https://doi.org/10.53656/igc-2025.26

MODERNIZATION OPPORTUNITIES IN ELECTRICAL EQUIPMENT MANUFACTURING ENTERPRISES

Nikolay Karev
University of Chemical Technology and Metallurgy, Sofia, Bulgaria
Angelina Terzieva
University of Chemical Technology and Metallurgy, Sofia, Bulgaria

Abstract. The article, based on a feasibility study, identifies the possibilities for modernization of the production process in the preparatory workshops of enterprises for the production of electrical equipment - power transformers. Based on an analysis of the production process in the specified workshops, the condition of the main equipment has been assessed and the "bottleneck" in the overall organization of the workshop has been identified. The possibilities for modernization are presented and the benefits for the enterprises of implementing modernization have been indicated.

Keywords: modernization; production; electrical equipment

JEL: D25, L23

Introduction

The topic of modernization in production processes is increasingly relevant in the context of contemporary industrial conditions, characterized by a high degree of automation, digitalization, global competition, and growing demands for energy efficiency and resource sustainability (Shterev, 2018, p. 15). Given these conditions, enterprises are compelled to seek innovative solutions to improve production efficiency, reduce costs, and enhance product quality (Bakardzieva, 2003, p. 116).

The production process in an industrial enterprise represents a purposeful and sequential activity aimed at transforming resources – raw materials, materials, semi-finished products, energy, labor, and information – into finished products with defined consumer value. This process underpins the existence of every manufacturing enterprise and reflects its primary function: creating material goods through technical, technological, and organizational means (Andreeva & Stefanov, 2020, p. 28).

At the core of the production process in the enterprise is the technological process, which is an organized sequence of actions and operations carried out at specific workplaces or production areas, directly influencing the physical, chemical,

or functional properties of the work objects. These actions modify their shape, dimensions, structure, state of aggregation, surface qualities, or other characteristics relevant to the final product (Valeva, 2021, p. 87).

The close interrelationship between the technological process and other functional activities requires a systems management approach, in which every unit of the production chain contributes to achieving the overall enterprise goals – high quality, low costs, minimal losses, and flexibility in response to market demand (Dimitrova, 2018, p. 412). The production process should not be viewed merely as a mechanical collection of actions but as a dynamic system with integral logic, whose improvement demands strategic thinking, operational discipline, and the capacity for innovation at every management level (Panayotova et al., 2023, p. 81).

It is important to note that the technological process is strictly governed by predefined technological maps, norms, and standards, ensuring the desired quality, cost-effectiveness, and repeatability of results. In addition to core operations, auxiliary and support processes significantly influence production efficiency and reliability. These include receiving, storing, and distributing materials and components; internal transport and logistics; workplace preparation and maintenance; technical service and equipment repair; quality control of intermediate and final products; energy and information supply; as well as sanitary, hygiene, and safety measures. Although these processes do not directly affect the work objects, they are functionally and organizationally inseparable from the technological core and play a key role in the rhythm, safety, and efficiency of production (Angelova & Kuzmov, 2024, p. 120).

According to classical economic theory and modern management concepts, the production process comprises three main stages:

– Preparatory stage – securing necessary resources, planning the production schedule, technological preparation, and logistical organization;

– Main stage – the actual transformation of materials through technological operations (mechanical, electrical, chemical, etc.);

– Final stage – quality control, packaging, storage, and shipment of finished products.

The production process in an industrial enterprise is connected to eco-innovations. It must be not only functionally sound and technologically justified but also maximally efficient in order to ensure sustainability and competitiveness in the modern market environment. The efficiency of production is measured through a set of quantitative and qualitative criteria that reflect the degree of resource utilization, the cost-effectiveness of operations, and the value of the final outcome (Nikolova-Alexieva et al., 2025).

Meeting the quantitative and qualitative criteria cannot be achieved through isolated efforts; it requires strategic coordination between departments in production management, as well as investments in innovation (Blagoev, 2018, p. 88). Staff

training, continuous monitoring of production indicators, the implementation of industrial information systems (such as ERP), and the use of intelligent technologies (IoT, AI, automation, and robotics) also contribute to meeting the specified criteria (Biolcheva & Sterev, 2024, p. 10). Only in this way can the industrial enterprise transform the production process into a source of value, sustainable development, and long-term market advantag (Gospodinova, 2021, p. 49).

The production process is the core of any industrial enterprise. Its rational organization, management, and continuous improvement are crucial for achieving sustainable competitive advantage, economic stability, and strategic development in the long term.

Analysis of the Production Process in the Preparatory Workshop of Electrical Equipment Enterprises

The production process for electrical equipment, as with other products, begins with material receipt and incoming inspection, which typically takes about 20 minutes per batch. This includes checking the delivered primary and auxiliary materials, such as electrical steel sheets, conductors, insulation materials, and other components. Inspection involves visual checks, dimensional measurements, electrical resistance tests of insulation materials, and verification against accompanying technical documentation. After material acceptance, cutting and mechanical processing are carried out in the enterprise's preparatory workshop.

This workshop is the first physical point in the production flow, crucial for supplying semi-finished products, parts, and components that form the main structure of the electrical equipment. In it, materials that have passed incoming control are prepared for inclusion in the main assembly. Activities include:

– Cutting and shearing electrical steel sheets;

– Cutting and shaping copper and aluminum conductors;

– Forming insulation elements;

– Producing spacers, seals, and other auxiliary components needed for assembling the active part.

The cutting of steel sheets is critical because the magnetic core of electrical equipment is constructed from thin sheets of electrical steel, which must be cut with high precision to ensure minimal magnetic losses and mechanical stability. Enterprises use specialized hydraulic guillotines and CNC-controlled automated machines, enabling precise cutting according to the geometric specifications of the electrical equipment. The average time to cut a steel sheet stack varies from 10 to 20 minutes, depending on complexity and number of cuts.

The next operation concerns the preparation of the conductive materials. Copper and aluminum wires are cut to specified lengths and processed through insulation, bending, and winding using semi-automatic winding machines. The conductor preparation is crucial for producing primary and secondary windings of electro-

technical apparatus. Errors in length, cross-section, or insulation can lead to malfunctions or energy losses.

Insulating parts are produced in-house using pressed cardboard, insulating paper, epoxy compounds, and heat-resistant tapes. Some components are made using custom templates, while more complex modules require thermopresses and dies. Production time per piece ranges from 5 to 15 minutes.

Analysis of the preparatory workshop shows a mix of new and old machines, some over 20 years in service. While some have been refurbished with component replacements or electronic controls, much of the machinery remains partially worn, affecting productivity, quality, and repeatability.

The main equipment includes hydraulic guillotines, mechanical shears, and manual cutting stations, which create operational delays and bottlenecks for larger series. Some machines lack CNC control, hindering automated adjustments and precise repeated operations.

During the assessment of production capacities in the preparatory workshops of enterprises manufacturing electro technical equipment, it has been established that the hydraulic guillotine represents a "bottleneck" in the overall organization of the workshop. It has a significant impact on the duration of the production cycle, energy efficiency, the quality of the manufactured components, and occupational safety.

The commonly used SPG-3250 hydraulic guillotine (manufactured in 1985) has the following parameters:

– Cutting length: up to 2500 mm;
– Cutting thickness: up to 4 mm;
– Working pressure: 16 MPa;
– Control: mechanical, without digital positioning.

Analysis shows reduced cutting accuracy, looseness in the back gauge mechanism, hydraulic leaks, and frequent motor overheating. Lack of digital control requires manual setup for each part, increasing preparation time by over 25%.

Opportunities for Modernization through New Machines

Based on the analysis, real opportunities exist for technological modernization and organizational restructuring to improve productivity, reduce internal losses, and enhance quality. A key solution is the implementation of new machines that meet modern requirements for speed, precision, automation, and digital compatibility.

For the preparation workshop, the following technological solutions are proposed: Current state of the section: The analysis showed that at present, the cutting of sheet metal and insulation elements is carried out using mechanical shears and semi-automatic guillotines, where:

– Each size adjustment requires manual setup;
– Precision depends on the operator's skills;

– Material losses due to deviations beyond the permissible tolerances are significant;
– Cutting time for a medium-complexity set can exceed 20 minutes.

The proposed modernization solution is the purchase and implementation of a CNC-controlled laser machine with automatic adjustment, designed for cutting electrical steel sheets, non-ferrous metals, and insulation composites. The techno-economic study shows that suitable models on the market include, for example, the TRUMPF TruLaser 2030 fiber or the Bystronic BySmart Fiber, which offer high speed, fine cutting, and the possibility of integration with ERP systems.

The suggested model is Bystronic BySmart Fiber 3015 – 4 kW. The technical characteristics of the model are:

– Laser cutting center with fiber-optic source, 4 kW laser power;
– Max sheet size: 3000 x 1500 mm;
– Max cutting thickness: stainless steel 20 mm, carbon steel 25 mm, aluminum 15 mm, copper/brass 10 mm;
– Positioning repeatability: ±0.01 mm;
– Cutting speed: up to 35 m/min;
– Automatic sheet loading/unloading;
– CAD/CAM and ERP system integration;
– Power consumption: ~15 – 18 kW/h;
– Setup time for batch change3: < 3min (automatic).

Expected improvements from the introduction of the specified model into production are:

1. Cutting time reduction:

– Current time for cutting one set of sheet metal parts (based on analysis data): ~20 minutes.
– Estimated time with Bystronic BySmart Fiber: ~13 – 14 minutes.

● A reduction of about 30 – 35% for an average transformer model.

2. Accuracy and defect reduction:

– Current defect rate from size discrepancies: ~3 – 5% of parts
– With the new machine: <1%

● Over 70% reduction in cutting waste, especially with insulation and thin metal materials.

3. Reduction of setup times:

– Current times for manual setup: ~10 – 15 min.
– With the new machine: <3 min (automatic recognition by program)

● Up to 80% reduction in losses when changing the model.

4. Accuracy and ability to work with an electronic map:

Moving from manual sketches and programs to direct loading from CAD/CAM, which eliminates human errors in arranging parts (nesting).

5. Flow and integration with ERP/MES:

Automatic marking of parts, enabling logical traceability and linkage with production orders.

● Improved internal logistics, traceability, and execution control.

Advantages of Bystronic BySmart Fiber are summarized in the table 1.

Table 1. Advantages of introduction Bystronic BySmart Fiber 315 – 4 kW

Indicator	Before implementation	After implementation
Average cutting time (min)	20	13 – 14
Average sets cut/day	20 sets	30 + sets
Number of operators	2	1 (automated set up)
Scrap costs (month)	~2 500 BGN	< 700 BGN
Automation potential	Limited	High (ERP integration)

Depending on the configuration, the price of the machine ranges from 95 to 115 thousand euros.

The expected return is within 2.5 to 3 years, which will be achieved through:

– Labor Cost Reduction;

– Defect Elimination;

– Increased productivity and flexibility.

Conclusions

Implementing the Bystronic BySmart Fiber 3015 – 4 kW laser cutting machine represents a high-efficiency investment combining technological advancement with organizational improvement. This step moves the production toward a fully digital, automated, and competitive process, where precision, speed, and predictability replace manual tolerances and production variability. Such an investment accelerates order fulfillment, improves accuracy, and enables full digitalization and automation in the early stages of transformer production—a critical factor for sustainable production and competitiveness.

REFERENCES

Andreeva, D. & Stefanov, R. (2020). *Industrial technologies and production process management*. St. Kliment Ohridski University Press. [in Bulgarian]

Angelova, Y., & Kuzmov, V. (2024). Application of the mathematical functions in the economic analysis of the enterprise. *Strategies for Policy in Science and Education, 32*(3s), 105 – 128. https://doi.org/10.53656/str2024-3s-10-app.

Bakardzhieva, R. (2003). Kompaniite kato subekti na inovatsiite. In *Bulgarskiyat prehod: Sbornik ot nauchno-prakticheska konferentsiya.* Gorex Press. [In Bulgarian]

Biolcheva, P., & Sterev, N. (2024). A model for calculating the indirect added value of AI for business. *Strategies for Policy in Science and Education, 32*(3s), 9 – 17. https://doi.org/10.53656/str2024-3s-1-mod.

Blagoev, D. (2018). State and trends in the development of the innovation environment in Bulgaria. In *Conference proceedings "Challenges to industrial growth in Bulgaria"* (pp. 87 – 95). https://www.industrialgrowth.eu/wp-content/uploads/2018/11/9.pdf. [In Bulgarian]

Dimitrova, K. (2018). Modeling, measurement and management of business processes in organization. In: A. Abraham, S. Kovalev, V. Tarassov, V. Snasel, M. Vasileva, A. Sukhanov (Eds.), *Proceedings of the Second International Scientific Conference "Intelligent Information Technologies for Industry"* (pp. 410 – 419). Springer. https://doi.org/10.1007/978-3-319-68324-9_45.

Gospodinova, A. (2021). Analysis and ьssessment of the шechnical and шechnological level of the vegetable oil industry in Bulgaria. *Industrial Management*, (1), 47 – 52. [in Bulgarian]

Shterev, N. (2018). Pazvitie na industriyata na Bulgaria: Sastoyanie i perspektivi. In *Conference proceedings "Challenges to industrial growth in Bulgaria"* (pp. 13 – 23). [In Bulgarian]

Nikolova-Alexieva, V., Valeva, K., & Gigova, T. (2025). Eco-innovation activity of industrial enterprises in Bulgaria. *AIP Conference Proceedings, 3274*(1), 080013. https://doi.org/10.1063/5.0259609.

Panayotova, T., Dimitrova, K., & Veleva, N. (2023). Study of the key factors influencing the effective planning and utilization of production facilities in the industrial enterprise. *Strategies for Policy in Science and Education, 31*(6s), 80 – 93. https://doi.org/10.53656/str2023-6s-7-stu.

Valeva, K. (2021). *Otsenka na ustoychivoto razvitie na idustrialnite predpriyatiya v Bulgaria*. Imeon. [in Bulgarian]

✉ **Prof. Nikolay Karev, PhD**
Department of Economy and Management
University of Chemical Technology and Metallurgy
8, Kl. Ohridski Blvd.
1756, Sofia, Bulgaria
E-mail: karev_nk@abv.bg,

✉ **Angelina Terzieva, PhD**
Department of Economy and Management
University of Chemical Technology and Metallurgy
8, Kl. Ohridski Blvd.
1756, Sofia, Bulgaria
E-mail: Ani_Terzieva@abv.bg