta}{\eta} \cdot (\frac{t}{\eta})^{\beta - 1} \tag{4}$$

here β $-$The parameter of the nature of wear, the resource parameter. If it is, the risk of failure increases rapidly over time, which corresponds to the sharp increase in the allowance on the eve of medium and major repairs shown in the table.$\eta - \beta > 1$

The probability of an accident occurring during a certain period of time is expressed as follows:Δt

$$P_{av}(t, \Delta t) = 1 - \exp\,(-\int_{t}^{t+\Delta t} \lambda(\tau) d) \tag{5}$$

V. EXPERIMENTAL RESULTS AND DISCUSSION

This expression shows that the probability of an accident is cumulative over time. In the traditional maintenance cycle, decisions are made only based on the current situation in most cases, and the future operating periodP_{av}increase in value is not taken into account. Therefore, expressions (1 – 5) constitute the theoretical basis of the cases presented in the table and quantitatively confirm that the dynamic change of the technical condition and the accident accumulation are not sufficiently taken into account in the traditional repair system [16].

International Journal of Advanced Research in Science, Engineering and Technology

ISSN: 2350-0328

Vol. 13, Issue 1, January 2026

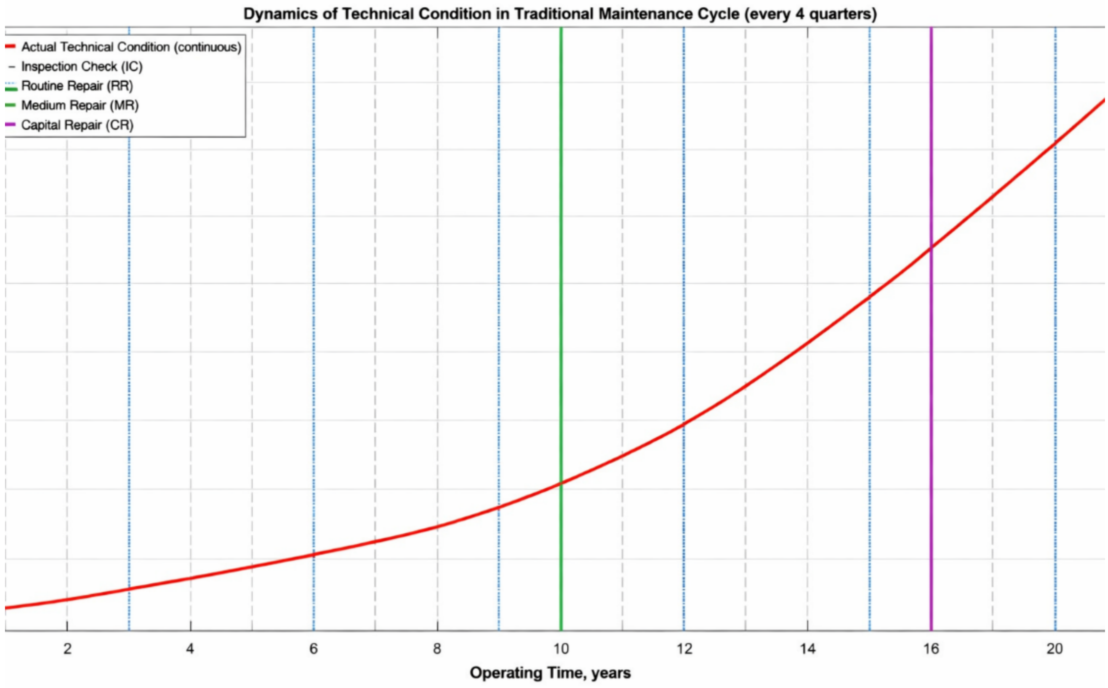

Figure 3. Dynamics of technical condition in the traditional repair cycle

1.4. – The curve shown in the figure reflects the integral effect of the conditional wear index W(t) and the associated risk of failure. According to expressions (1) and (2), the wear index W(t) has a graph-increasing character over time. Therefore, the line representing the technical condition in the graph grows continuously and does not change sharply at the points of calendar repairs. This indicates that in the traditional repair system, the wear process does not correspond to the repair times. The types of repairs in the graph are indicated by points determined by calendar time: technical inspections (TI) - annual control measures, current repairs (RM) - service work repeated at a certain interval, intermediate repairs (MR) - deep intervention in the middle stage of the resource, major repairs (MR) - restoration measures close to the end of the resource. The analysis of the graph shows that, despite the frequent repetition of technical inspection (TI) points, the tendency of the technical condition curve to grow remains almost unchanged. This means that in practice, technical inspections perform a more "detective" function, but their impact on risk reduction is limited.

V. CONCLUSION AND FUTURE WORK

The overall increase in risk does not stop at current maintenance (RM) points either, that is, these measures are often limited to local and short-term impact. It is observed that medium and capital repair points coincide with the time when the technical condition is high or has entered the critical zone. This reveals a fundamental flaw in the traditional plan-schedule system. Therefore, the functional scheme of the traditional repair approach does not sufficiently take into account dynamic changes in the technical condition of electrical equipment. Inspection and repair measures organized on a calendar basis can be a delayed reaction to the real risk accumulation, which can lead to an increase in the probability of an accident and a decrease in operational reliability.

REFERENCES

1. Jumayev, Z.I., Karshibayev, A.I., Sayidov, M.K., & Shirinov, S.G. *Analysis of climate-meteorological and technological factors affecting electricity consumption of mining enterprises.* Vibroengineering Procedia, Vol. 54, pp. 293-299 (Apr. 4 2024). https://doi.org/10.21595/vp.2024.24047
2. Galyautdinova, A. R. *Intelligent system for online monitoring and control of the technical condition of oil-filled power transformers of 35/6(10) kV distribution networks*. PhD diss., Kazan State Power Engineering University, Kazan, 2024, 171 p. URL: https://www.dissercat.com/content/intellektualnaya-sistema-onlain-monitoringa-i-kontrolya-tekhnicheskogo-sostoyaniya-silovykh

3. Yang, M., Wei, L., Qiu, P., Hu, G., Liu, X. и др. "Research on Fault Diagnosis of High-Voltage Circuit Breakers Using Gramian-Angular-Field-Based Dual-Channel Convolutional Neural Network." *Energies*, vol. 18, no. 14, 2025, article 3837. https://doi.org/10.3390/en18143837
4. Mavlonov J.A., Sayidov M.K. Assessment of the Reliability of Power Supply for Mining Enterprises Taking into Account Changes in the Technical Condition of Transformers. Zenodo (DOI orqali). https://doi.org/10.5281/zenodo.15743063
5. Mavlonov J.A. IMPROVEMENT OF METHODS OF ENSURING ENERGY EFFICIENCY OF ENERGY-INTENSIVE EQUIPMENT IN THE MINING AND METALLURGICAL INDUSTRY (PDF). American Journal of Technology and Applied Sciences, Vol. 41 (2025). https://americanjournal.org/index.php/ajtas/article/download/3110/2961/3240
6. N Ataullayev, A Norqulov, B Muxammadov, A Majidov, I Togayev. Principles of protection against single phase earth faults in networks with capacitive current compensation. E3S Web of Conferences 548, 06008. https://doi.org/10.1051/e3sconf/202454806008
7. IB Tog'Ayev, AA Tursunova, MA Eshmirzayev. Problems and scientific solutions 4 (3), 285-287. Center of science and enlightenment. Problems and scientific solutions, 2022.
8. I Togaev, A Tovbaev, G Nodirov. Systematic analysis of reactive power compensation in electric networks is essential for improving electricity quality enhancing system stability, and reducing operational costs. AIP Conference Proceedings 3331 (1), 030099. https://doi.org/10.1063/5.0305740
9. S Abdullaev, Z Eshmurodov, I Togaev. A systematic analysis of the gradual increase in quality indicators of electricity using reactive power sources involves several steps. AIP Conference Proceedings 3331 (1), 040051. https://doi.org/10.1063/5.0306786
10. SF Amirov, AO Ataullaev, MK Sayidov, IB Togayev - Journal of Physics: Conference Series, 2021. Methods of reduction of interference signals in electromagnetic conductors that measure fluid flow. DOI 10.1088/1742-6596/2094/5/052053
11. A Tovbaev, I Togaev, U Usarov, G Nodirov. Reactive power compensation helps maintain a stable voltage profile across the network. AIP Conference Proceedings 3331 (1), 060014. https://doi.org/10.1063/5.0307209
12. AA Tovboyev, IB Tog'Ayev. YUQORI KUCHLANISHLI HAVO LINIYALARIDA TOJLANISHNING PAYDO BO 'LISH MEXANIZMI VA UNING SAMARALI BOSHQARISH USULLARI. Journal of Advances in Engineering Technology, 41-49.
13. A Tovboyev, I Tog'Ayev. KONVEYER TRANSPORT TIZIMLARINING ISHONCHLILIGI VA SAMARADORLIGIGA ELEKTR ENERGIYASI SIFATINING TA'SIRINI BAHOLASH. Journal of Advances in Engineering Technology, 45-51.
14. A Tovboyev, I Tog'Ayev, S Norbayev. ELEKTR TA'MINOTI TIZIMIDA FILTR KOMPENSATSIYA QURILMALARI YORDAMIDA ELEKTR ENERGIYASI SIFAT KO 'RSATKICHLARINI OSHIRISHNING TIZIMLI TAHLILI. Journal of Advances in Engineering Technology, 25-32.
15. AN Tovboyev, IB Tog'Ayev. Elektr energiyasi sifat ko 'rsatkichlarini oshirishda reaktiv quvvat manbalarini tadqiq qilish. Journal of Advances in Engineering Technology, 59-62.
16. TA Nurmonovich, O Tog'Ayev Islom Bekpo'Lat. HAVO ELEKTR UZATISH LINIYALARINI BAHOLASHDA MONITORING O'TKAZISH. Journal of Advances in Engineering Technology, 34-38.

AUTHOR'S BIOGRAPHY

Full name	**Mavlonov Jonibek Ashurovich**
Science degree	Candidate of technical science
Academic rank	Senior Research Fellow
Institution	Navoi State Mining and Technology University, Navoi, Uzbekistan

Full name	**Sayidov Muzaffar Karimtoshevich**
Science degree	Senior teacher
Academic rank	Independent researcher
Institution	Navoi State Mining and Technology University, Navoi, Uzbekistan