

Integrating VR into Power Testing: Opportunities and Challenges

Chen Zhao^{a,*}, Mingqiang Chen, Hongjing Li, Jianing Nie, Xinhai Chen

Xinjiang Power Transmission and Transformation Co., Ltd, Urumqi, Xinjiang, 830000, China

^a814427992@qq.com

*Corresponding author

Abstract: This article delves into the opportunities and challenges posed by virtual reality (VR) technology in the realm of power testing. It scrutinizes the potential benefits of VR technology in enhancing testing efficiency, personnel training, and fostering global cooperation. The article analyzes innovative solutions for monitoring and optimizing power systems. Furthermore, it addresses challenges, such as technical standardization, costs, and ergonomics, which may be encountered during implementation. The article concludes by summarizing the prospects of VR technology in power testing and suggesting a new developmental trajectory for the digital and intelligent future of the industry.

Keywords: virtual reality technology, power testing, testing efficiency, personnel training, global cooperation, intelligence, challenges, opportunities, digitalization, power system

1. Introduction

1.1 Background introduction

In today's society with the rapid development of science and technology, virtual reality (VR) technology, as an innovative tool, has shown strong potential in all walks of life. As VR technology continues to mature and application scenarios expand, we are witnessing its emergence in the field of power testing. Electric power testing, as an important means to ensure the reliability and safety of power systems, usually requires facing complex and changeable environments and equipment[1]. The introduction of VR technology brings new possibilities to power testing, providing a more intuitive, efficient and safe testing environment^[2].

1.2 Research background

At present, the field of power testing still faces a series of challenges, including the complexity of testing, the need for personnel training, and the complexity of data processing. The application of virtual reality technology can provide innovative solutions to these challenges. By simulating a real power system environment, engineers and technicians can conduct real-time testing in a virtual environment without actually being on site. This not only improves the efficiency and accuracy of testing, but also reduces reliance on testing equipment and facilities^[3].

This study aims to deeply explore the application of VR technology in power testing and analyze its potential opportunities in improving test efficiency, personnel training, and solving challenges faced by power testing. Through comprehensive analysis and empirical research on relevant literature, we hope to provide theoretical support and practical guidance for the introduction of VR technology in the field of power testing. This research will not only help promote innovation in power testing technology, but will also provide useful experience and inspiration for the wider application of virtual reality technology in the industrial field[4].

2. Application of VR in power testing

2.1 Potential advantages of VR technology in power testing

The application of virtual reality (VR) technology brings significant potential advantages to the

field of power testing. VR technology can provide a highly realistic virtual environment to simulate the complex operation of the power system and various abnormal conditions^[5]. By using advanced 3D modeling and simulation technology, VR can restore the physical structure and operating status of the power system, allowing engineers to conduct accurate testing and analysis in the virtual environment. In daily maintenance and troubleshooting of power systems, VR technology provides workers with a safe and efficient way. Engineers can enter the virtual power station by wearing VR devices, observe the operation of power equipment in real time, detect potential problems and take timely measures. This not only avoids the risk of actually entering a dangerous environment, but also improves work efficiency and accuracy^[6].

On the other hand, VR technology plays an important role in power system training. Through virtual reality, engineers and technicians can receive realistic training experiences, including operating complex equipment, handling emergency situations, and more. This virtual training not only improves personnel's skill levels, but also reduces training costs and reliance on physical equipment. Engineers can practice repeatedly in a virtual environment to improve their ability to deal with complex problems in real scenarios. The introduction of VR technology also provides new means for power system monitoring and data analysis. By collecting and analyzing data in a virtual environment, engineers can gain a more comprehensive understanding of the operation of the power system and identify potential problems in a timely manner. The data visualization capabilities of virtual reality enable engineers to understand complex power data more intuitively, thereby better formulating maintenance and optimization plans. The potential advantages of VR technology in power testing are reflected in improving test efficiency, ensuring work safety, improving the quality of personnel training, and improving data analysis. This series of advantages not only provides technical support for the power industry, but also lays a solid foundation for the development and maintenance of future power systems^[7].

2.2 Existing VR application cases

In the field of power testing, a series of eye-catching VR application cases have emerged, bringing innovative solutions to the industry. Many power companies have adopted virtual reality technology to simulate the actual operation of the power system. By using advanced 3D modeling and simulation technology, these companies are able to accurately restore various equipment and components of the power station in the virtual environment to achieve a high degree of simulation of the power system. Engineers and technicians can wear VR devices to feel as if they are in an actual power station, monitor the operating status of the equipment in real time, identify potential faults and take corresponding countermeasures. Some power companies have also introduced VR technology in actual maintenance and troubleshooting. By simulating various failure scenarios in a virtual environment, engineers can conduct real-time fault diagnosis and solution verification without actually entering the hazardous environment. This virtual troubleshooting approach not only improves engineer safety, but also reduces additional risks that may arise from real operations. Virtual reality technology is also widely used in the field of power system training. Some power companies and training institutions use VR to simulate the operating procedures of various power equipment and emergency handling processes. Through virtual training, engineers and operators can practice repeatedly in a safe environment to improve their adaptability and operational skills in actual work. This immersive training experience not only improves the effectiveness of training, but also effectively reduces the cost of actual training. Some power companies are also using VR technology for meetings and collaboration. In a virtual environment, engineers and team members can meet remotely through virtual headsets to discuss the design and implementation plans of power projects. This kind of virtual collaboration not only improves work efficiency, but also breaks the constraints of geographical distance, allowing professionals around the world to work together on projects and share experiences. These existing VR application cases have brought substantial benefits to the power testing field, improving testing efficiency, reducing costs, improving personnel training, and promoting innovation in a wider range of the power industry. These cases not only demonstrate the potential value of VR technology, but also provide useful experience for future development.

2.3 Innovations in integrating VR into power testing

The integration of VR into the field of power testing has brought many innovations, injecting new vitality and efficiency into traditional power testing methods. Here are some innovations:

- (1) Real-time data monitoring and analysis: VR technology enables power engineers to monitor

various data of the power system in real time in a virtual environment. Through virtual instruments and data visualization technology, engineers can intuitively understand the operating status of power equipment, quickly identify potential problems and take corresponding measures to achieve more efficient data analysis and monitoring.

(2) Combination of virtual simulation and actual operation: VR provides a safe and real virtual platform for power testing, and engineers can conduct simulation operations of actual equipment in the virtual environment. This combination allows engineers to simulate various scenarios without the actual equipment being affected, understand the response and performance of the equipment in advance, and provide better preparation for actual operations.

(3) Personalization and interactivity of virtual training: VR technology provides a highly personalized learning experience for power system training. Through virtual scenarios, engineers can choose specific training modules according to their own needs and arrange their own learning plans according to actual conditions. Virtual training is also highly interactive. By simulating actual scenarios, students can more deeply understand and apply the knowledge they have learned.

(4) Remote collaboration and teamwork: VR technology provides a new way of collaboration for the power testing team. Engineers and professionals can collaborate remotely from different geographical locations through virtual headsets. This kind of remote teamwork not only improves work efficiency, but also reduces communication barriers caused by geographical location and promotes the sharing of professional resources on a global scale.

(5) Visual reporting and decision support: VR technology can generate highly visual test reports and display all aspects of the power system through virtual reality. This visual report allows decision makers to understand the test results more intuitively and make decisions quickly. This provides a faster and more intuitive means for emergency handling and decision-making.

The innovative point of integrating VR into power testing lies not only in the advanced application of technology, but also in providing new ideas and solutions for power engineering. These innovations promote the digital transformation of power testing and provide more sustainable support for the reliability, safety and efficiency of future power systems.

3. Challenges and needs of power testing

3.1 Complexity and Challenges of Power Testing

Power testing faces a range of complexities and challenges that directly impact the reliability and safety of power systems. The complexity of the power system itself is a major challenge. Modern power systems include complex equipment, networks and control systems, making testing extremely complex due to their size and interconnectedness. The interaction between different power equipment and the system response under different operating conditions require test engineers to have a comprehensive and in-depth understanding of the operating mechanism of the entire system. Electrical testing involves performance and stability evaluation of various devices. These devices include transformers, generators, switchgear, etc. The stability of their performance is directly related to the reliability of the entire power system. Test engineers need to face the performance evaluation of these devices under extreme conditions such as long-term operation, high-load operation, and response to emergencies, which increases the complexity and difficulty of testing. Another challenge is the security needs of power systems. In power testing, ensuring the safety of engineers and test equipment is critical. In actual operations, you may face dangerous factors such as high voltage, high temperature, and electromagnetic radiation. However, existing testing methods often require engineers to directly enter the site, which poses potential safety risks. Wear and aging of equipment during the test process may also lead to safety hazards, and innovative means are required to ensure test safety. The complexity of power systems also leads to uncertainty in testing. Under different operating conditions, power systems may exhibit different performance characteristics, which makes the consistency and accuracy of test results a challenge. Test engineers need to consider the potential impact of various external factors on test results and use scientific and effective methods to deal with these uncertainties to ensure the reliability of test results.

While addressing these challenges, there are also obvious needs in the field of power testing. There is an increasing need for more efficient and accurate testing methods. As the scale and complexity of power systems increase, traditional testing methods can no longer meet the requirements for testing

efficiency and accuracy. The power industry urgently needs innovative testing methods to improve the speed and accuracy of testing. The need for more secure testing methods is also evident. In power testing, safety issues are directly related to the life safety of engineers and field personnel. Therefore, there is an urgent need for innovative means and equipment that can reduce testing risks. This includes avoiding direct entry into hazardous environments and reducing equipment operation risks. The demand for more intelligent testing tools and systems in the field of power testing is also increasing. Intelligent testing systems can use advanced data analysis and artificial intelligence technology to better understand the operating status of the power system, discover problems in a timely manner and propose solutions. This creates an increasingly urgent need for real-time monitoring and remote control of power systems. The complexity and challenges in the field of power testing require us to continuously innovate testing methods and tools to cope with the evolving needs of the power system and ensure its reliability, safety and efficiency. This also provides a strong impetus for the application of VR technology in power testing, and provides new ideas and possibilities for the digital transformation and improvement of the industry.

3.2 Problems VR technology may face in power testing

Although virtual reality (VR) technology has great potential in the field of power testing, its application may still face some challenges and problems. The cost of implementation and maintenance of VR technology can be a constraint. Adopting high-performance VR equipment and systems requires substantial investment, including hardware, software, and training personnel. This can be a burden on the budgets of some power companies and laboratories, especially small and medium-sized enterprises. The applicability of virtual reality technology needs to be verified. The complexity and particularity of the power system make VR technology not applicable in some situations. For example, for some test tasks that require high-precision measurement and fine operations, VR technology may face problems that are difficult to meet actual needs. This requires a comprehensive assessment of the applicable scope of VR technology to ensure that it can effectively function in all aspects of power testing. The realism and accuracy of virtual environments is a critical issue. Power testing often involves a high degree of simulation of complex equipment and environments, and the accuracy of the virtual environment is critical to the reliability of test results. If the virtual environment cannot accurately reproduce the real scene, it may lead to distortion of test results, thus affecting the correct assessment of power system performance. Therefore, it is necessary to continuously improve the simulation capabilities of VR technology to ensure its reliability in power testing. Virtual reality technology may face challenges related to ergonomics and human-computer interaction. Although VR equipment continues to develop, long-term use may still cause eye fatigue, motion sickness and other problems. Engineers' operating experience in a virtual environment also needs to take into account ergonomic factors in actual work to ensure their work efficiency and health. The standardization and industry standardization of virtual reality technology is also a potential issue. The lack of unified VR technology standards may lead to compatibility and consistency issues between different systems. In a critical field such as power testing, it is crucial to ensure the interoperability and stability of various VR systems, which requires the development and compliance of a series of strict technical specifications.

Although VR technology has significant potential in power testing, its implementation and applicability still face a series of challenges. Overcoming these issues requires global cooperation and innovation to ensure that VR technology can achieve maximum benefit in power testing.

3.3 Industry needs and expectations

The power testing industry has increasingly strong demands and expectations for virtual reality (VR) technology, mainly because this technology is expected to solve many challenges faced by traditional testing methods and bring innovative solutions to the industry. The power testing industry urgently needs to improve testing efficiency and accuracy to cope with the increasing complexity of power systems. As power equipment and networks continue to evolve, traditional testing methods may become too cumbersome and time-consuming. By introducing VR technology, power testers can conduct real-time testing in a virtual environment, improve testing efficiency, reduce dependence on field operations, and obtain test results more quickly and accurately. The power testing industry has an urgent need to improve the training effect and safety of testers. Virtual reality technology provides testers with a highly simulated training environment, allowing them to simulate various complex operations and emergency situations in virtual scenarios, thereby improving their ability to cope with actual work challenges. This not only reduces the risks that may be faced during field training, but also

provides testers with a more in-depth and practical training experience to better deal with the diversity and dynamics of power systems. The power testing industry has increasing expectations for innovative digital testing tools and systems. As the power system becomes intelligent and digitally transformed, testing tools also need to develop accordingly. Virtual reality technology provides a more intuitive and interactive means of data visualization, allowing testers to more clearly understand the operating status of the power system. By using VR technology, testers can operate and analyze test data more flexibly, providing more accurate decision support for system maintenance and optimization. The demand for remote collaboration and teamwork is also increasing in the power testing industry. As power projects around the world become increasingly complex, virtual reality technology offers the possibility of remote collaboration among geographically dispersed professionals. Through virtual headsets, team members can share the virtual environment in real time, discuss and solve problems together, and improve team collaboration efficiency to better cope with the diversification and internationalization of power testing projects.

The demand for virtual reality technology in the power testing industry not only comes from the desire to improve testing efficiency, train personnel and digital testing tools, but is also reflected in more flexible remote collaboration methods. By meeting these needs, VR technology is expected to bring revolutionary changes to the field of power testing and promote the industry to develop in a more intelligent, efficient and safe direction.

4. Opportunities for integrating VR into power testing

4.1 Opportunities to improve testing efficiency and accuracy

VR technology has shown great opportunities when integrated into the field of power testing, one of which is to improve testing efficiency and accuracy. Virtual reality technology can simulate complex power system environments, allowing engineers to conduct real-time testing in a virtual environment without actually entering the site. This provides testers with a more flexible way of working and avoids being restricted by various limitations of actual equipment and environments, thus greatly improving testing efficiency. By using VR equipment, engineers can intuitively observe the operating conditions of power equipment and simulate different operating scenarios. This real-time virtual test environment enables testers to have a more comprehensive understanding of the working status of the power system, discover potential problems in a timely manner, and achieve faster fault diagnosis and resolution. Compared with traditional field testing methods, testing in this virtual environment greatly reduces the time cost of testing and improves the accuracy of testing. Virtual reality technology provides a more intuitive and interactive data visualization method for power testing. Engineers can view the performance indicators, data charts, etc. of the power system in real time through the virtual reality interface to more intuitively understand the operation of the system. This visual data analysis method not only improves engineers' ability to understand test data, but also makes monitoring and analysis of complex power systems more efficient, thereby improving accuracy during the test process. In addition, real-time simulation in a virtual environment allows engineers to better predict the performance of power systems under different loads and operating conditions, allowing for more accurate system optimization and adjustment. This virtual optimization process helps to detect potential problems in advance, reduces the trial and error cost of actual equipment adjustment and optimization, and ultimately improves test accuracy and system stability.

The integration of VR technology into the power testing field provides unique opportunities to improve testing efficiency and accuracy. By creating a virtual environment, engineers can conduct testing and analysis more flexibly, obtain system data in real time, and discover problems in advance, thereby achieving more reliable and efficient results in power testing. This opportunity not only promotes innovation in power testing methods, but also promotes the development of the entire power industry in the direction of digitalization and intelligence.

4.2 Opportunities for personnel training and skills improvement

The integration of VR technology in the field of power testing provides unique opportunities for personnel training and skills improvement. Virtual reality technology can provide a highly simulated training environment, allowing engineers and technicians to operate and maintain actual equipment in a virtual scene. This virtual training environment has the characteristics of highly simulating real scenes, allowing trainers to face various complex operating procedures and emergency situations, and practical

experience that is difficult to obtain in actual operations can be exercised in the virtual environment. This provides power testers with a training experience that is closer to actual work and helps improve their ability to cope with actual work. Virtual reality technology provides a more flexible learning method for power testers. Traditional training usually requires people to gather at a specific location to participate in training courses, but VR technology allows training to be conducted anytime and anywhere. By wearing VR devices, engineers and technicians can experience virtual training anywhere without the support of actual equipment. This flexibility not only reduces training time and geographical restrictions, but also enables power testers to arrange their learning plans more independently, improving learning efficiency.

In addition, the personalized features of virtual training also provide a more customized path for power testers to improve their skills. Through virtual reality technology, training can be adjusted according to individual needs to meet the learning speed and level of different people. Engineers can choose specific training modules and focus on their own needs to improve their personal skills more efficiently. This personalized training method not only improves students' interest in learning, but also strengthens their professional capabilities in the field of power testing.

Virtual reality technology brings significant opportunities to the field of power testing in terms of personnel training and skills improvement. By providing a highly simulated, flexible and personalized training experience, VR technology helps improve power testers' operational skills, emergency response capabilities and overall understanding of the power system. This opportunity not only helps to cultivate more professional power testing talents, but also promotes the upgrading and development of the overall talent structure of the power industry.

4.3 Other potential opportunities

In addition to opportunities to improve testing efficiency and personnel training, VR technology opens up other potential opportunities in the field of power testing. Virtual reality technology provides a new way for the design and planning of power systems. Through the virtual reality environment, engineers and designers can create three-dimensional models of power systems in virtual space and demonstrate the effects of different design solutions in real time. This not only helps discover and solve potential problems, but also improves creativity and efficiency in the design process, providing more intuitive visual support for the construction and transformation of power systems. Virtual reality technology provides new possibilities for the operation and maintenance of power systems. By simulating the actual operation of power equipment in a virtual environment, engineers can monitor equipment performance in real time, predict potential failures, and take maintenance measures in advance. This virtual operation and maintenance method not only improves the availability and stability of the equipment, but also reduces the risks and costs in actual maintenance work. Virtual operation and maintenance can also provide a more convenient means for remote maintenance and monitoring of equipment, helping to realize intelligent management of the power system. In addition, virtual reality technology brings more global cooperation opportunities to the field of power testing. In the virtual environment, engineers and professionals can collaborate remotely through virtual headsets to participate in the design, testing and optimization of power projects. This virtual collaboration method not only breaks the restrictions of geographical distance, but also promotes the sharing and exchange of professional resources on a global scale. This global cooperation approach is expected to promote technological innovation and experience sharing in the field of power testing, providing a broader space for the overall development of the industry.

Virtual reality technology has created many opportunities for the field of power testing. From design planning to operation and maintenance to global cooperation, VR technology provides innovative solutions for all aspects of the power system. These opportunities not only help improve the efficiency and reliability of the power system, but also provide broader prospects for the digital transformation and intelligent development of the power industry.

5. Technical implementation and methods

5.1 Selection and adaptation of VR technology

When integrating VR technology into the field of power testing, it is crucial to select appropriate VR technology and effective adaptation methods. For power testing needs, you can choose VR technology based on head-mounted display devices, such as Oculus Rift, HTC Vive, etc. Such devices

can provide high-resolution, low-latency virtual reality experiences, allowing engineers to more realistically experience the environment and operation of power systems.

Room-level positioning and tracking technologies should be considered to enhance user freedom in virtual environments. Using external sensors or built-in cameras for spatial perception allows users to perform more natural and flexible operations in virtual scenes. This degree of freedom is crucial especially for the fine operation and real-time monitoring of power equipment. In addition, in order to improve the realism of the virtual environment, choosing a hand tracking device that supports virtual interaction is also an important technical choice. Hand tracking technology allows engineers to use their own hands to operate in a virtual environment, simulating the feeling of real operations, thereby improving the practicality and fidelity of power testing. In terms of adaptation methods, targeted training must first be conducted to ensure that engineers are proficient in the use and operation of VR equipment. This includes skills training on how to wear the device, use hand tracking, operate virtual interfaces, and more. In order to reduce training costs, VR-based training modules can be developed to simulate the power testing process and help engineers become familiar with operations in the virtual environment. On the other hand, adaptation methods also include the design of virtual environments for power test scenarios. It is necessary to ensure that the virtual environment matches the actual power system scenario to improve the efficiency and realism of engineers in the virtual environment. This may involve 3D modeling of power equipment, scene rendering and other technologies to ensure the precision and realism of the virtual environment.

In order to better promote the application of VR technology in power testing, a progressive implementation method can be adopted. First, conduct a pilot project on a small scale to evaluate the performance and effect of VR technology in actual tests. Through feedback and continuous improvement, the scope of application is gradually expanded to ensure the stability and adaptability of the system. This incremental approach to implementation helps reduce the risk of technology integration and ensures that the complexity and diversity of power testing can be better accommodated as applications are rolled out.

Choosing the right VR technology and effective adaptation methods are crucial to introducing virtual reality into the field of power testing. Through scientific technology selection and adaptation methods, the needs of power testing can be better met, testing efficiency and reliability can be improved, and new ideas and possibilities can be provided for the maintenance and optimization of power systems.

5.2 Data collection and processing methods

When integrating virtual reality (VR) technology into power testing, data collection and processing methods are a crucial part. This involves taking data from real power systems and effectively applying it in a virtual environment. The following are some key data collection and processing methods: Comprehensive data collection of the power system is a critical step. This includes real-time monitoring of the operating status of power equipment, collecting sensor data, recording equipment performance parameters, etc. The application of sensor technology is indispensable, and data can be obtained in real time through sensors installed on power equipment. These data can cover key parameters such as voltage, current, and temperature, providing accurate power system status information for the virtual environment. Adopt appropriate communication protocols and data standards to ensure that data obtained from the power system can be recognized and processed by the virtual environment. This may involve data integration with existing monitoring and control systems in the power system, using common data formats to ensure data interoperability. This data standardization helps to accurately restore the real status of the power system in the virtual environment. In terms of data processing, it is crucial to adopt real-time data processing technology. The status of the power system may change in a short period of time, so data in the virtual environment needs to be processed and updated in real time. This includes the use of real-time data streaming techniques to ensure that the power system model in the virtual environment is synchronized with the state of the actual system. The visualization and presentation of data is also an important link. By using advanced data visualization technology, power system data is presented in a virtual environment in an intuitive way, allowing engineers to have a clearer understanding of the operating status of the power system. This could include using virtual reality headsets to display real-time data, drawing three-dimensional power system models, and more. In order to improve the quality and accuracy of data, it is also necessary to adopt data correction and filtering techniques. There may be some noise and uncertainty in the power system. By using appropriate filtering algorithms and correction methods, the stability and reliability of the data can be improved, ensuring that the power system model in the virtual environment is more

realistic and credible.

During the entire process of data collection and processing, attention should be paid to data security and privacy protection. Power systems involve sensitive information, and it is very important to ensure that data can be fully protected in all aspects of collection, transmission and processing. Taking into account data quality, real-time and security, the effective application of virtual reality technology in power testing can be better realized.

6. Summary

This paper explores the opportunities and challenges of virtual reality (VR) technology in power testing. By analyzing the application of VR in power testing, its potential advantages in improving testing efficiency, personnel training, and global cooperation are revealed. Specifically, VR technology provides innovative solutions for power system monitoring and optimization in terms of improving test efficiency and accuracy. In terms of personnel training and skill improvement, VR technology provides power testers with a highly simulated, flexible and personalized training experience. Opportunities in global cooperation, design planning, operation and maintenance and other fields have also brought unprecedented development possibilities to power testing. However, implementation challenges such as technical standardization, cost, and ergonomics need to be addressed. The integration of VR technology in power testing has brought a promising digital and intelligent future to the industry.

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