

Research on Innovative Design of Electrical Products under the Integration of Art and Engineering

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ABSTRACT

The integration of art and engineering synergistically optimizes functionality and aesthetics in electrical products, enhancing user experience while addressing complex technical challenges. In the field of electrical design, this approach manifests in artistically designed interfaces that reduce operational cognitive load and engineering-optimized designs that improve equipment maintainability and environmental adaptability. Responding to industry demand for interdisciplinary professionals, this study proposes a cross-disciplinary graduate education model. We establish an 'Art-Engineering-Electricity' integrated framework and validate its application value through theoretical analysis and a case study on mobile charging piles.

Keywords: Art-engineering integration, interdisciplinary education, electrical design.

INTRODUCTION

Research Background and Significance

Globally, the advancement of carbon neutrality goals has accelerated the transformation of energy structures. As the core domain of this energy transition, power systems now face unprecedented challenges and opportunities. "Art and engineering integration", also known as "art and engineering fusion", refers to the combination of art with engineering and technology. It aims to break down disciplinary barriers, achieve complementary advantages on the basis of their differences, and promote the integration of knowledge and capabilities (Dai & Zhang, 2021). Art-Engineering Integration emphasizes cross-disciplinary convergence between artistic and engineering disciplines. By incorporating engineering education, this approach enhances designers' capabilities and professional vision, cultivating interdisciplinary talent equipped with engineering mindsets and technical competencies. This effectively overcomes the limitations of conventional design education, which often produces professionals with narrow perspectives and singular skill sets. Guided by the development of new engineering and new liberal arts, we will vigorously develop disciplines that are in line with regional economic and social development, strengthen the connection with professional directions such as computer digital twin technology, automated intelligent robots, management, art, and blockchain, and create a disciplinary feature of "the integration of art and engineering" (Chen & Xu, 2023).

In the power design field, Art-Engineering Integration not only elevates equipment user experience but also addresses complex technical challenges through innovative design thinking. For instance, artistically crafted interfaces reduce users' cognitive load during equipment operation, while engineering-optimized designs enhance device maintainability and environmental adaptability.

As the complexity and interdisciplinary nature of power design intensify, professionals with single-discipline backgrounds increasingly fail to meet industry demands. Aligned with industrial evolution, the Art-Engineering talent development model necessitates urgent exploration of interdisciplinary frameworks within graduate education – the critical stage for cultivating advanced professionals. This requires integrating engineering principles with design pedagogy according to disciplinary education patterns to develop a new generation of designers possessing both engineering acumen and creative capabilities.

Research Status and Issues

In Art-Engineering Integration research, Western institutions pioneered earlier developments. The MIT Media Lab, for instance, has advanced deep convergence between art and engineering through interdisciplinary collaboration. While China has increasingly prioritized this approach in recent years, its application within power design remains exploratory. Current power design research predominantly focuses on technical optimization of power systems (e.g., smart grids and renewable energy integration), with inadequate attention to user experience and interaction design. Regarding graduate education research, interdisciplinary models concentrate primarily on medicine and computer science, while cross-disciplinary studies integrating power design with artistic design remain scarce.

Traditional power equipment design prioritizes functionality at the expense of users' emotional needs and operational experience. Within existing graduate education frameworks, curricula for artistic design and power engineering operate independently, lacking effective interdisciplinary collaboration mechanisms. Theoretical research in power design is abundant yet suffers from insufficient connection to practical application scenarios, resulting in significant implementation barriers.

Research Objectives and Innovation Points

This research establishes an Art-Engineering integrated framework for power product design and explores synergistic innovation pathways between artistic design and power engineering. Through an original case study on mobile charging piles, it validates the application value of Art-Engineering Integration in power design. The study further proposes optimized interdisciplinary graduate education models to provide theoretical support for cultivating composite power design talent.

In theoretical innovation, we introduce the "Art-Engineering-Electricity" fusion framework, offering new perspectives for interdisciplinary research in power design while exploring concrete implementation approaches for Art-Engineering Integration in power product development.

Regarding practical innovation, the mobile charging pile case study demonstrates real-world applications of this integrated approach. Through user research and iterative optimization, we deliver actionable design improvement solutions.

For educational innovation, we construct a cross-disciplinary graduate education framework providing practical references for cultivating versatile power design professionals. Industry-academia collaboration projects facilitate knowledge transfer and application of research outcomes.

THE THEORETICAL FRAMEWORK OF ART AND TECHNOLOGY INTEGRATION AND THE ANALYSIS OF POWER DESIGN REQUIREMENTS

Theoretical Foundations of Art-Engineering Integration

Within power design, Art-Engineering Integration addresses not only technical performance but also prioritizes user experience, environmental adaptability, and cultural expression.

Design thinking—a user-centered innovation methodology—comprises five phases: empathizing, problem definition, ideation, prototyping, and testing. In power design, this approach enables teams to develop innovative solutions rooted in user needs. For instance, user research revealing operational complexities in charging piles can drive the creation of more intuitive interfaces.

User experience design emphasizes users' sensory and emotional engagement during product interaction, encompassing usability, efficiency, and affective response. Interaction design theories (e.g., cognitive ergonomics) provide scientific foundations for power equipment interfaces. Practical applications include reducing operational steps and cognitive load to enhance device usability.

Engineering design prioritizes functionality, safety, and maintainability—principles critically applied in power design. Charging pile development, for example, in terms of safety attributes, the design of the charging station must comply with all technical specifications and configuration requirements, and also be convenient for maintenance and upgrades (Jin, 2021).

The pain points and innovation directions in the field of power design

Firstly, power design needs to take safety into account. Power equipment involves high voltage electricity and complex circuits, and the design must comply with strict safety standards. Secondly, functionality should be considered. Power equipment needs to meet specific technical performance requirements, such as power conversion efficiency and load capacity. Finally, sustainability is also of great importance. Under the goal of carbon neutrality, the design of power equipment needs to consider energy efficiency and environmental impact.

In terms of user experience, the traditional design of power equipment focuses more on technology and less on user experience, resulting in complex operations for users and high learning costs. For instance, the interface design of charging stations is not intuitive enough, making it difficult for users to quickly master the usage methods. In terms of environmental impact, the design of some power equipment does not fully consider the diversity of usage scenarios. For example, fixed charging stations cannot meet the temporary charging needs. In terms of cultural expression, power equipment, as public facilities, often lack regional cultural characteristics and are difficult to coexist harmoniously with the surrounding environment.

Through artistic design, enhance the aesthetic appeal of power equipment while ensuring its functionality remains unaffected, achieving the unity of function and beauty. Utilize technologies such as AR/VR and voice recognition to construct multi-dimensional sensory fusion navigation scenarios, improve the interactive experience of power equipment, and realize intelligent interactive design (Yin & Xiang, 2025). Design modular power equipment that supports rapid deployment and flexible adjustment, achieving modularity and mobility.

Key elements of interdisciplinary graduate education

The complexity and comprehensiveness of the field of power design require talents to possess a multidisciplinary knowledge background. The integration of art and engineering mainly manifests in the following two characteristics: First, the intuitive thinking of art design and the rational thinking of engineering design are organically combined; second, the artistic qualities, skills, and engineering knowledge, skills are organically integrated (Dai & Zhang, 2021). The term "integration" here refers to integrating appropriate engineering courses into the design field, that is, the cross-combination of design and engineering, to cultivate new types of design talents who possess both artistic qualities, artistic skills, and engineering experience, as well as engineering capabilities.

The fundamentals of the power system cover the basic principles and technical requirements of power engineering. The principles of interaction design introduce the basic methods of user experience design and interface design. Sustainable design explores how to incorporate environmental protection concepts into power design. The school-enterprise cooperation project uses actual power design projects as the carrier to cultivate students' practical abilities. The interdisciplinary workshops solve complex design problems through teamwork (Lv, 2025).

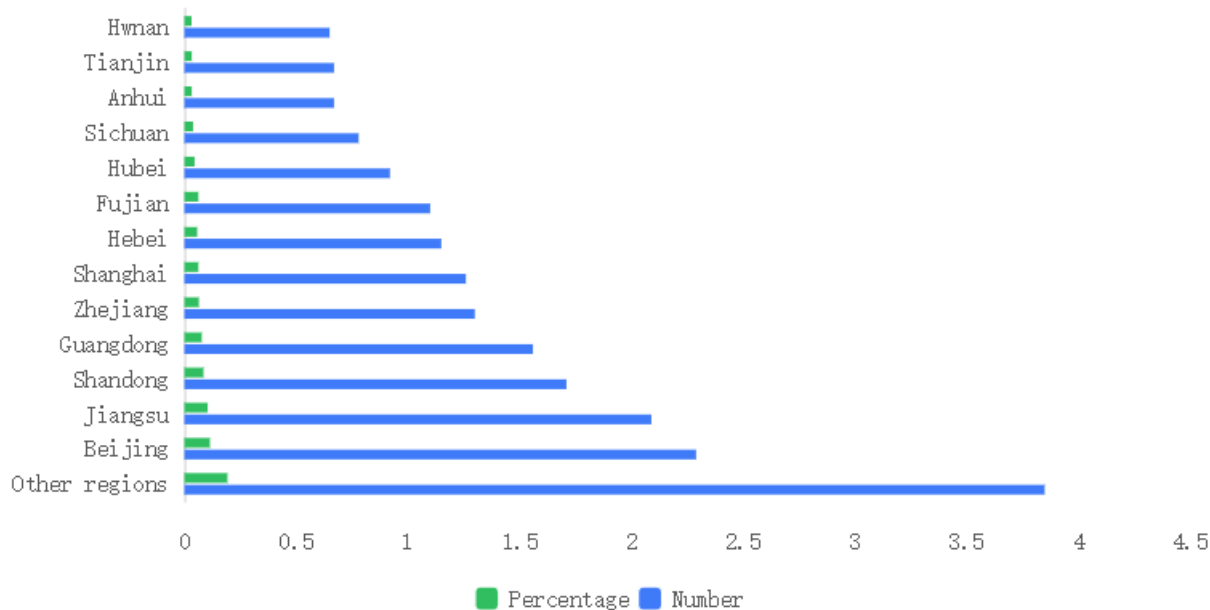
Forming a high-level interdisciplinary teaching team is an important supporting force for achieving the integration of art and engineering. The school closely follows the requirements for the teaching staff in the cultivation of applied talents, vigorously implements the talent-driven strategy, and collaborates with enterprises to build a "dual-qualified" teaching team (Wang, Gao, & Miao, 2023). Through the dual-mentor system, mentors from the fields of art design and power engineering jointly guide students to ensure the combination of theory and practice. Through rapid prototyping design and user testing, students' iterative optimization ability is cultivated. Using practical cases as the starting point, students are helped to understand the specific application of the integration of art and engineering. An electricity design innovation laboratory is established to provide hardware and software support for students. Cooperation with power enterprises is carried out to offer internship and project practice opportunities for students. Through cooperation with international universities and enterprises, students' horizons are expanded (Manager's Journal Editorial Department, 2025).

THE ARTISTIC AND TECHNOLOGICAL INTEGRATION DESIGN PRACTICE OF MOBILE CHARGING STATIONS

Preliminary research and analysis of design concepts

Amid the global surge in new energy vehicle development, developed economies including Europe, the US, and Japan have achieved phased progress in charging infrastructure deployment. However, significant gaps persist in overall scale and deployment efficiency compared to China. Taking the United States, Germany, and Japan as examples, their charging networks remain concentrated in urban cores, with pronounced supply shortages in peri-urban areas and emerging communities. Notably, DC fast-charging piles constitute less than 30% of their total installations.

In contrast, China has established the world's largest charging infrastructure system. As of August 2023, public charging points reached 2.27 million units while private installations totaled 4.94 million, demonstrating a distinctive "volume leadership with structural diversity" advantage. This leapfrog development stems from robust propulsion by China's new energy vehicle industry, with total charging points projected to exceed 6.54 million by 2025—fully manifesting the nation's strategic capacity in new energy infrastructure (Figure 1).



Source: This study

Figure 1: Number and proportion of public DC charging stations in China by region - per unit quantity (ten thousand units, %)

Modern public service facility design requires systems thinking to integrate functionality with social value, emphasizing foresight and intensiveness at the planning level. Through demand forecasting models and moderately (forward-looking construction standards), such as reserving 30% capacity redundancy in new energy vehicle charging networks, while enhancing facility sharing rates via grid-based layouts to reduce redundant construction. Transportation facility design should apply fluid dynamics principles to optimize flow paths, dynamically regulating traffic efficiency with intelligent algorithms—exemplified by AI guidance systems around charging stations that alleviate peak-hour congestion.

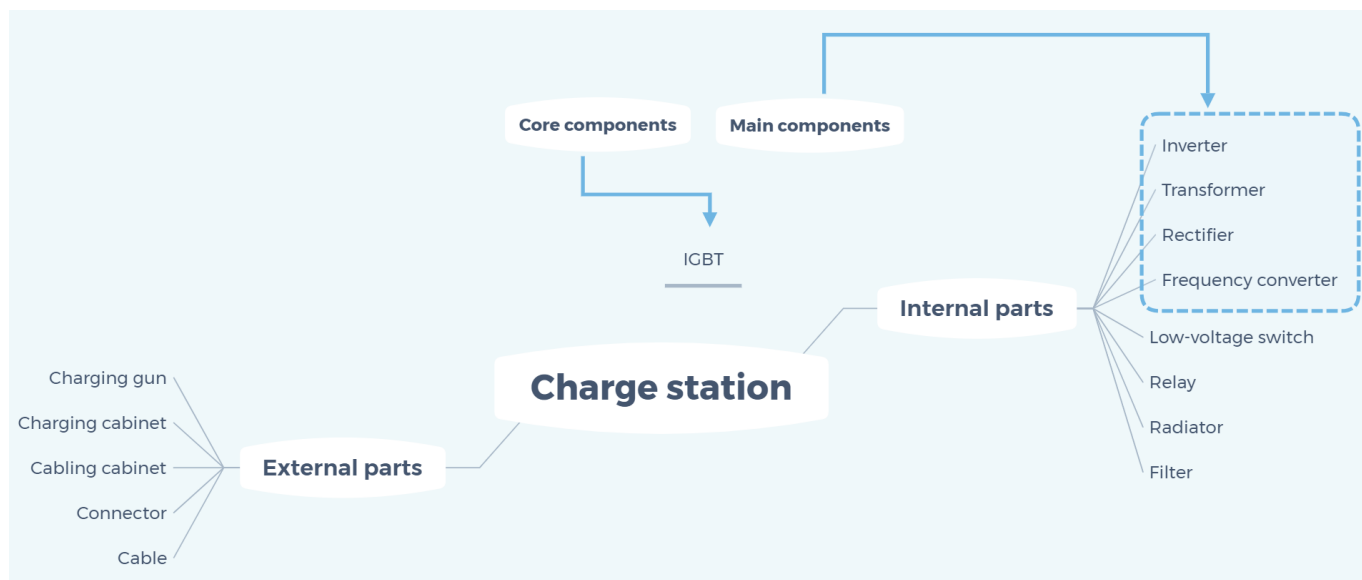
Material selection adheres to low-carbon principles: phase-change energy-storage walls reduce building energy consumption, while photovoltaic glass canopies enable energy self-sufficiency. Equipment specification prioritizes high-efficiency energy conservation—DC fast-charging piles must achieve >95% conversion efficiency, and LED lighting systems with photosensitive modulation technology can reduce energy use by 40%. Ecological protection implements "facility symbiosis" concepts: rainwater collection systems embedded beneath charging bays and vertical greening modules atop structures integrate facilities with the environment organically.

Safety-economic equilibrium mechanisms are crucial for operations. A three-tier "prevention-monitoring-response" safety framework employs flame-retardant cables and intelligent fusing devices, with IoT systems providing real-time monitoring of temperature and current parameters. Economic viability requires innovative business models: beyond basic service fees, diversified revenue streams include peak-valley pricing arbitrage and energy storage frequency regulation services. To address utilization challenges, the "tidal charging" strategy leverages daytime availability in commercial zones and nighttime resources in residential areas, combined with dynamic pricing models to increase daily utilization per pile to over 1.5 cycles.

Human-centered dimensions focus on experience enhancement: interface design follows universal principles with accessibility features like voice interaction and sign language guidance; charging gun grips employ ergonomic contours. Cultural empowerment transforms regional symbols into interactive elements—charging pile housings integrate projections of urban intangible cultural heritage patterns. Specialized services include on-demand mobile charging and dedicated bays for persons with disabilities, forming an inclusive service network where infrastructure embodies urban civilization.

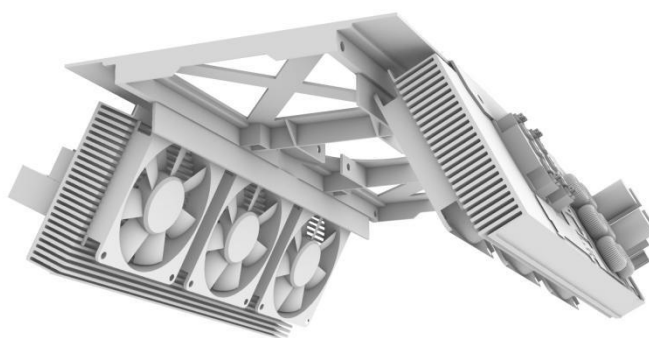
Product operation mode and technical setup

The core components of charging piles are primarily integrated within the power conversion module. As the central subsystem, its operational efficiency governs power transmission losses and determines service capacity—including compatibility with diverse automotive charging protocols and the maximum number of vehicles served per unit time. These parameters provide fundamental references for optimizing single-pile utilization rates. Being the primary heat source within the system, this design implements innovative thermal management solutions (Figs. 2 and 3).



Source: This study

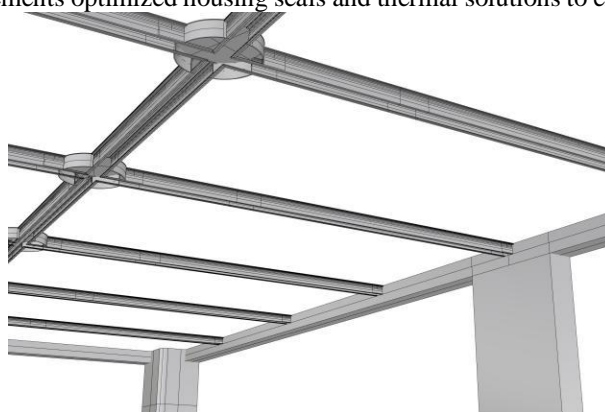
Figure 2: Schematic diagram of main components of the charging station

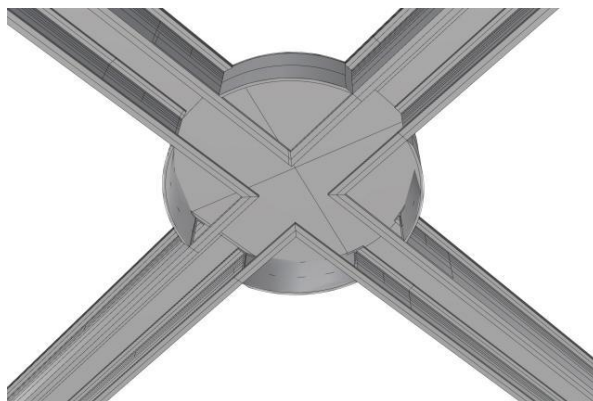


Source: This study

Figure 3: Power charging station structural components

Referencing waterproof enclosure technologies, outdoor public charging facilities must achieve IPX6-rated waterproof standards—ensuring no water ingress occurs during direct high-pressure jets from any direction—to guarantee operational stability and electrical safety compliance. Given that public DC fast-charging equipment requires dedicated cooling channels during operation, this design implements optimized housing seals and thermal solutions to ensure outdoor deployability (Fig. 4).





Source: This study

Figure 4: Schematic diagram of waterproofing components for outdoor facilities

Addressing the limitations of top-down cable strain imposed by the larger cross-section and increased weight of DC fast-charging cables, this design proposes a novel bidirectional retraction mechanism. The solution leverages cable resilience through a downward-spiral retraction system (Fig. 5).



Source: This study

Figure 5: Schematic diagram of waterproofing components for outdoor facilities

Simultaneously, this system incorporates automatic charging termination functionality. By integrating the cable retraction mechanism with vehicle-targeting capabilities, the design significantly minimizes temporal inefficiencies associated with charging completion waits and queue delays.

CONSTRUCTION OF AN INTERDISCIPLINARY GRADUATE EDUCATION MODEL

Analysis of the Demand for Interdisciplinary Graduate Education

The escalating complexity and interdisciplinary nature of power design have intensified industry demand for professionals possessing dual expertise in technology and design. Power enterprises increasingly require talent capable of developing intelligent, user-friendly electrical equipment while demonstrating competencies in both engineering and artistic design.

Within traditional graduate education frameworks, curricula for artistic design and power engineering remain segregated, limiting students' interdisciplinary integration capabilities. Insufficient exposure to authentic projects during academic training hinders effective translation of theoretical knowledge into practice. Furthermore, while cross-disciplinary initiatives necessitate collaboration among specialists from diverse fields, students often lack adequate experience in cross-functional teamwork.

Current graduate education models fail to address industry needs for interdisciplinary professionals, urgently necessitating educational reforms that enhance students' comprehensive competencies through cross-disciplinary pedagogy.

The construction of an interdisciplinary graduate education model

Curriculum Architecture

In the core course module, the "Fundamentals of Electrical Engineering" course covers topics such as power system principles and electrical safety standards, providing students with a technical foundation. The "Art and Design" course includes design thinking, user experience design, and interaction design principles, fostering students' design capabilities. Additionally, interdisciplinary integrated courses like "Innovative Design of Electrical Products" and "Smart Grid and Interaction Technology"

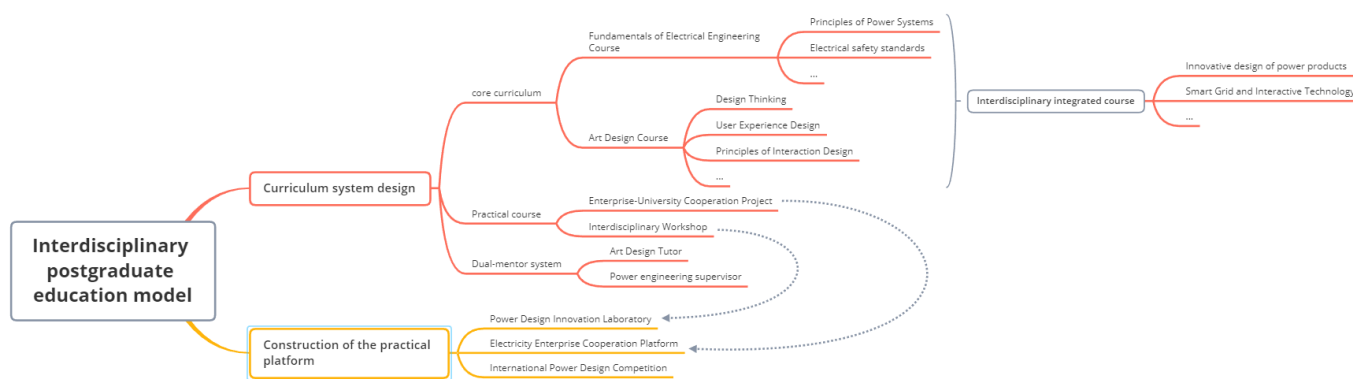
are offered to promote the integration of art and engineering.

In the practical course module, students' practical abilities are cultivated through actual electrical design projects. For instance, they collaborate with power enterprises to develop mobile charging piles. Interdisciplinary workshops are established, where students solve complex design problems through teamwork, enhancing their comprehensive abilities.

A dual-mentor system is implemented, with mentors from both the art and design and electrical engineering fields guiding students to ensure the integration of theory and practice. Moreover, rapid prototyping and user testing are conducted to cultivate students' iterative optimization capabilities. Actual cases are also used to help students understand the specific applications of the integration of art and engineering.

Practical Platform Development

Establish an electrical design innovation laboratory to provide students with hardware and software support. For instance, equip with 3D printers, interactive design software, etc.; collaborate with power enterprises to offer internship and project practice opportunities for students. For example, participate in the research and testing of power equipment; expand students' horizons through cooperation with international universities and enterprises (Manager's Journal Editorial Department, 2025). For instance, organize students to participate in international electrical design competitions.



Source: This study

Figure 6: Exploration Framework Diagram of Interdisciplinary Graduate Education Model

Educational Practice of the Mobile Charging Station Project

As an innovative product in the field of power design, mobile charging piles involve interdisciplinary collaboration among art design, interaction technology, and power engineering. Through school-enterprise cooperation projects, graduate student teams participate in the design and development of mobile charging piles, applying theoretical knowledge to practice. Through user research and industry analysis, the design requirements of mobile charging piles are clarified. The art design team proposes appearance and interaction interface solutions, while the power engineering team assesses technical feasibility. Utilizing on-campus laboratory resources, prototypes of mobile charging piles are produced. User tests are conducted in actual scenarios to collect feedback and optimize the design. Through project practice, students have mastered interdisciplinary collaboration methods, enhancing their practical abilities and teamwork skills.

DISCUSSION AND OUTLOOK

The limitations of the integration of art and craftsmanship

The application of art and engineering integration in power design requires a significant investment of resources, including hardware equipment (such as AR/VR devices, 3D printers) and software tools (such as interaction design software, simulation platforms). For some universities and enterprises, the high technical costs may become an obstacle to promoting the integration of art and engineering.

There are differences in the thinking patterns and work processes between the fields of art design and power engineering, which may lead to low team collaboration efficiency. For instance, designers focus more on user experience and aesthetic expression, while engineers pay more attention to technical feasibility and safety. The communication between the two requires time and adjustment.

The innovative design of art and engineering integration may face issues of user acceptance. For example, elderly users may feel uncomfortable with complex interaction interfaces. Market promotion needs to fully consider the diversity of user groups and enhance the acceptance of the product through user education.

Future research directions

Apart from mobile charging stations, the integration of art and engineering can also be applied to other power design scenarios.

For instance, power inspection robots can enhance the user experience and work efficiency of the inspection robots through artistic appearance design and intelligent interactive interfaces.

Technology provides intelligent tools to quickly generate design plans and improve design efficiency (Du & Song, 2024). Through VR/AR technology to simulate the operating environment of power equipment, the design and user experience can be optimized. Moreover, by exploring environmentally friendly materials and manufacturing processes, the environmental impact of power equipment can be reduced.

CONCLUSION

This study systematically validates the multidimensional value of Art-Engineering Integration in power design through theoretical analysis and a mobile charging pile case study. Technologically, interdisciplinary collaboration between art and engineering has not merely optimized equipment functionality and user experience via modular architectures, intelligent interfaces, and sustainable design—but more crucially overcome traditional technical bottlenecks including high-power thermal management efficiency, dynamic resource allocation, and complex environmental adaptability through innovative design thinking.

Educationally, the research establishes an "Art-Engineering-Electricity" convergence framework, proposing: interdisciplinary curricula (e.g., bidirectional integration of interaction design principles with power systems fundamentals); dual-supervision project practicums (industry-academia co-development of mobile charging piles); and intelligent laboratory platforms. This ecosystem cultivates professionals possessing both technical logic and aesthetic discernment.

For industry implementation, the outcomes enhance charging infrastructure deployment flexibility, streamline user operations, and strengthen socio-environmental adaptability—providing replicable methodological support for smart-city charging networks while establishing foundations for Art-Engineering applications in emerging domains like power inspection robotics and home energy management systems. Future research will deepen interdisciplinary collaboration mechanisms, exploring AI and generative design integration pathways for power product innovation to propel the industry toward intelligent, sustainable, and human-centered evolution.

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