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Digital Tools for Electrical Engineering: The Most Popular and Efficient Simulators

Herramientas Digitales para Ingeniería Eléctrica: Simuladores más Populares y Eficientes

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Abstract. The evolution of digital tools in electrical engineering has significantly transformed the way electrical systems are modeled, analyzed, designed, and optimized. The development of specialized software has promoted a methodological shift from predominantly manual procedures toward more accurate, dynamic, and efficient processes based on simulation, modeling, analysis, and control. This article presents a narrative review of the main simulation tools used in electrical engineering, with emphasis on their historical evolution, technical capabilities, applications, advantages, limitations, and emerging trends. The review examines representative software used in academic and industrial contexts, including MATLAB and Simulink, ETAP, DIgSILENT PowerFactory, PSIM, PSpice, Multisim, AutoCAD Electrical, EPLAN, PVsyst, HOMER Pro, and LabVIEW. In addition, the study discusses the influence of artificial intelligence, digital twins, cyber-physical systems, cloud-based simulation, IoT integration, and interoperable platforms on the future development of electrical simulation environments. The findings show that simulation software has become an essential component of contemporary electrical engineering, supporting system behavior prediction, risk reduction, design optimization, renewable energy integration, smart grid development, and decision-making in increasingly complex energy systems. The study concludes that these tools are not only relevant for improving engineering practice and education, but also fundamental for addressing current challenges related to sustainability, energy decentralization, and the transition toward renewable technologies.

Keywords. Electrical engineering simulation; power systems; power electronics; digital twins; artificial intelligence; renewable energy systems.

Resumen. La evolución de las herramientas digitales en la ingeniería eléctrica ha transformado significativamente la forma en que los sistemas eléctricos son modelados, analizados, diseñados y optimizados. El desarrollo de software especializado ha promovido un cambio metodológico desde procedimientos predominantemente manuales hacia procesos más precisos, dinámicos y eficientes basados en la simulación, el modelado, el análisis y el control. Este artículo presenta una revisión narrativa de las principales herramientas de simulación utilizadas en ingeniería eléctrica, con énfasis en su evolución histórica, capacidades técnicas, aplicaciones, ventajas, limitaciones y tendencias emergentes. La revisión examina software representativo empleado en contextos académicos e industriales, incluyendo MATLAB y Simulink, ETAP, DIgSILENT PowerFactory, PSIM, PSpice, Multisim, AutoCAD Electrical, EPLAN, PVsyst, HOMER Pro y LabVIEW. Además, el estudio analiza la influencia de la inteligencia artificial, los gemelos digitales, los sistemas ciberfísicos, la simulación basada en la nube, la integración del IoT y las plataformas interoperables en el desarrollo futuro de los entornos de simulación eléctrica. Los hallazgos muestran que el software de simulación se ha convertido en un componente esencial de la ingeniería eléctrica contemporánea, al apoyar la predicción del comportamiento de los sistemas, la reducción de riesgos, la optimización del diseño, la integración de energías renovables, el desarrollo de redes inteligentes y la toma de decisiones en sistemas energéticos cada vez más complejos. El estudio concluye que estas herramientas no solo son relevantes para mejorar la práctica y la educación en ingeniería, sino que también resultan fundamentales para abordar los desafíos actuales relacionados con la sostenibilidad, la descentralización energética y la transición hacia tecnologías renovables.

Palabras clave. Simulación en ingeniería eléctrica; sistemas de potencia; electrónica de potencia; gemelos digitales; inteligencia artificial; sistemas de energía renovable.

1. Introduction

Electrical engineering increasingly relies on the integration of mathematical modeling, physical principles, computational analysis, and digital technologies to address complex problems related to the generation, transmission, distribution, control, and efficient use of electrical energy (Fasinu & Alant, 2023). Traditionally, many engineering tasks were performed through manual calculations, simplified analytical models, technical tables, diagrams, and direct experimentation. Although these approaches remain conceptually important, the growing complexity of electrical systems, the expansion of renewable energy technologies, and the need for more reliable, flexible, and cost-effective design processes have increased the relevance of computational simulation in both academic and professional contexts.

The development of digital computers and specialized simulation platforms enabled engineers to model nonlinear phenomena, solve complex equations, evaluate dynamic operating conditions, and analyze scenarios that would be costly, impractical, or unsafe to reproduce experimentally (Kantaros et al., 2025; Schmidt et al., 2024). In this context, simulation has become a key support tool for studying faults, optimizing system design, testing control strategies, estimating energy performance, and anticipating system behavior before physical implementation. Its value lies not only in accelerating engineering calculations, but also in supporting decision-making under technical uncertainty.

At present, electrical engineering simulation covers a wide range of domains, including electronic circuit design, power system analysis, power electronics, industrial electrical documentation, photovoltaic system sizing, hybrid microgrid planning, automation, data acquisition, and intelligent grid management. These domains require different types of software, since no single platform can address all technical needs with the same level of suitability. For example, tools used for power-flow analysis differ substantially from those designed for circuit-level simulation, electrical CAD documentation, renewable energy feasibility studies, or real-time monitoring and control.

The continuous development of simulation software has also influenced engineering education. Digital tools allow students to visualize electrical phenomena, test design alternatives, and explore system behavior in virtual environments before interacting with physical equipment. In industrial settings, simulation platforms support planning, operation, maintenance, and risk reduction, particularly in contexts involving renewable energy integration, smart grids, cyber-physical systems, digital twins, artificial intelligence, and IoT-based monitoring (Almutairi et al., 2024; Cerdá et al., 2012; Rahmani-Sane et al., 2025).

Despite the broad availability of electrical engineering simulators, the selection of an appropriate tool remains highly dependent on the application domain, user profile, modeling requirements, licensing conditions, interoperability needs, and expected level of analytical depth. Therefore, a descriptive list of software is insufficient for understanding their practical relevance. A more useful approach is to analyze representative platforms according to their technical scope, typical applications, strengths, limitations, and relationship with emerging technological trends.

Accordingly, this article presents a narrative review of representative digital tools used in electrical engineering simulation. The objective is to examine the historical evolution of these tools, classify them by application domain, describe their main technical uses, compare their strengths and limitations from a functional perspective, and discuss emerging trends such as artificial intelligence, digital twins, cloud-based simulation, IoT integration, and smart grid applications. Rather than providing a quantitative benchmark or ranking of software efficiency, the review seeks to offer a structured and critical synthesis that supports readers in understanding the current role and future direction of simulation platforms in electrical engineering.

2. Narrative Review Methodology

This study was designed as a narrative review aimed at synthesizing historical, technical, and contextual information on representative digital tools used in electrical engineering simulation. A narrative approach was considered appropriate because the objective was not to conduct a formal meta-analysis or a systematic performance benchmark, but to provide an integrated overview of software evolution, application domains, comparative characteristics, and emerging technological trends.

The review was guided by four analytical questions: (i) how have digital simulation tools evolved within electrical engineering? (ii) how can the main simulators be classified according to their application domain? (iii) what are the main strengths, limitations, and typical uses of representative simulation platforms? and (iv) what emerging trends are influencing the future development of electrical engineering simulation?

The literature search considered academic and technical sources related to electrical simulation, platforms? power electronics, electrical CAD software, renewable energy systems, digital twins, artificial intelligence, IoT-based monitoring, and engineering education. The databases and search platforms consulted included IEEE Xplore, ScienceDirect, Scopus, and Google Scholar (Valente et al., 2022). Complementary sources, such as specialized books, technical manuals, software documentation, conference proceedings, institutional reports, and developer documentation, were also considered when they provided relevant historical or technical information about specific simulation platforms.

The search was primarily focused on publications from the last 25 years, to capture recent developments in digital simulation, renewable energy integration, artificial intelligence, digital twins, cloud-based tools, and smart grid applications. However, earlier sources were also considered when they were necessary to explain the historical emergence of foundational tools and computational methods in electrical engineering.

The search strategy combined terms related to the general field and specific application domains. The search expressions included combinations such as “electrical engineering simulation,” “power system simulation software," "power electronics simulation," "electrical CAD software," "renewable energy system simulation," "photovoltaic simulation software," "hybrid microgrid simulation," "digital twins in power systems," "artificial intelligence in electrical engineering," "IoT simulators," and "engineering simulation tools." Searches were also complemented with terms associated with specific platforms analyzed in the manuscript, including MATLAB/Simulink, ETAP, DIgSILENT PowerFactory, PSIM, PSpice, Multisim, AutoCAD Electrical, EPLAN, PVsyst, HOMER Pro, and LabVIEW.

Sources were included when they met at least one of the following criteria: direct relevance to electrical engineering simulation; discussion of software tools used in power systems, electronics, power electronics, renewable energy, automation, or electrical design; contribution to understanding the historical evolution of simulation platforms; technical description of simulator capabilities; or discussion of emerging trends such as digital twins, artificial intelligence, IoT, cloud simulation, or smart grids. Sources were excluded when they were unrelated to electrical engineering, addressed simulation only in a generic way without technical relevance to the field, lacked sufficient bibliographic or technical information, or did not contribute to the analytical categories defined for this review.

The selection of simulators was purposive rather than statistical. Platforms were considered representative when they were associated with one or more of the following conditions: recurrent use in academic or professional contexts, relevance within a specific electrical engineering domain, availability of technical documentation, presence in scientific or technical literature, and applicability to common engineering tasks such as circuit analysis, power system studies, converter modeling, renewable energy planning, electrical documentation, automation, or data acquisition. Therefore, the review does not claim to rank the tools according to market share, user statistics, or experimentally measured computational performance.

Comparative analysis was developed from a functional perspective. The tools were examined according to their main domain, typical applications, strengths, limitations, accessibility, user profile, and suitability for specific engineering tasks. Consequently, terms such as "efficiency" are understood in this article as contextual or functional suitability for a given type of analysis, rather than as a quantitative measure of simulation speed, numerical accuracy, computational performance, or market popularity. This limitation is important because the review does not include experimental benchmarking or direct software performance testing.

Finally, the information extracted from the selected sources was organized thematically into historical evolution, classification of simulators, analysis of representative tools, comparative synthesis, emerging trends, discussion, and conclusions. This structure was adopted to reduce fragmentation, improve coherence among sections, and align the review method with the analytical purpose of the article.

3. Historical Evolution of Electrical Engineering Software

The evolution of electrical engineering software reflects the broader transition of the discipline from manual analytical procedures to computational modeling, simulation-based design, and data-driven decision support. This process has not occurred as a linear replacement of traditional engineering methods, but rather as a progressive integration of numerical computation, graphical interfaces, specialized simulation environments, and, more recently, intelligent and connected systems. Understanding this evolution is relevant because many current simulation platforms preserve methodological principles that originated in earlier computational approaches, while incorporating new capabilities associated with automation, interoperability, and real-time analysis.

During the early decades of the twentieth century, electrical engineering practice relied primarily on manual calculations, simplified analytical models, technical tables, graphical methods, and direct experimentation. Studies involving load flow, short-circuit analysis, and system stability required extensive mathematical work and often depended on simplifying assumptions due to the limited availability of computational resources. In power system planning, the complexity of the calculations frequently demanded considerable time and increased the possibility of numerical or modeling errors, particularly when dynamic phenomena such as transient fault responses, oscillations, or nonlinear behaviors had to be approximated (Makanju et al., 2024).

The development of digital computers in the 1940s introduced a significant change in engineering analysis. Although early computers were initially associated with military and scientific calculations, their capacity to process complex numerical operations soon made them valuable for engineering applications. The introduction and diffusion of FORTRAN in the 1950s further supported this transition, as it provided a programming language oriented toward scientific and numerical computation. From this period onward, engineers began to develop specialized programs for solving electrical engineering problems through matrix formulations, iterative methods, and algorithmic procedures, although the interaction with these systems remained highly technical and dependent on manual data entry (Rui et al., 2022).

A major milestone in circuit simulation occurred in 1973 with the development of SPICE at the University of California, Berkeley. SPICE allowed electronic circuits to be represented through mathematical models of components such as resistors, capacitors, transistors, diodes, and operational amplifiers. Its capacity to perform transient analysis, frequency-domain analysis, and parameter evaluation contributed substantially to the professionalization of electronic circuit design. The influence of SPICE was also reflected in the emergence of derivative tools such as PSpice, LTSpice, and HSpice, which extended its use in academic, industrial, and design-oriented environments. By enabling engineers to evaluate circuit behavior before physical prototyping, SPICE-based tools contributed to reducing design iterations, development costs, and implementation errors (Ullrick et al., 2026).

In parallel, power engineering required tools capable of representing large-scale electrical networks and transient phenomena. The development of programs such as EMTP responded to this need by enabling the analysis of electromagnetic transients, overvoltage propagation, fault conditions, switching events, and oscillatory behavior in power systems. These capabilities were particularly relevant for transmission networks and high-voltage studies, where direct experimentation can be costly, risky, or technically impractical. As a result, EMTP and related tools contributed to the consolidation of simulation as a central method for power system planning, protection analysis, and operational assessment (Gharehpetian et al., 2023).

During the 1980s, the expansion of personal computers and graphical interfaces facilitated the adoption of computer-aided design tools in electrical engineering. CAD software improved the preparation of electrical schematics, wiring diagrams, control panel layouts, and industrial documentation. In this stage, the contribution of digital tools was not limited to numerical simulation; it also transformed engineering documentation, standardization, and communication among designers, technicians, and project stakeholders. AutoCAD and later specialized electrical CAD platforms became important in this context because they supported more efficient and consistent technical drawing workflows.

The 1990s marked another important stage with the widespread adoption of MATLAB and Simulink in engineering education, research, and industrial development. MATLAB provided a flexible environment for numerical computation, matrix operations, signal processing, and the solution of differential equations. Simulink complemented these capabilities with a graphical block-based modeling environment suitable for dynamic systems, control design, power electronics, electrical machines, and energy conversion processes.

This combination contributed to the growth of model-based design approaches, particularly in areas such as motor control, DC-DC converters, inverters, photovoltaic systems, and automated control systems.

During the same period, specialized power system simulators such as ETAP and DIgSILENT PowerFactory gained relevance in professional and research contexts. These platforms supported detailed studies of load flow, short-circuit conditions, protection coordination, transient stability, contingency analysis, and renewable energy integration. Their development reflected the increasing need for tools capable of modeling large and complex electrical networks with greater technical detail. While ETAP became widely associated with industrial electrical system analysis and operational studies, DIgSILENT PowerFactory became particularly relevant for detailed power system modeling, dynamic simulation, and research-oriented applications (Wu et al., 2023).

The twenty-first century introduced new requirements associated with renewable energy integration, distributed generation, microgrids, and energy storage. In this context, tools such as PVsyst and HOMER Pro became relevant because they addressed problems that traditional circuit or power-flow simulators did not fully cover. PVsyst supported the design and performance estimation of photovoltaic systems by considering factors such as solar resource, shading, losses, inverters, and annual energy production. HOMER Pro contributed to the analysis of hybrid energy systems by integrating technical, economic, and environmental variables in the evaluation of microgrids and isolated energy projects. These platforms illustrate how the diversification of the energy sector has encouraged the development of domain-specific simulation tools (Giedraityte et al., 2025).

More recently, the evolution of electrical engineering software has been influenced by artificial intelligence, digital twins, cloud-based simulation, smart grids, cyber-physical systems, and IoT-enabled monitoring. These technologies are expanding the role of simulation from offline design and analysis toward real-time supervision, predictive maintenance, fault diagnosis, and operational optimization. For example, sensor infrastructures and communication systems allow operational data to be incorporated into analytical models, while machine learning techniques support forecasting, anomaly detection, and decision-making in complex electrical systems (Swain et al., 2022). However, these developments should be understood as complementary to established simulation methods rather than as complete replacements for physical modeling, numerical analysis, or engineering judgment.

Overall, the historical evolution of electrical engineering software shows a progressive expansion of simulation capabilities: from manual calculations to numerical programs, from circuit and power system simulators to graphical and domain-specific platforms, and from offline analysis to increasingly connected and data-informed environments. This trajectory explains why contemporary electrical engineering depends on a diverse ecosystem of tools, each suited to particular technical problems, levels of complexity, and professional contexts.

4. Classification of Electrical Simulators

Electrical simulators can be classified according to their primary application domain, modeling scope, level of technical specialization, and type of engineering problem they address. This classification is useful because electrical engineering does not rely on a single category of software, but on a heterogeneous ecosystem of tools designed for different analytical, design, educational, and industrial purposes (Bali & Mughal, 2023). For this reason, the suitability of a simulator depends on the type of system being studied, the required level of modeling detail, the user's technical expertise, the available computational resources, and the intended output of the analysis.

A domain-based classification also helps avoid treating all simulators as directly comparable. For example, a power system analysis platform cannot be evaluated using the same criteria as an electronic circuit simulator, a photovoltaic design tool, or an electrical CAD environment. Each category responds to different technical needs and produces different types of results. Therefore, the following classification organizes representative electrical engineering simulators into six main groups: power system simulators, electronic circuit simulators, power electronics simulators, electrical CAD tools, renewable energy simulators, and control, automation, and data acquisition platforms.

4.1. Power System Simulators

Power system simulators are designed for the analysis of large-scale electrical networks, including generation plants, transmission systems, distribution networks, substations, and industrial electrical installations. These tools support studies related to power flow analysis, short-circuit calculation, transient stability, harmonic analysis, contingency assessment, protection coordination, and system expansion planning (Dai, 2025). Software platforms such as ETAP, DIgSILENT PowerFactory, PSCAD, CYME, and PSS®E are commonly associated with this category because they allow engineers to model complex network structures and evaluate operating conditions under different technical scenarios.

The main strength of this category is its capacity to represent interconnected systems with a high level of electrical detail. These tools are especially relevant for utilities, grid operators, engineering consultants, and researchers working on power system planning, renewable energy integration, and grid reliability. However, their use often requires specialized knowledge, access to accurate technical data, and, in many cases, commercial licenses and advanced computational resources.

4.2. Electronic Circuit Simulators

Electronic circuit simulators focus on the design and analysis of analog, digital, and mixed-signal circuits. Tools such as PSpice, Multisim, and LTSpice enable transient analysis, frequency-domain analysis, parametric sweeps, operating-point analysis, and the modeling of components such as resistors, capacitors, diodes, transistors, operational amplifiers, filters, oscillators, and integrated circuits.

This category is particularly useful in electronics education, circuit prototyping, and professional design validation. Its main advantage is the possibility of testing circuit behavior before physical implementation, reducing prototyping costs and identifying design errors at early stages. Nevertheless, the accuracy of the results depends on the quality of component models, parameter selection, and the assumptions used in the simulation environment.

4.3. Power Electronics Simulators

Power electronics simulators are specialized tools for modeling systems involving energy conversion, switching devices, converters, inverters, PWM control, electric drives, semiconductor devices, and renewable energy interfaces. Simulators such as PSIM and MATLAB/Simulink are frequently used in this domain because they allow the representation of fast dynamic behaviors, control loops, and interactions between electrical machines, converters, and control strategies.

These platforms are particularly relevant for the design of motor drives, DC-DC converters, photovoltaic inverters, grid-connected converters, and energy storage interfaces. Their value lies in their ability to model dynamic and nonlinear behavior in systems where switching frequency, control architecture, and transient response are critical. However, the level of detail required in power electronics simulations may increase model complexity and demand careful interpretation of results.

4.4. Electrical CAD and Documentation Tools

Electrical CAD tools are mainly intended for the preparation of technical drawings, wiring diagrams, schematics, panel layouts, control circuits, and industrial electrical documentation. AutoCAD Electrical and EPLAN Electric P8 are representative examples of this category. Unlike analytical simulators, these platforms focus primarily on design documentation, standardization, component organization, and communication among engineers, technicians, and project stakeholders.

Their main contribution is the improvement of design consistency, documentation quality, project traceability, and workflow efficiency in industrial and construction environments. However, their analytical capabilities are usually limited when compared with simulation platforms designed for dynamic modeling, numerical analysis, or system behavior prediction. Therefore, electrical CAD tools should be understood as complementary to simulation environments rather than substitutes for them.

4.5. Renewable Energy and Microgrid Simulators

Renewable energy simulators are designed to evaluate solar, wind, hybrid, and storage-based energy systems. Tools such as PVsyst and HOMER Pro are widely used to model photovoltaic systems, hybrid microgrids, wind generation, battery storage, diesel backup, load profiles, energy losses, and techno-economic feasibility (Mohammadi & Gezegin, 2022). These platforms are particularly relevant in the context of distributed generation, rural electrification, energy transition projects, and decentralized energy planning.

PVsyst is commonly associated with photovoltaic system design and performance estimation, while HOMER Pro is frequently used for hybrid energy system optimization and economic evaluation. Their main advantage is the integration of technical and economic variables, which supports decision-making in renewable energy projects. However, their scope is more specialized than that of general-purpose electrical simulators, and their results depend strongly on the quality of climatic data, load assumptions, cost parameters, and system configuration.

4.6. Control, Automation, and Data Acquisition Platforms

Control, automation, and data acquisition platforms support the monitoring, control, and integration of electrical and industrial systems. LabVIEW and SCADA-based platforms are representative examples of this group. These tools are used for real-time data acquisition, instrumentation, process monitoring, controller implementation, hardware integration, and industrial automation.

Their relevance lies in their ability to connect computational environments with physical equipment, sensors, actuators, and measurement devices. This makes them useful in laboratories, industrial facilities, testing environments, and cyber-physical systems. Unlike traditional simulation platforms, these tools often operate at the intersection between modeling, experimentation, monitoring, and control. Their limitations are usually related to hardware compatibility, system integration requirements, licensing, and the technical expertise needed for implementation. Table 1 summarizes the proposed classification of representative electrical engineering simulators according to their main domain, typical applications, and general purpose.

Table 1. Classification of representative electrical engineering simulators by application domain.

Category	Representative tools	Main applications	Typical users	Main purpose
Power system simulators	ETAP, DIgSILENT PowerFactory, PSCAD, CYME, PSS®E	Load flow, short circuit, transient stability, protection coordination, grid planning	Utilities, consultants, researchers, grid operators	Analysis of large-scale electrical networks
Electronic circuit simulators	PSpice, Multisim, LTSpice	Analog, digital, and mixed-signal circuit analysis	Students, electronics designers, researchers	Circuit design, validation, and prototyping
Power electronics simulators	PSIM, MATLAB/Simulink	Converters, inverters, PWM control, motor drives, energy conversion	Researchers, power electronics engineers, graduate students	Dynamic modeling of energy conversion systems
Electrical CAD tools	AutoCAD Electrical, EPLAN Electric P8	Schematics, wiring diagrams, control panels, technical documentation	Designers, technicians, industrial engineers	Electrical documentation and project standardization
Renewable energy and microgrid simulators	PVsyst, HOMER Pro	Photovoltaic systems, hybrid microgrids, storage systems, techno-economic analysis	Renewable energy engineers, planners, consultants	Design and feasibility assessment of sustainable energy systems
Control, automation, and data acquisition platforms	LabVIEW, SCADA-based platforms	Monitoring, instrumentation, automation, real-time control	Laboratory engineers, automation specialists, industry users	Integration of simulation, measurement, and control

5. Analysis of the Most Widely Used Simulators

MATLAB and Simulink are widely regarded as fundamental tools for the analysis of dynamic systems. MATLAB provides advanced mathematical capabilities through matrix operations, differential equations, numerical methods, and signal transformations. Simulink, in turn, enables system modeling through a visual block-diagram environment, facilitating the simulation of electronic converters, automated control systems, electrical machines, power devices, and interconnected networks. Their widespread adoption in education, academic research, and industrial development is largely due to their versatility, computational power, and modeling accuracy.

ETAP is a specialized simulator for power systems that enables comprehensive analysis of medium- and high-voltage electrical networks. Its graphical interface simplifies the construction of complex system models, while its specialized modules support load flow analysis, short-circuit studies, stability assessments, protection coordination, transient analysis, and industrial power system evaluation. ETAP is extensively used by generation, transmission, and distribution companies because of its reliability and engineering-grade analytical capabilities.

DIgSILENT PowerFactory is another advanced simulator focused on electrical power networks. Its ability to perform highly detailed dynamic simulations makes it an essential tool for the planning and operation of modern electrical systems. It is widely used in academic research due to its capacity to model renewable energy integration, hybrid energy systems, and microgrids with high levels of technical detail. PSpice remains one of the most widely used simulators for electronic circuit analysis. It enables precise simulation of operational amplifiers, transistors, semiconductor devices, and complex electronic circuits. Its continued relevance in the electronics industry is closely tied to the analytical precision required for professional circuit design and validation.

PSIM has established itself as a leading simulator for power electronics, particularly because of its speed and efficiency in simulations involving converters and control systems. Its strong capability for modeling PWM-based systems makes it a valuable tool for the development of inverters, motor drives, and photovoltaic energy applications. PVsyst is a specialized simulator for photovoltaic systems, allowing engineers to model solar panels, inverters, shading conditions, system losses, and overall energy performance. It is widely used for the sizing and optimization of both residential and industrial solar power plants.

HOMER Pro is designed for the analysis of hybrid microgrids that integrate solar, wind, diesel generation, and battery storage. Its capacity to evaluate technical, environmental, and economic dimensions has made it a widely recognized standard for isolated communities, rural electrification projects, and decentralized energy planning. LabVIEW enables data acquisition, system control, and industrial automation through a graphical block-based programming environment. It is extensively used in research laboratories and engineering applications due to its ability to integrate external hardware, instrumentation systems, and real-time monitoring processes.

6. Comparison of Simulator Efficiency

The comparison among electrical engineering simulators demonstrates that no single tool can universally address all engineering needs with equal efficiency. Each simulator possesses specific characteristics that make it more suitable for particular types of analysis and applications. MATLAB and Simulink stand out for their exceptional versatility, as they can be applied across multiple domains, including control systems, power electronics, electrical machine modeling, and signal processing. However, their learning curve can be considerable, particularly for beginners, and their licensing costs may represent a barrier for some institutions and independent users.

ETAP and DIgSILENT PowerFactory offer high precision for power system analysis and are considered industry-grade solutions for professional electrical engineering applications. Nevertheless, the execution of highly detailed and large-scale models often requires robust computational hardware and advanced technical expertise. PSpice is recognized for its high level of analytical precision in electronic circuit simulation, making it particularly suitable for professional electronic design. In contrast, Multisim provides a more intuitive and user-friendly interface, making it more accessible for students and novice users, although it may offer less analytical depth for specialized applications.

PSIM is distinguished by its speed and efficiency, particularly in power electronics simulations involving converters and control systems. However, its application domain is more specialized compared to broader simulation platforms. Renewable energy simulators such as PVsyst and HOMER Pro are indispensable within their respective domains due to their strong technical and techno-economic analysis capabilities. However, they offer limited flexibility outside renewable energy and hybrid energy system applications.

Electrical CAD platforms are essential for technical documentation and industrial design workflows, although they do not provide dynamic simulation or analytical modeling capabilities comparable to engineering simulation environments.

7. Current and Future Trends in Electrical Simulation

Recent advances in electrical engineering software are increasingly shaped by digital transformation, automation, and data-driven technologies. Among the most relevant trends is the integration of artificial intelligence into simulation environments. AI-based approaches allow the development of predictive models using real operational data, supporting fault detection, electrical network optimization, renewable energy forecasting, and stability analysis in complex systems. Through machine learning and deep learning techniques, simulation platforms are evolving from static analysis tools into intelligent environments capable of anticipating system behavior under different operating conditions.

Digital twins represent another major innovation in this field. A digital twin can be understood as a virtual representation of a physical system that is continuously updated through real-time data obtained from sensors, monitoring devices, and communication infrastructure. In electrical engineering, this technology enables engineers to evaluate the behavior of power systems without direct physical intervention, reducing risks and improving decision-making. Digital twins are increasingly being applied in power plants, substations, transmission lines, distribution networks, and industrial electrical systems for monitoring, optimization, diagnosis, and predictive maintenance.

Cloud-based simulation is also gaining relevance. By allowing complex simulations to be executed without relying exclusively on high-cost local computing infrastructure, cloud platforms facilitate broader access to advanced engineering tools. Solutions such as MATLAB Online, HOMER Pro, and PVsyst Cloud illustrate this transition toward more flexible and accessible simulation environments, where users can model and analyze systems from virtually any internet-connected device.

The digitalization of electrical networks has also promoted the development of simulation platforms focused on smart grids, microgrids, electric vehicles, and energy storage systems. These tools increasingly incorporate battery models, renewable generation profiles, climate forecasting data, and advanced control strategies. As a result, simulation software is becoming essential for evaluating the interaction between distributed generation, storage technologies, demand response, and grid stability.

Finally, the integration of Internet of Things technologies with simulation environments is opening new possibilities for real-time analysis. Operational data collected from electrical equipment can be directly transferred to simulation platforms, allowing continuous monitoring, performance evaluation, system optimization, and predictive maintenance. This convergence between IoT, simulation, and data analytics is expected to strengthen the reliability, efficiency, and resilience of future electrical systems.

8. Discussion

Computational simulation has contributed significantly to the development of safer, more efficient, sustainable, and reliable electrical systems. Its use has transformed both engineering education and industrial practice by enabling the analysis of scenarios that would be difficult, expensive, or risky to reproduce under real operating conditions. Through simulation, engineers can evaluate extreme operating conditions, equipment failures, dynamic responses, transient phenomena, and high-uncertainty scenarios within controlled virtual environments. This capacity is particularly relevant in modern electrical systems, where increasing complexity, renewable energy integration, and digitalization require more advanced modeling and decision-support tools (Artibani, 2025).

The reviewed simulation tools show that no single platform fully covers all areas of electrical engineering. Instead, each software package responds to specific technical needs. MATLAB and Simulink are widely used for model-based design, multidomain simulation, control systems, and system-level analysis. ETAP and DIgSILENT PowerFactory are more oriented toward power system studies, including load flow, short-circuit analysis, protection coordination, and stability assessment. In contrast, PSpice and Multisim are more suitable for electronic circuit simulation, while PSIM is frequently applied in power electronics. Similarly, PVsyst and HOMER Pro are specialized in renewable energy and hybrid energy system analysis, with HOMER Pro being especially relevant for microgrid and distributed generation optimization (UL Solutions, 2026). Therefore, the selection of an appropriate simulator depends on the purpose of the study, the level of modeling detail required, the type of electrical system, and the available computational resources.

Despite their advantages, simulation tools also present important challenges. Their effective use requires technical training, theoretical knowledge, and continuous adaptation to new software functionalities. As simulation platforms evolve, engineers must strengthen their skills in mathematical modeling, programming, data analysis, control systems, and computational engineering. This requirement becomes even more relevant with the incorporation of artificial intelligence, digital twins, cloud computing, and IoT-based monitoring. Digital twins, for example, require the integration of physical models, real-time data, communication infrastructure, and predictive analytics to support diagnosis, optimization, and maintenance decisions in complex electrical systems (Sifat et al., 2023).

Another important aspect is the reliability of simulation results. Although modern software can represent complex systems with high precision, the quality of the results depends on the accuracy of input data, the validity of mathematical models, the correct configuration of simulation parameters, and the interpretation of outputs. For this reason, simulation should not be understood as a replacement for engineering judgment, experimental validation, or field experience. Rather, it should be considered a complementary tool that supports analysis, design, optimization, and decision-making. This is especially important in predictive maintenance and digital twin applications, where model uncertainty, computational burden, data quality, and system complexity remain relevant challenges (van Dinter et al., 2022; Zhong et al., 2023).

Overall, simulation will continue to be a central component of technological development in electrical engineering. The modernization of electrical grids, the expansion of renewable energy, the electrification of transportation, and the increasing demand for efficient energy systems require simulation environments that are more powerful, flexible, interoperable, and data-driven. In this context, artificial intelligence, digital twins, cloud-based simulation, and IoT integration are expected to strengthen the role of simulation software in both academic and industrial environments.

9. Conclusions

This review shows that electrical simulation software is a fundamental component of modern engineering practice. The evolution of these tools has improved model accuracy, reduced operational risks, optimized design processes, and accelerated innovation in several areas of electrical engineering. The analyzed simulators address different technical domains and contribute to the design, analysis, and optimization of electrical systems. MATLAB stands out for its versatility and broad application in modeling, control, and numerical analysis. ETAP and DIgSILENT PowerFactory are especially relevant for power system studies. PSpice and Multisim provide strong capabilities for electronic circuit simulation. PSIM is widely recognized for its efficiency in power electronics applications. PVsyst and HOMER Pro are specialized tools for renewable energy systems, while LabVIEW offers strong potential for integrating simulation, automation, instrumentation, and real-world hardware.

The findings also highlight that the future of electrical simulation will be strongly influenced by artificial intelligence, digital twins, cloud-based platforms, IoT integration, and smart grid technologies. These trends are transforming simulation software into more intelligent, connected, and adaptive environments. Electrical simulation tools will continue to play a decisive role in engineering education, research, and industry. Their proper use can support the development of safer, more reliable, and more sustainable electrical systems, while also preparing engineers to respond to the technological challenges of future energy systems.

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References

Almutairi, R., Bergami, G., & Morgan, G. (2024). Advancements and Challenges in IoT Simulators: A Comprehensive Review. Sensors, 24(5), 1511. https://doi.org/10.3390/s24051511

Artibani, F. S. (2025). The Role of Digital Technologies in Promoting the Transition to Decarbonized Energy Systems in Europe and Italy and Their Legal Ramifications. In A. Barichella & J. Yada (Eds.), The Palgrave Handbook of Cybersecurity, Technologies and Energy Transitions (pp. 1–44). Palgrave Macmillan. https://doi.org/10.1007/978-3-031-04196-9_46-1

Bali, A., & Mughal, Y. (2023). The Impact of Different Computing Tools in Electrical Engineering Learning. Journal of Engineering and Computational Intelligence Review. https://jecir.com/index.php/jecir/article/view/12

Cerdá, E., André, F. J., & De Castro, L. M. (2012). Las energías renovables en el ámbito internacional. Cuadernos Económicos de ICE, (83). https://doi.org/10.32796/cice.2012.83.6031

Dai, J. (2025). Suggested Approaches to Perform Transient Stability Studies for Industrial and Commercial Power Systems. IEEE Transactions on Industry Applications, 61(3), 4833–4846. https://doi.org/10.1109/TIA.2025.3533500

Fasinu, G. V., & Alant, B. P. (2023). University electronics engineering students' approaches of integrating mathematical ideas into the learning of physical electronics in basic electronics. Eurasia Journal of Mathematics, Science and Technology Education, 19(1), em2214. https://doi.org/10.29333/ejmste/12797

Gharehpetian, G. B., Yazdani, A., & Zaker, B. (2023). Power System Transients: Modelling Simulation and Applications. Power System Transients: Modelling Simulation and Applications, 1–234. https://doi.org/10.1201/9781003255130

Giedraityte, A., Rimkevicius, S., Marciukaitis, M., Radziukynas, V., & Bakas, R. (2025). Hybrid Renewable Energy Systems—A Review of Optimization Approaches and Future Challenges. Applied Sciences (Switzerland), 15(4), 1–30. https://doi.org/10.3390/app15041744

Kantaros, A., Ganetsos, T., Pallis, E., & Papoutsidakis, M. (2025). From Mathematical Modeling and Simulation to Digital Twins: Bridging Theory and Digital Realities in Industry and Emerging Technologies. Applied Sciences (Switzerland), 15(16), 9213. https://doi.org/10.3390/app15169213

Makanju, T. D., Shongwe, T., & Famoriji, O. J. (2024). Machine Learning Approaches for Power System Parameters Prediction: A Systematic Review. IEEE Access, 12, 66646–66679. https://doi.org/10.1109/ACCESS.2024.3397676

Mohammadi, S. A. D., & Gezegin, C. (2022). Design and Simulation of Grid-Connected Solar PV System Using PVSYST, PVGIS and HOMER Software. International Journal of Pioneering Technology and Engineering, 1(01), 36–41. https://doi.org/10.56158/jpte.2022.24.1.01

Rahmani-Sane, G., Azad, S., Taghi Ameli, M., & Haghani, S. (2025). The Applications of Artificial Intelligence and Digital Twin in Power Systems: An In-Depth Review. IEEE Access, 13, 108573–108608. https://doi.org/10.1109/ACCESS.2025.3580340

Rui, X., Zhang, J., Wang, X., Rong, B., He, B., & Jin, Z. (2022). Multibody system transfer matrix method: The past, the present, and the future. International Journal of Mechanical System Dynamics, 2(1), 3–26. https://doi.org/10.1002/msd2.12037

Schmidt, A., Elagroudy, P., Draxler, F., Kreuter, F., & Welsch, R. (2024). Simulating the Human in HCD with ChatGPT: Redesigning Interaction Design with AI. Interactions, 31(1), 24–31. https://doi.org/10.1145/3637436

Sifat, M. M. H., Choudhury, S. M., Das, S. K., Ahamed, M. H., Muyeen, S. M., Hasan, M. M., Ali, M. F., Tasneem, Z., Islam, M. M., Islam, M. R., Badal, M. F. R., Abhi, S. H., Sarker, S. K., & Das, P. (2023). Towards electric digital twin grid: Technology and framework review. Energy and AI, 11, 100213. https://doi.org/10.1016/j.egyai.2022.100213

Swain, A., Abdellatif, E., Mousa, A., & Pong, P. W. T. (2022). Sensor Technologies for Transmission and Distribution Systems: A Review of the Latest Developments. Energies, 15(19), 7339. https://doi.org/10.3390/en15197339

UL Solutions. (2026). HOMER Pro: Microgrid Optimization Software. Accessed: Jul. 4, 2026.

Ullrick, T., Deschrijver, D., Spina, D., Bogaerts, W., & Dhaene, T. (2026). Wavelength-tunable equivalent circuit models for SPICE-based photonic–electronic co-simulation. Journal of Computational Electronics, 25(1), 2-. https://doi.org/10.1007/s10825-025-02448-6

Valente, A., Holanda, M., Mariano, A. M., Furuta, R., & Da Silva, D. (2022). Analysis of Academic Databases for Literature Review in the Computer Science Education Field. Proceedings - Frontiers in Education Conference, FIE. https://doi.org/10.1109/FIE56618.2022.9962393

van Dinter, R., Tekinerdogan, B., & Catal, C. (2022). Predictive maintenance using digital twins: A systematic literature review. Information and Software Technology, 151, 107008. https://doi.org/10.1016/j.infsof.2022.107008

Wu, Q. H., Lin, Y., Hong, C., Su, Y., Wen, T., & Liu, Y. (2023). Transient Stability Analysis of Large-scale Power Systems: A Survey. CSEE Journal of Power and Energy Systems, 9(4), 1284–1300. https://doi.org/10.17775/CSEEJPES.2022.07110

Zhong, D., Xia, Z., Zhu, Y., & Duan, J. (2023). Overview of predictive maintenance based on digital twin technology. Heliyon, 9(4), e14534. https://doi.org/10.1016/j.heliyon.2023.e14534

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