

Research on Training Strategies for Intelligent Manufacturing Engineering Professionals Based on the Needs of the Power Transmission and Transformation Equipment Industry Chain

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Abstract: With global energy structure transitions and increasing power demands, China's power transmission and transformation equipment industry chain faces unprecedented opportunities and challenges. Industrial 4.0-driven intelligent manufacturing technology is being increasingly applied to this sector, creating a pressing need for skilled professionals. In this context, cultivating intelligent manufacturing engineering professionals is crucial. This paper proposes training strategies tailored to the specific needs of China's power transmission industry, addressing the demand for intelligent manufacturing professionals in the sector.

1. Introduction

Amid the global transition in energy structures and rising power demands, the health of the power transmission and transformation equipment industry chain, a vital part of the transmission system, directly impacts national energy security and sustainable economic development. Industrial 4.0-centered intelligent manufacturing technology, applied within this industry chain, can increase productivity, reduce operational costs, enhance automation, and ultimately improve grid stability. Thus, focusing on the power transmission equipment industry chain, this study explores intelligent manufacturing engineering training strategies to cultivate high-skilled professionals essential for the industry's growth.

2. Analysis of Industry Chain Needs

2.1 Current Status of the Power Transmission Equipment Industry Chain

China's power transmission and transformation equipment industry chain is undergoing significant growth, propelled by technological innovation and evolving market demands. This rapid development is largely influenced by global energy transitions towards renewable sources and the increasing adoption of smart grid technologies. The shift to clean energy, including wind and solar

power, has heightened the demand for advanced transmission equipment that ensures efficient and reliable energy distribution. To stay competitive, the industry is prioritizing the integration of intelligent manufacturing technologies such as automation, robotics, the Internet of Things (IoT), big data analytics, and artificial intelligence (AI). These advancements not only enhance production efficiency and product quality but also reduce operational costs and improve system reliability. Major state-owned enterprises like China XD and State Grid Corporation of China lead the market, leveraging their strong research and development capabilities. However, the rise of private and medium-sized enterprises is introducing more innovation and flexibility into the sector. Despite the positive growth trajectory, the industry faces challenges including reliance on imported core technologies and a shortage of skilled professionals. Addressing these issues requires a focus on talent cultivation, emphasizing a strong foundation in traditional electrical engineering combined with interdisciplinary skills in big data and machine learning. By fostering such expertise, China's power transmission equipment industry chain is well-equipped to meet the demands of a smart, sustainable energy future.

2.2 Industry Demand for Intelligent Manufacturing Engineering Professionals

As global energy structures shift towards more sustainable and renewable sources and smart grid technologies continue to advance, the demand for skilled professionals in intelligent manufacturing is significantly increasing in China. The adoption of Industry 4.0 principles is transforming the manufacturing landscape, pushing it towards smarter, more networked, and service-oriented practices. This transformation necessitates engineers who not only have a strong foundation in electrical engineering but also possess interdisciplinary skills in areas such as big data analytics, robotics, and the Internet of Things (IoT). The integration of these advanced technologies into the power transmission and transformation equipment industry requires professionals who can design, implement, and manage complex systems that enhance efficiency and reliability. For instance, big data analytics enables the optimization of energy distribution, while robotics and automation improve production processes and maintenance operations. Additionally, IoT facilitates real-time monitoring and control of equipment, leading to predictive maintenance and reduced downtime. Training high-quality professionals is crucial for maintaining the competitiveness and sustainability of the entire industry chain. To meet this demand, a multi-faceted training approach is essential. This approach should include industry-academic partnerships that provide students with practical, hands-on experience and exposure to the latest technologies. Collaborative projects, internships, and co-developed curricula can bridge the gap between theoretical knowledge and real-world applications, ensuring that graduates are well-equipped to address the future needs of the power transmission equipment industry chain. By fostering such comprehensive training programs, China can cultivate a workforce capable of driving innovation and sustaining growth in this critical sector.

3. Importance of Intelligent Manufacturing Engineering Training in Response to Industry Chain Needs

3.1 Strategic Role of Professionals in the Industry Chain

Intelligent manufacturing professionals are indispensable to the advancement of China's power transmission and transformation equipment industry chain. In the era of Industry 4.0, traditional manufacturing paradigms are being transformed into highly intelligent, automated, and interconnected systems. Professionals in this field are pivotal in driving this transformation by leveraging their expertise to enhance operational efficiency through innovative design and optimized production processes. Their ability to integrate advanced technologies such as the

Internet of Things (IoT), big data analytics, and cloud computing is essential for creating smarter and more resilient manufacturing systems. These professionals play a strategic role in reducing energy consumption and operational costs by utilizing data-driven insights and intelligent control mechanisms. For example, through sophisticated data analysis, they can identify inefficiencies in the production line and implement solutions that streamline operations, thereby minimizing waste and energy usage. Additionally, intelligent control systems enable precise regulation of manufacturing processes, ensuring optimal performance and reducing the likelihood of costly errors or downtime. Aligning with the national "Industrial 4.0" strategy, the training of these professionals emphasizes the integration of IoT, big data, and cloud computing to achieve seamless equipment intelligence and connectivity. Smart monitoring systems, developed and managed by these skilled engineers, facilitate real-time tracking of equipment status and enable predictive maintenance. This proactive approach not only reduces unexpected downtimes but also enhances the overall reliability and safety of the power transmission infrastructure. Furthermore, intelligent manufacturing professionals contribute to the scalability and adaptability of the industry chain, allowing it to respond swiftly to market changes and technological advancements. Their expertise ensures that the power transmission equipment remains at the forefront of innovation, maintaining China's competitive edge in the global market. By fostering a workforce capable of driving continuous improvement and technological integration, these professionals are key to sustaining the growth and sustainability of the entire industry chain. In summary, intelligent manufacturing professionals are central to the strategic development of China's power transmission equipment industry chain. Their role in enhancing efficiency, reducing costs, and implementing advanced technologies aligns with national strategic goals, ensuring the industry remains robust, competitive, and capable of meeting future energy demands.

3.2 Role of Talent Development in Driving Industry Chain Growth

The continuous improvement of China's power transmission equipment industry chain has made intelligent manufacturing talent cultivation an important force for the sector's upgrade and transformation. In Industry 4.0, intelligent manufacturing technology is increasingly applied in this field, demanding highly skilled talent capable of driving innovation, optimizing production processes, and enhancing overall industry competitiveness. Training professionals with advanced skills, like predictive maintenance systems, can lower equipment failure rates, extend equipment life, and minimize production interruptions. For reliable grid operations, close collaboration between universities and industries is essential, with a joint curriculum that combines theoretical knowledge with practical application, ensuring graduates are industry-ready.

3.3 Evolution of Competency Requirements for Professionals in Industry Chain Development

As China's power transmission and transformation equipment industry chain rapidly grows, the demand for intelligent manufacturing professionals continues to evolve. These engineers are required not only to have a solid foundation in traditional electrical engineering but also to master the ability to analyze and interpret big data to optimize production processes and enhance overall efficiency. For instance, experts can apply machine learning technologies to predict equipment failures, thereby enabling preventive maintenance, reducing downtime, and improving the reliability and lifespan of equipment. In the Industry 4.0 era, professionals must integrate traditional electrical engineering knowledge with emerging disciplines such as computer science, artificial intelligence (AI), and the Internet of Things (IoT) to meet the increasingly complex demands of the industry. Furthermore, with the continuous advancement of intelligent manufacturing technologies, engineers must also possess interdisciplinary collaboration skills to effectively communicate and

cooperate within multifunctional teams. This includes understanding and applying advanced automation technologies, intelligent control systems, and data-driven decision-making methods. Additionally, as the industry places greater emphasis on sustainable development and energy efficiency, professionals must also have environmental awareness and resource management skills to promote green manufacturing and energy conservation. To adapt to these changes, the education and training systems must accordingly adjust, offering courses and practical opportunities that encompass multidisciplinary knowledge. By collaborating with enterprises to develop customized training programs, it is possible to cultivate versatile talents who are not only technically proficient but also innovative. This approach is essential to effectively support the sustained development and competitiveness enhancement of the power transmission and transformation equipment industry chain. In summary, the competency requirements for intelligent manufacturing professionals are evolving towards a more comprehensive and diversified direction to address the rapid changes and future challenges of the industry.

3.4 Alignment of Training with National Strategy

Amid China's ongoing industrial transformation, intelligent manufacturing has emerged as a cornerstone of the national strategy, pivotal for sustaining future industrial growth. The "Made in China 2025" initiative underscores the importance of advancing manufacturing capabilities through innovation and technology, positioning intelligent manufacturing at the heart of this vision. Cultivating skilled professionals in intelligent manufacturing is therefore essential to achieving the goals set forth by this initiative. These professionals must possess not only advanced technical knowledge in areas such as automation, robotics, and artificial intelligence but also interdisciplinary skills that bridge traditional engineering with emerging technologies like big data and the Internet of Things (IoT). Additionally, innovative capabilities are crucial for addressing the complex and evolving demands of the power transmission equipment industry chain. To effectively align training strategies with national priorities, a multifaceted approach is necessary. This includes fostering robust industry-academic partnerships that facilitate the exchange of knowledge and resources between universities and leading manufacturing enterprises. Practical learning experiences, such as internships, co-op programs, and hands-on projects, are integral to bridging the gap between theoretical education and real-world application. Furthermore, implementing a robust feedback mechanism ensures that training programs remain responsive to the dynamic needs of the industry and national development goals. Continuous evaluation and adaptation of curricula based on industry trends and technological advancements help maintain the relevance and effectiveness of training initiatives. By aligning training strategies with national priorities, China ensures that its workforce is well-equipped to support the sustainable growth of the manufacturing sector. This alignment not only enhances the competitiveness of the power transmission equipment industry chain but also contributes to the broader objectives of economic resilience and technological leadership on the global stage. Ultimately, a strategic alignment between training programs and national initiatives like "Made in China 2025" is fundamental to nurturing a talent pool capable of driving innovation and sustaining long-term industrial advancement.

3.5 Importance of Cultivating Innovation Skills in Professionals from an Industry Chain Perspective

With the rapid growth of China's power transmission equipment industry chain, higher standards for intelligent manufacturing professionals have emerged. In the context of Industry 4.0, intelligent manufacturing drives industry chain upgrades, and professionals play a strategic role in promoting technological and product innovation. The core competency of intelligent manufacturing

professionals is their ability to innovate. Thus, educational institutions should design curriculum and practical projects that stimulate creative thinking and problem-solving skills. For example, lean innovation models that emphasize rapid iteration and user feedback can help students turn creative ideas into practical products and services. Moreover, industry partnerships allow students to engage in real-world projects, deepening their understanding of industry chain operations and enhancing their innovation skills. Cultivating future leaders and advancing the power transmission equipment industry chain's innovation and development depend on effectively training intelligent manufacturing professionals.[1]

4. Strategies for Training Intelligent Manufacturing Engineering Professionals Based on the Needs of the Power Transmission and Transformation Equipment Industry Chain

4.1 Defining Training Goals for Intelligent Manufacturing Professionals in the Industry Chain Context

With the rapid development of China's power transmission and transformation equipment industry chain, the training goals for intelligent manufacturing professionals have evolved. Professionals in this field need not only solid knowledge in traditional electrical engineering but also interdisciplinary skills in big data analysis, machine learning, and IoT. Training objectives should align with the industry chain's sustainability needs, emphasizing environmental awareness, energy conservation, and resource efficiency. For example, integrating circular economy principles into production processes can make manufacturing greener and smarter, reducing energy consumption and waste. Furthermore, aligning training goals with national strategies, such as "Made in China 2025," is essential for future-oriented, strategic talent development. Using SWOT analysis to evaluate the role of intelligent manufacturing professionals within the industry chain enables more scientific training plans. Collaborations with leading companies, like State Grid, ensure seamless alignment between training and industry needs, providing students with real-world experience and developing a talent pool suited to the industry's future demands.[2]

4.2 Reforming the Curriculum Based on Industry Chain Needs

The rapid development of the power transmission equipment industry chain necessitates comprehensive reforms in the curriculum for intelligent manufacturing. To remain relevant and effective, the curriculum must closely align with current and emerging industry needs. This includes the introduction of new courses focused on smart grid technology, big data analytics, and the Internet of Things (IoT), which are pivotal in modernizing and optimizing power transmission systems. Additionally, curriculum reforms should emphasize the cultivation of creative thinking and innovation, encouraging students to explore novel solutions and contribute meaningful advancements to the industry chain. Adapting the curriculum to incorporate the latest industry advancements is crucial. For instance, integrating 5G technology into the curriculum addresses the need for high-speed, low-latency communication essential for smart manufacturing environments. This ensures that graduates are proficient in the latest technologies that drive efficiency and connectivity in power transmission systems. Furthermore, case-based teaching methods are vital; by analyzing real-world successes and failures within the global power transmission industry, students can develop a deeper understanding of practical challenges and enhance their problem-solving abilities. Practical training components, such as hands-on projects, internships, and strong industry-academic partnerships, further strengthen the curriculum. These elements provide students with direct exposure to real-world projects, allowing them to apply theoretical knowledge in practical settings and gain valuable industry experience. Collaborations with leading companies in

the power transmission sector enable the development of tailored training programs that meet specific industry requirements. By engaging directly with industry professionals and participating in live projects, students are better prepared for their future roles, ensuring a seamless transition from education to employment. This holistic approach to curriculum reform not only meets the immediate needs of the power transmission equipment industry chain but also fosters a generation of skilled, innovative professionals poised to drive future advancements.[3]

4.3 Innovation in Talent Training Models through Industry-Academia Cooperation

Innovative industry-academia collaboration models are essential for bridging the gap between educational offerings and the dynamic demands of the power transmission equipment industry. These partnerships ensure that the curriculum remains relevant and responsive to the latest technological advancements and industry trends. By integrating industry requirements directly into the educational framework, students gain exposure to cutting-edge technologies and real-world work environments, which significantly enhances their practical skills and employability. One effective model is the co-development of specialized courses and modules that are jointly designed by academic institutions and industry experts. This ensures that the content is both academically rigorous and practically applicable. Additionally, establishing on-campus and off-campus training bases, such as state-of-the-art laboratories and industry-sponsored research centers, provides students with hands-on experience in real settings. These training bases serve as incubation hubs for innovation, where students can work on live projects, experiment with new technologies, and collaborate with seasoned professionals. Furthermore, regular evaluation meetings and feedback sessions with industry partners are crucial for maintaining the alignment of teaching plans and content with evolving industry-specific talent needs. These interactions facilitate the continuous improvement of educational programs, allowing for timely updates and the incorporation of emerging technologies and methodologies. For example, incorporating the latest advancements in artificial intelligence and IoT into the curriculum can prepare students to handle sophisticated smart grid systems and predictive maintenance technologies. Moreover, internships, apprenticeships, and cooperative education programs integrated into the academic schedule enable students to gain valuable work experience while still completing their studies. These experiential learning opportunities not only enhance technical competencies but also develop soft skills such as teamwork, problem-solving, and communication, which are highly valued in the industry. By fostering strong industry-academia collaborations, educational institutions can cultivate a pipeline of highly skilled, industry-ready professionals who are equipped to drive innovation and sustain the growth of China's power transmission equipment industry chain. This symbiotic relationship ultimately benefits both the educational sector and the industry, ensuring a steady supply of talent that meets current and future technological and operational demands.[4]

4.4 The Role of Practical Teaching and Optimization Strategies in Talent Development

Practical teaching is vital for training intelligent manufacturing professionals, as it bridges theoretical knowledge and real-world application. Project-based learning, for instance, allows students to engage in all stages of power transmission equipment design, production, installation, and maintenance, gaining valuable experience. Collaborating with industry leaders to develop course content and projects ensures that teaching aligns with industry advancements. Practical teaching should also encourage self-reflection, helping students develop problem-solving and continuous learning skills.[5]

4.5 Building a Quality Evaluation and Feedback Mechanism for Talent Training Based on Industry Chain Needs

Establishing a quality evaluation and feedback mechanism ensures educational outcomes align with industry needs. By collecting and analyzing industry data, the training program can identify essential skills and knowledge areas for intelligent manufacturing. Using dynamic models like PDCA (Plan-Do-Check-Act), the curriculum and teaching methods are continually updated. Integrating case studies in teaching, analyzing both successful and unsuccessful examples in the global industry, enhances students' practical application and problem-solving skills, supporting innovation-oriented development.

5. Conclusion

As global energy structures shift and smart grid technology rapidly advances, China's demand for intelligent manufacturing talent continues to grow. Against this backdrop, the strategic role of intelligent manufacturing professionals is increasingly prominent—not only as drivers of industry growth but also as core agents of innovation. Thus, training strategies must align with national development objectives to adapt to evolving industry needs, particularly for innovative capabilities, ensuring China's competitive advantage in the global power transmission equipment industry chain.

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