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Integration of Modern Standards for Design Documentation Formatting into the Educational Process and Industrial Practice for Circuit Diagrams

Abstract:
The article examines the urgent issue of Ukraine's transition from the outdated ESKD system (Unified System for Design Documentation) to modern international IEC (International Electrotechnical Commission) standards in the field of design and electrotechnical documentation. This transition represents an important stage in the process of European integration and the digital transformation of technical education and industry. The study analyzes the regulatory and technical documents traditionally used in Ukraine for creating electrical diagrams, including GOST 2.102, GOST 2.701, GOST 2.702, GOST 2.710, and GOST 2.721, and identifies their modern international counterparts: SSU EN 61355–1:2022 (IEC 61355–1:2008), SSU EN 61082–1:2022 (IEC 61082–1:2014), SSU EN IEC 81346–1:2022 and SSU EN 81346–2:2022 (IEC 81346–1:2022, IEC 81346–2:2019), and SSU IEC 60617:2018 (IEC 60617:2012 DB). A systematic comparison of their provisions has been carried out, highlighting the key differences and advantages of adopting IEC standards in modern technical design. It has been established that the transition to IEC standards ensures the unification of approaches to classification, identification, and graphical representation of elements, creating a functional-structural model of the object compatible with modern CAD/CAE systems. The article emphasizes the importance of implementing these standards in engineering education to prepare future specialists for work in an international digital environment. It demonstrates that the integration of IEC standards promotes the digitalization of technical documentation, enhances transparency, and ensures international compatibility of electrotechnical projects. It is concluded that the implementation of IEC standards in national education and industrial practice is a strategic direction for the development of Ukraine's engineering culture. This will enable the creation of a unified information ecosystem for technical documentation, ensure digital integration with international systems, enhance the competitiveness of Ukrainian engineers in the global labor market, and facilitate the effective transition to digital manufacturing in line with the principles of Industry 4.0.

Keywords: electrical circuit, element, standard, documentation, IEC, State Standard of Ukraine.

Abbreviations:
DCC is Document Kind Classification Code,
IEC is International Electrotechnical Commission,
ISO is International Organization for Standardization,
SSU is State Standard of Ukraine,
$USDD$ is Unified System for Design Documentation (ESKD),
USTD is Unified System for Technological Documentation.

Introduction

In the context of the active process of European integration, Ukraine is aligning not only its legislation but also its standards. This is confirmed by the relevant orders of state authorities (*On the package adoption…, 2022*), according to which certain SSUs based on old Soviet standards have already been repealed, while those still in force have a limited validity period. Moreover, around 20,000 new ISO standards have been introduced. Among them are standards regulating the development of design documentation, replacing the outdated USDD/ESKD system, which can be accessed on the Budstandart portal (*Budstandart Document Service, n.d.*).

Considering the above, and in the current conditions of technological development, the integration of international standards for the preparation of design documentation into the educational process and industrial practice has become particularly relevant. In particular, in electrical engineering and automation, electrical schematic diagrams are a key element of technical communication between designers, manufacturers, and maintenance services. The implementation and use of international standards ensure the unification of graphic symbols, the structuring of functional elements, and the improvement of the accuracy of schematic interpretation. This contributes not only to enhancing the quality of future engineers' training but also to adapting Ukrainian enterprises to the requirements of the international market.

Continuing the process of integrating modern standards for the preparation of design documentation into education and industrial practice, this article focuses on creating electrical diagrams in accordance with the new requirements. The main standards and existing differences between the newly introduced and repealed regulatory documents will be examined.

Thus, the systematic implementation of modern standards for electrical schematic design into educational programmes and production processes is an important step toward technical compatibility, digitalisation, and professional mobility of specialists.

Literature Review

Within the framework of the study, a search and critical analysis of new textbooks and teaching aids published in Ukraine in recent years (*Vanin et al., 2018*; *Hlushko, 2019*; *Kovbashyn & Pik, 2023*), concerning the rules for preparing design documentation, were conducted. It was established that most of them do not take into account recent amendments to regulatory standards and remain oriented towards the use of the USDD/ESKD system.

The situation in enterprises is even more conservative. Over the past 30 years, the requirements for preparing design documentation have hardly changed, particularly in enterprises operating in the domestic market. Typically, such enterprises have their internal standards or regulations based on USDD/ESKD, USTD, and other outdated standards. This attitude is understandable, since their main priorities are indicators such as cost, quality, and competitiveness, while internal design documentation management is considered of secondary importance. Considering that the implementation of new standards or compliance of documentation with international standards is always associated with additional expenses, only those enterprises that enter new sales markets for their products are willing to take such steps.

Active work on implementing modern international standards into the educational process—and consequently into production—is being performed by Prof. O.V. Chernikov. In his publication (*2024*), he raises the pressing issue of the necessity of transitioning the educational process to new international standards. As part of this transition, new ISO-compliant templates have been developed for drawings with updated title blocks and specification sheets. Active work is also underway to create a library of fasteners according to the updated SSU standards, based on existing ISO and DIN standard libraries. It is important to note that all these developments are not merely formal but serve as practical add-ons to Autodesk software products (AutoCAD, Inventor, Fusion), which students actively use in the educational process. Other works (*Chernikov et al., 2021*; *Chernikov et al., 2023*) describe the automation processes in Autodesk Inventor and the depiction of views on drawings according to the standards.

Based on the analysis of the publications, it can be concluded that the process of integrating modern standards for preparing design documentation into the educational process is a highly relevant task, and that work in this area has only just begun. This is especially important for educational institutions subordinated to state authorities, since at the state level the implementation of new international standards has already taken place, and compliance with them will soon become a key requirement.

Results

Main Documents Commonly Used for Creating Electrical Schematics:

- GOST 2.102–68 USDD/ESKD. Types and Completeness of Design Documents;
- GOST 2.701–84 USDD/ESKD. Schematics. Types and Categories. General Requirements for Execution;
- GOST 2.702:2013 Unified System for Design Documentation. Rules for the Execution of Electrical Schematics (GOST 2.702–2011, IDT);
- GOST 2.710–81 Letter-Numeric Designations in Electrical Schematics;
- GOST 2.721–74 USDD/ESKD. Graphical Symbols in Schematics. General-Purpose Designations.

This list is not exhaustive and can be extended, but it provides a general idea of the key aspects. Considering that some of the listed standards have already lost validity in Ukraine and others will soon become obsolete, a reasonable question arises: which standards should be used? Services such as *Budstandart* do not provide direct recommendations on which standards to transition to, most likely because there are no direct equivalents in terms of document content.

Given the process of European integration, it becomes clear which international standards should be implemented and applied. One such example is the recent adoption of European approaches to defining power-quality parameters, in particular, the transition to a nominal voltage of 230/400 V (*European voltage and new standards…, n.d.*). Issues related to standardisation in the field of electrical, electronic and related technologies are managed by the IEC, of which Ukraine has been a member since 1993 (*International Electrotechnical Commission, n.d.*). Therefore, it is advisable to use IEC standards for developing electrical schematics.

The types, categories, and codes of design documentation familiar to us—e.g., CA (circuit diagram), LA (parts list), LCC (connection list), CC (connection diagram, wiring or installation schematic), MA (electrical installation drawing), or TST (test programme and methodology)—as proposed in GOST 2.102–68 and GOST 2.701–84, should now be classified and designated using SSU EN 61355–1:2022 *Classification and Designation of Documents for Plants, Systems and Equipment. Part 1: Rules and Classification Tables* (EN 61355–1:2008, IDT; IEC 61355–1:2008, IDT).

The essence of this standard is to define a structured document-classification system based on content and form of presentation. Its goal is to ensure unified document identification throughout the entire life cycle of technical objects. The main provisions are as follows:

- defines the concept of a "document kind" as a type characterised by the content of information and its form of presentation;
- introduces DCC enabling systematic document organisation;
- covers both technical and non-technical documents, including drawings, schematics, specifications, instructions, protocols, reports, etc.;
- applies to the preparation, exchange, management, and archiving of documentation among project participants.
- The DCC code consists of three letters with specific logical meaning:
- the first letter indicates the document group and its general type (e.g., schematic, list, installation, instruction);
- the second specifies the main sub-category within the group (e.g., principal schematic, wiring schematic, installation schematic);
- the third (optional) provides additional classification, detailing, or specific purpose (e.g., detailed, functional, test).

New types and categories of certain designations according to IEC 61355–1 are presented in comparative Table 1 (*Appendix*).

Thus, the transition from obsolete USDD/ESKD standards (GOST 2.102–68, GOST 2.701–84) to the international standard SSU EN 61355–1:2022 (IEC 61355–1) enables the structuring of design-documentation classification under unified rules. The use of DCC codes provides unified document identification regardless of industry, promotes digital data integration, simplifies information exchange between departments, and enhances compatibility with modern CAD/CAE systems.

The SSU GOST 2.702:2013 standard regulating the rules for electrical-schematic preparation can be replaced by SSU EN 61082–1:2022 *Preparation of Documents Used in Electrotechnology. Part 1: Rules* (EN 61082–1:2015, IDT; IEC 61082–1:2014, IDT). Both documents pursue similar goals—regulating the drafting of electrotechnical documentation, particularly schematics—but they are not fully equivalent, and direct substitution requires adaptation.

The main differences primarily involve the use of corresponding standards that affect the overall layout. It is worth noting that IEC 61082–1 has a more flexible adaptation system—from sheet-format sizes to element notation and placement—facilitates address-based schematic creation, and represents a digitally oriented standard ensuring scalability and international compatibility, especially in digital environments.

Hence, replacing SSU GOST 2.702:2013 with SSU EN 61082–1:2022 is a step toward a modern, digitally oriented system for preparing electrotechnical documentation. IEC 61082–1 provides flexibility in schematic design, supports international interoperability, and meets the requirements of computer-aided design, whereas the outdated GOST standard retains limitations inherent to paper formats and obsolete methodologies.

The GOST 2.710–81 standard, which governs alphanumeric designations in electrical schematics, should be replaced by SSU EN IEC 81346–1:2022 *Industrial Systems, Installations, Equipment and Industrial Products—Structuring Principles and Reference Designations. Part 1: Basic Rules* (EN IEC 81346–1:2022, IDT; IEC 81346–1:2022, IDT) and SSU EN 81346–2:2022 *Industrial Systems, Installations, Equipment and Industrial Products—Structuring Principles and Reference Designations. Part 2: Classification of Objects and Codes for Classes* (EN 81346–2:2019, IDT; IEC 81346–2:2019, IDT).

When examining the first part of the standard using simple schematic examples, at first glance, the structure of compound alphanumeric designations appears nearly identical. However, in more complex, structured schematics, the USDD/ESKD standard fails to define a clear identification structure, coding format, or inter-level relationships, resulting in enterprise-specific interpretations.

In contrast, IEC 81346–1 follows a functional-structural approach at all levels, offering a clear methodology and syntax for combining levels within a unified code, transforming them into a universal, digitally readable identification model. This allows integration of schematics, structures, databases, and documents into a single system.

The second part of the standard, dealing with the classification of objects and class codes, presents more differences. The primary distinction lies in the classification of designations: in USDD/ESKD, these are element-type groups where letters form part of the symbolic designation (e.g., K—contactor, SB—button, FU—fuse). In IEC 81346–2, these are classes and subclasses where the first letter is a class code defining the element's function within a system (K—switching device, Q—circuit breaker, F—protective device), and the second letter specifies type or principle of operation within the base class (KM—power contactor, QF—load circuit breaker, FU—fuse). A third letter or digit may be added for deeper detailing, allowing classification of specific device families or serial numbering within a product.

Certain designations, such as C (capacitor), R (resistor), L (inductance coil), M (motor), and several others, coincide, while others differ slightly. Such similarity and grouping are logical since GOST 2.710–81 was originally based on IEC recommendations of the 1960s–70s. Over time, the IEC standard evolved substantially with scientific and technological progress, while GOST 2.710–81 remained a closed system.

Occasionally, electrical schematics feature other non-IEC designations, e.g., CB (circuit breaker) or TB (terminal block), which are English-language functional abbreviations borrowed from North American standards. According to IEC, their respective designations are QF and XT.

Thus, replacing GOST 2.710–81 with SSU EN IEC 81346–1:2022 and SSU EN 81346–2:2022 ensures a shift from the outdated alphanumeric-designation system to a modern functional-structural object-identification model. IEC 81346 standards establish clear coding rules reflecting functional, locational, and product interrelations, enabling detailed class and subclass specification and ensuring unification, scalability, and digital compatibility with international design systems.

Regarding the graphical symbols in electrical schematics—standardised by GOST 2.721–74 USDD/ESKD *Graphical Symbols in Schematics. General-Purpose Symbols* and related standards (number range 721–769 of USDD/ESKD) covering graphical symbols for groups of electrical devices from motors, switching and protection equipment to semiconductors and communication devices—it is advisable to use IEC 60617:2018 *Graphical Symbols for Diagrams* (IEC 60617:2012 DB, IDT).

This standard is one of the fundamental documents for electrotechnical design, defining a unified system of graphical symbols used in electrical, electronic, automation, and telecommunication diagrams. It includes 10 main groups covering all types of electrical elements—from basic symbols to telecommunication systems. The standard currently contains about 1,900 symbols (compared to about 600 in USDD/ESKD) and is continuously updated. Each symbol has its Sxxxxx code, description, reference to IEC 81346 (class of element), and an SVG graphic file. The standard is available in the electronic database IEC 60617 DB (*Graphical Symbols for Diagrams, n.d.*). The main groups of the standard are presented in Table 2 (*Appendix*), each subdivided by device type and subgroup.

Hence, the transition from GOST 2.721–74 to SSU IEC 60617:2018 ensures the use of a globally unified system of graphical symbols encompassing all types of electrical, electronic, and telecommunication elements. IEC 60617 contains over 1,900 current symbols, supports digital formats, and aligns with IEC 81346, making it a foundation for modern schematic design within CAD/CAE environments and ensuring international documentation compatibility.

It is also worth noting that the aforementioned standards are implemented in engineering platforms such as EPLAN, AutoCAD Electrical, SEE Electrical, and SolidWorks Electrical. Therefore, using these programmes enables the creation of electrical schematics in compliance with the international IEC standard and other regional regulations.

Discussion

The integration of international IEC standards into the system of preparing electrical engineering documentation is not only a demand of the time but also a key prerequisite for enhancing the competitiveness of national production. An analysis of the presented documents shows that the transition from the USDD/ESKD (GOST) system to the IEC 61082, IEC 61355, IEC 81346, and IEC 60617 series of standards does not imply a mechanical replacement of drafting rules, but rather a transformation in the very philosophy of technical documentation development.

From the perspective of the educational process, such integration requires a revision of curricula. Students should not merely learn drawing rules but should master systems thinking, where a schematic is not a static illustration but an integral part of a product's information model.

Ultimately, the transition to IEC standards not only modernises design documentation but also paves the way for the complete digitalisation of design processes, unification of data exchange between enterprises, and international interoperability. However, the process requires methodological support, official translation and adaptation of terminology, as well as the training of specialists capable of working simultaneously within the IEC, ISO, and USDD/ESKD environments.

Conclusion

The analysis of the evolution of design documentation standards has shown that the USDD system, represented by GOST 2.701, 2.702, 2.710 and others, no longer meets the requirements of digital and international engineering. The international IEC standards—specifically series IEC 61082, IEC 61355, IEC 81346 and IEC 60617—offer a modern, structurally and functionally coherent system for describing technical objects. This system is oriented toward digital design, automation, and product lifecycle management, where:

- IEC 61082–1 provides digitally oriented rules for the preparation of electrical diagrams, enables scaling and automated generation of addressing systems, which makes it adaptable to modern CAD/CAE platforms;
- IEC 61355–1 introduces a DCC system that allows for the integration of design, technological, and operational documentation into a single information base;
- IEC 81346–1 and IEC 81346–2 define the principles of object identification and classification according to functional, positional, and product-related aspects, forming the basis for a universal object model suitable for machine processing;
- IEC 60617 provides a globally unified system of graphical symbols for diagrams that covers modern elements of electronics, automation, and telecommunications, with dynamic updates via the IEC 60617 DB database.

The transition to international IEC standards requires a comprehensive approach—adapting terminology, developing methodological recommendations for educational institutions, updating engineering curricula, and implementing engineering platforms compatible with IEC standards.

Thus, the implementation of IEC standards in national education and production practices represents a strategically important step toward creating a unified information engineering ecosystem that meets contemporary international requirements, supports the principles of digital manufacturing, and opens opportunities for Ukraine's integration into the global technical space.

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Conflict of Interest

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Appendix

Table 1. Comparison of document designations according to the standard USDD/ESKD and IEC 61355-1

Designation according to USDD/ESKD		Designation according to IEC 61355-1	
Code	Name in Ukrainian	Name in English	DCC Code
Е3	Схема електрична принципова	Circuit diagram	CA
Е4	Схема електрична з'єднань	Connection diagram	CC
ПЕ3	Перелік елементів	Parts list	LA
ТБ33	Таблиця з'єднань	Connection list	LCC
ПМ	Програма і методика перевірки	Test specification / procedure	TST
МЕ	Електромонтажний кресленик	Mounting / installation drawing	MA

Table 2. List of the main groups of element designations according to the standard IEC 60617:2012

Group Code	Name	Ukrainian Translation	Examples of Symbols
01	Basic and general symbols	Основні та загальні графічні символи	Lines, points, intersections, grounding, polarity, arrows, etc.
02	Conductors and connecting devices	Провідники та з'єднувальні елементи	Conductors, terminals, connectors, jack plugs
03	Semiconductors and electron tubes	Semiconductors and electron tubes	Diodes, transistors, thyristors, tubes
04	Passive components	Пасивні елементи	Resistors, capacitors, coils, filters
05	Production and conversion of electrical energy	Генерування та перетворення електроенергії	Sources, generators, batteries, converters
06	Switching and protective devices	Комутаційні та захисні пристрої	Switches, relays, contactors, fuses, circuit breakers
07	Measuring instruments, lamps and signalling devices	Вимірювальні прилади, лампи, сигнальні пристрої	Ammeters, voltmeters, indicators, lighting
08	Transmission, conversion and control of signals	Передавання, перетворення та керування сигналами	Amplifiers, logic elements, signal filters
09	Telecommunication, transmission and processing systems	Телекомунікаційні та обчислювальні системи	Telephony, network circuits, microprocessors
10	Miscellaneous symbols	Різні (спеціальні) символи	Symbols without category or with combined functions