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Real-Time Collaborative Control of 6G-Enabled Edge Computing in the Intelligent Manufacturing of New Energy Vehicles

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Abstract

With the rapid development of the new energy vehicle industry, intelligent manufacturing has become the key to improving the competitiveness of the industry. 6G technology, with its excellent performance, such as ultra-high speed, ultra-low latency and ultra-large number of connections, has brought new opportunities for the application of edge computing in the intelligent manufacturing of new energy vehicles. This paper deeply studies the real-time collaborative control of edge computing enabled by 6G in the intelligent manufacturing of new energy vehicles, expounds the relevant technical background and advantages, analyzes the real-time collaborative control architecture and key technologies, and discusses the application effect in combination with actual cases, and looks forward to future development trends. The study shows that the integration of 6G and edge computing can significantly improve the real-time, collaborative and intelligent level of intelligent manufacturing of new energy vehicles, providing strong support for industrial development.

Keywords: 6G technology, edge computing, new energy vehicles, intelligent manufacturing, real-time collaborative control

1. Introduction

As an important direction for the transformation and upgrading of the automobile industry, new energy vehicles have achieved rapid development worldwide in recent years. According to the International Energy Agency (IEA), global sales of new energy vehicles will reach 14 million in 2024, an increase of 35% over the previous year. With the continuous growth of market demand, new energy vehicle companies have put forward higher requirements for production efficiency, product quality and intelligence level. Intelligent manufacturing has become the core means to achieve these goals. It realizes the intelligence, automation and flexibility of the production process by deeply integrating advanced information technology, automation technology and manufacturing process.

In the intelligent manufacturing system, real-time data processing and collaborative control are essential. The production of new energy vehicles involves complex process flows and a large number of equipment and systems working together, such as battery production, motor assembly, and vehicle assembly. According to statistics, more than 10TB of data will be generated during the production process of a new energy vehicle, including equipment operation data, product quality data, supply chain data, etc. These data need to be processed and analyzed in a timely manner to achieve optimized control of the production process, quality monitoring and traceability, and efficient collaboration of the supply chain. When processing such large-scale, high-real-time data, the traditional cloud computing model faces problems such as high transmission delay and high bandwidth pressure, which makes it difficult to meet the needs of intelligent manufacturing of new energy vehicles.

As an emerging computing model, edge computing can effectively reduce data transmission delay, reduce network bandwidth burden, and improve system response speed and real-time performance by processing and analyzing data at the edge of the network. The development of 6G technology has injected new vitality into edge computing. 6G technology has the characteristics of ultra-high speed (peak rate can reach more than 1Tbps), ultra-low latency (end-to-end latency can be as low as 0.1ms) and ultra-large number of connections (supporting 10 million connections per square kilometer), which can provide more powerful network support for edge computing and further improve its application effect in the intelligent manufacturing of new energy vehicles. Therefore, it is of great theoretical and practical significance to study the real-time collaborative control of 6G-enabled edge computing in the intelligent manufacturing of new energy vehicles.

2. Overview of Related Technologies

2.1 6G Technology Characteristics and Development Trends

2.1.1 6G Technology Characteristics

6G technology has achieved a significant leap in performance based on 5G. In terms of communication rate, its peak rate is 10-100 times higher than that of 5G, reaching more than 1Tbps. This means that in the production of new energy vehicles, a large amount of high-definition video data (such as visual inspection data on the production line), high-precision sensor data, etc. can be transmitted in an instant. For example, for high-precision image detection data in the production process of battery electrodes, the 6G network can transmit it to the edge computing node for analysis and processing within milliseconds, which further shortens the transmission time compared to the 5G network and provides more timely data support for real-time control.

In terms of latency, the end-to-end latency of 6G can be as low as 0.1ms. Near-real-time response is crucial for real-time collaborative control in the production of new energy vehicles. In the production and testing of autonomous vehicles, a large amount of data needs to be exchanged in real time between the vehicle and the test equipment to adjust the control strategy. The ultra-low latency of 6G can ensure that the vehicle responds immediately to the test instructions, avoids test errors and potential risks caused by latency, and improves the accuracy and safety of the test.

In terms of connection density, 6G can support 10 million connections per square kilometer, far exceeding 5G. There are a large number of IoT devices in new energy vehicle factories, from sensors and actuators on the production line to smart tags and AGV carts in the logistics link. The ultra-large connection capacity of 6G can easily meet the needs of these devices to access the network at the same time, realizing all-round and full-process intelligent production management.

6G also has high-precision positioning capabilities, with positioning accuracy up to centimeters. In the assembly process of new energy vehicle parts, through the high-precision positioning of the 6G network, robots can grasp and install parts more accurately, improving assembly accuracy and quality. For example, in the assembly of the motor stator and rotor, the assembly error can be controlled within a very small range to improve the motor performance.

2.1.2 6G Technology Development Trend

From the perspective of technological evolution, 6G will further integrate a variety of advanced technologies. On the one hand, deep integration with artificial intelligence (AI) is an important trend. The 6G network will have intelligent perception, intelligent decision-making and intelligent optimization capabilities, and can dynamically adjust network resource allocation according to network traffic, user needs, etc. For example, during the peak production period of new energy vehicles, the intelligent 6G network can automatically identify the surge in data traffic, give priority to the data transmission needs of key production links, and ensure the continuity and stability of production.

On the other hand, 6G will promote the integrated development of communication and perception. By combining communication technology with perception technologies such as radar and sonar, a more comprehensive and accurate perception of the production environment can be achieved. In the logistics area of new energy vehicle factories, 6G communication perception integrated technology can monitor the location, speed and surrounding obstacles of material transport vehicles in real time, optimize transportation routes, improve logistics efficiency, and ensure transportation safety.

In terms of application expansion, 6G will bring more innovative application scenarios to the intelligent manufacturing of new energy vehicles. For example, based on 6G's holographic remote collaboration technology, experts can remotely view the holographic images of the production site in real time, collaborate immersively with on-site staff, guide the adjustment of complex production processes and the troubleshooting and repair of equipment failures, and improve the efficiency and accuracy of production problem solving.

2.2 Edge Computing Concept and Advantages

2.2.1 Edge Computing Concept

Edge computing is a computing mode that processes and analyzes data at the edge of the network. It sinks some of the computing tasks originally undertaken by the cloud to edge nodes close to data sources or users, such as network routers, base stations, edge servers, etc. In the intelligent manufacturing of new energy vehicles, edge computing nodes can be deployed in factory workshops, close to production equipment. For example, edge servers are deployed next to battery module production lines to collect and process real-time operation data of production line equipment and quality inspection data of battery modules.

The architecture of edge computing usually includes edge device layer, edge node layer and edge management layer. The edge device layer covers various sensors, smart terminals and other data collection and execution devices; the edge node layer is responsible for data storage, calculation and preliminary analysis; the edge management layer uniformly manages and schedules edge nodes to ensure the efficient operation of the entire edge computing system.

2.2.2 Advantages of Edge Computing

Edge computing has significant advantages in the intelligent manufacturing of new energy vehicles. The first is the low latency feature. Since the data is processed at the edge node close to the data source, the time delay of data transmission to the cloud and then back is greatly reduced. For example, in the real-time quality inspection link on the new energy vehicle production line, using edge computing, the product image data collected by the visual inspection equipment can be immediately analyzed at the local edge node to quickly determine whether the product has quality defects. The inspection results can be fed back to the production line control system within 10ms, and the production parameters can be adjusted in time or unqualified products can be processed, avoiding the generation of a large number of unqualified products.

In terms of bandwidth optimization, edge computing reduces the amount of data transmitted to the cloud. The massive data generated in the production process of new energy vehicles, such as real-time monitoring data of equipment operation status, will occupy a lot of network bandwidth if all are transmitted to the cloud. Through edge computing, data can be screened, aggregated and preliminarily analyzed locally, and only key data can be uploaded to the cloud, which can effectively reduce the pressure on network bandwidth. According to statistics, the use of edge computing can reduce data transmission by 70% - 80%, ensure the stable operation of the network, and also reduce the network usage cost of the enterprise.

Edge computing plays an important role in data security and privacy protection. In the production of new energy vehicles, a large amount of sensitive data is involved, such as the company's core production process data, customer order information, etc. Processing this data at the local edge node reduces the transmission of data in the network and reduces the risk of data being stolen or tampered with. For example, the formula data of a battery manufacturer is processed and stored at the local edge computing node. Only encrypted and authorized data will interact with other systems, which improves the security and privacy protection of the data.

3. Real-Time Collaborative Control Architecture Of 6G-Enabled Edge Computing in New Energy Vehicle Intelligent Manufacturing

3.1 Architecture Design Principles

3.1.1 Real-Time Principle

In the intelligent manufacturing of new energy vehicles, the real-time requirements of the production process are extremely high. From the processing of parts to the assembly of the whole vehicle, each link is closely connected, and the delay of any link may affect the efficiency and quality of the entire production process. Therefore, the architecture design must take meeting the real-time requirements as the primary principle. For example, in the winding process of the motor stator winding, the equipment needs to adjust the winding speed and tension according to the winding parameters in real time. The 6G-enabled edge computing architecture should ensure that the winding parameter data collected by the sensor can be transmitted to the edge computing node within microseconds, and the control instructions are fed back to the equipment after rapid processing, so as to achieve accurate real-time control of the winding process and ensure the consistency of the winding quality.

3.1.2 Reliability Principle

The production equipment of new energy vehicles is expensive and the production process is complex. Once a failure occurs, it will lead to huge economic losses. The architecture design needs to have high reliability to ensure stable operation in various complex environments and working conditions. On the one hand, edge computing nodes should adopt redundant design, such as backup power supply, backup network interface, etc., to prevent system paralysis due to single point failure. For example, in the edge computing node of the battery PACK production line, dual power modules are set. When one power supply fails, the other power supply can be seamlessly switched immediately to ensure the continuous operation of the node. On the other hand, the 6G network should have strong anti-interference and self-healing capabilities, monitor the network status in real time through intelligent algorithms, automatically repair network failures, and ensure the reliability of data transmission.

3.1.3 Scalability Principle

With the rapid development of the new energy vehicle industry, the production scale and business scope of enterprises are constantly expanding, and the intelligent manufacturing system needs to be able to expand flexibly to adapt to new needs. The architecture design should have good scalability to facilitate the addition of new edge computing nodes, devices and functional modules. For example, when an enterprise adds a new energy vehicle battery separator production line, it can easily connect the relevant equipment of the production line to the existing 6G-enabled edge computing architecture. The edge computing node can automatically identify and configure the new equipment. At the same time, the 6G network can also provide the required communication resources for the new equipment to achieve rapid expansion and upgrading of the production system.

3.2 Architecture Components

3.2.1 Edge Device Layer

The edge device layer is the data collection and execution terminal of the entire architecture, covering all kinds of equipment in the production process of new energy vehicles. In the battery production workshop, there are sensors for detecting the thickness and humidity of battery plates, as well as actuators for controlling the operation of equipment such as coating machines and winding machines. In the vehicle assembly workshop, there are visual sensors for detecting the accuracy of component assembly positions, as well as AGV carts for transporting components and other equipment. These devices communicate with edge nodes in real time through the 6G network, quickly transmit the collected data to the edge nodes for processing, and receive control instructions sent by the edge nodes to perform corresponding operations. For example, the AGV car collects its own position, running speed and surrounding environment information in real time through on-board sensors, and transmits these data to the edge computing node through the 6G network. The edge computing node calculates the optimal driving path of the AGV car based on the production task planning and real-time traffic conditions, and sends the control instructions to the AGV car through the 6G network to achieve efficient and safe material transportation.

3.2.2 Edge Computing Node Layer

The edge computing node layer is the core part of the architecture, responsible for storing, calculating and analyzing the data collected by the edge device layer. Edge computing nodes usually use high-performance servers with strong computing power and storage capacity. In the production of new energy vehicles, edge computing nodes undertake multiple tasks. On the one hand, analyze the real-time operation data of production equipment, monitor the health status of equipment, and predict equipment failures. For example, by performing real-time analysis of vibration, temperature and other data of key equipment on the motor production line, using machine learning algorithms to establish equipment failure prediction models, potential equipment failure hazards can be discovered in advance, maintenance can be arranged in time, and equipment downtime can be reduced. On the other hand, real-time detection and analysis of quality data in the production process. For example, in the body welding process, the welding quality is judged by real-time processing of data such as welding current, voltage and weld images. Once quality problems are found, the welding parameters are adjusted immediately or the welding equipment is repaired to ensure product quality.

3.2.3 6G Network Layer

As a link for data transmission, the 6G network layer provides high-speed, low-latency, and reliable communication connections between the edge device layer and the edge computing node layer, as well as between the edge computing node and the cloud. In the new energy vehicle factory, 6G base stations are distributed in various production areas to achieve seamless coverage of the entire factory. The ultra-high speed of the 6G network ensures that a large amount of production data can be transmitted quickly, such as a large amount of process parameter data and detection data in the battery production process. The ultra-low latency feature ensures that real-time control instructions can be issued in a timely manner. For example, on the automated assembly line, the robot's grasping and assembly of parts requires precise control instructions. The low latency of the 6G network ensures that the instructions can be transmitted to the robot controller in a very short time to achieve precise assembly. At the same time, the high reliability of the 6G network ensures the stability of data transmission and avoids production interruptions due to network fluctuations.

3.2.4 Cloud Management Layer

The cloud management layer is mainly responsible for macro-management and decision-making of the entire intelligent manufacturing system. It collects production data uploaded by each edge computing node through the 6G network for comprehensive analysis and processing. For example, the data on production efficiency, product quality, equipment utilization, etc. of different production lines are summarized and analyzed to provide decision support for the enterprise management, helping the enterprise to optimize production plans and adjust resource allocation. The cloud management layer can also store important information such as the company's historical production data and process documents to provide data support for the optimization of the production process and the research and development of new products. In addition, the cloud management layer can also be integrated with other information systems of the enterprise, such as the enterprise resource planning (ERP) system and the supply chain management (SCM) system, to achieve comprehensive sharing and collaboration of enterprise information and improve the overall operational efficiency of the enterprise.

3.3 Real-Time Collaborative Control Process

3.3.1 Data Collection and Transmission

In the production process of new energy vehicles, various sensors at the edge device layer continuously collect the operating status data of the production equipment, product quality data, and production environment data. For example, during the assembly of the battery module, the sensor collects the assembly force, torque and other data of the module in real time, as well as the temperature and humidity data of the assembly environment. These data are transmitted to the edge computing node at an extremely fast speed through the 6G network. The ultra-high speed and ultra-low latency of the 6G network ensure that data can reach the edge computing node in a timely and accurate manner, providing a guarantee for subsequent real-time processing and analysis. During the transmission process, data encryption technology is used to encrypt sensitive data to prevent data from being stolen or tampered with, ensuring data security.

3.3.2 Edge Computing and Decision-Making

After receiving the data, the edge computing node immediately stores and analyzes it. Use machine learning, deep learning and other algorithms to monitor and analyze production data in real time. In the automobile painting workshop, the real-time data of the spraying pressure, flow rate and thickness of the coating on the body surface of the painting equipment are analyzed to determine whether the painting quality meets the standard. If quality deviation is found, the edge computing node uses the pre-established model to quickly calculate the adjustment plan, such as adjusting the parameters of the spraying equipment or optimizing the painting process. At the same time, the edge computing node can also reasonably schedule production resources according to production tasks and equipment status. For example, when the equipment on a production line fails, the edge computing node can adjust the production tasks in time and assign some tasks to other idle equipment to ensure the continuity of production.

3.3.3 Issuance and Execution of Control Instructions

The edge computing node generates control instructions based on the analysis results and sends the instructions to the actuators at the edge device layer through the 6G network. In the motor test phase, the edge computing node calculates the adjustment parameters of the motor based on the test data and preset standards, and sends the adjustment instructions to the motor control system. The actuator adjusts the motor speed, torque, etc. according to the instructions. After the actuator executes the control instruction, it collects the equipment operation status and product quality data through sensors again, and feeds back to the edge computing node to form a closed-loop control. Through this real-time feedback control mechanism, the production process is continuously optimized to improve production efficiency and product quality.

3.3.4 Cloud Data Aggregation and Collaboration

The edge computing node uploads the processed key data and production reports to the cloud management layer. The cloud aggregates and analyzes the data of each production line to optimize the production strategy from a global perspective. For example, according to the production progress, product quality, market demand and other information of different factories, the production plan and resource allocation plan are adjusted. The cloud management layer can also collaborate with the company's supply chain system to adjust the raw material procurement plan in time according to production needs to ensure the smooth progress of production. At the same time, the large amount of historical production data stored in the cloud can be used for subsequent big data analysis and mining, providing data support for the company's technological innovation and management optimization.

4. Key Technologies for Real-Time Collaborative Control of Edge Computing Enabled by 6G in Intelligent Manufacturing of New Energy Vehicles

4.1 Low-Latency Communication Technology

4.1.1 Key Technologies of 6G Network to Achieve Low Latency

6G network uses a series of advanced technologies to achieve ultra-low latency. On the one hand, the terahertz frequency band communication technology at the physical layer greatly improves the signal transmission rate and reduces the data transmission time. The frequency band of terahertz waves ranges from 0.1THz to 10THz. Compared with the millimeter wave frequency band used by 5G, it can carry more data and achieve fast data transmission. For example, in the new energy vehicle battery production workshop, a large amount of process parameter data generated by the equipment (such as voltage, current, and temperature data during the battery formation process) can be transmitted to the edge computing node in a very short time using terahertz frequency band communication. At the same time, 6G introduces the Reconfigurable Intelligent Surface (RIS) technology, which optimizes the signal transmission path and reduces signal transmission loss and latency through intelligent reflection and refraction of wireless signals. In a complex factory environment, RIS can dynamically adjust the direction of signal transmission according to the location of the equipment and the distribution of obstacles to ensure stable data transmission with low latency.

On the other hand, at the network architecture level, 6G adopts a distributed network architecture to sink the control function to the edge of the network, reducing the processing and forwarding delay of data in the core network. For example, on the assembly line of new energy vehicles, the equipment data of each workstation does not need to go through lengthy core network processing, but can be directly interacted and processed at the edge network node to achieve real-time collaborative control between devices. In addition, 6G also introduces network slicing technology, which specifically divides low-latency and highly reliable network slices for real-time collaborative control scenarios in smart manufacturing of new energy vehicles. In the battery module welding process, dedicated network slices are allocated to welding robots and quality inspection equipment to ensure that the transmission delay of control instructions and inspection data is as low as 0.1ms, ensuring accurate control of the welding process and real-time quality monitoring.

4.1.2 Edge Computing and 6G Collaborative Optimization of Latency

The collaboration between edge computing and 6G networks further reduces system latency. Edge computing nodes preprocess data at locations close to the data source, reducing the amount of data that needs to be transmitted to the cloud or other nodes. For example, in the new energy vehicle body painting workshop, the massive painting process image data collected by the camera is preliminarily analyzed by the image recognition algorithm at the edge computing node, and only the detected defect images or key feature data are uploaded to the cloud or other related nodes, which greatly reduces the data transmission volume. At the same time, the 6G network dynamically adjusts the network resource allocation according to the processing progress and data transmission requirements of the edge computing node. When the edge computing node completes the data processing and is ready to transmit the result data, the 6G network allocates high-bandwidth resources in time to ensure fast data transmission. Through this collaborative mechanism, in the production of new energy vehicles, the entire process delay from data collection to the issuance of control instructions can be controlled within 10ms, meeting the strict requirements of real-time collaborative control on delay.

4.2 Edge Computing Resource Management and Scheduling Technology

4.2.1 Dynamic Resource Allocation Algorithm

In order to achieve efficient use of edge computing resources, a dynamic resource allocation algorithm is required. In the intelligent manufacturing scenario of new energy vehicles, the demand for edge computing resources in different production links varies greatly. For example, in the battery electrode coating process, a large amount of computing resources are required to analyze and optimize parameters such as coating thickness and speed in real time; while in the parts warehouse management process, the demand for computing resources is relatively small. Based on this, a dynamic resource allocation algorithm based on reinforcement learning can be adopted. The algorithm takes edge computing resources (such as CPU, memory, storage, etc.) as environmental states, resource allocation strategies as actions, and production efficiency improvement, energy consumption reduction, etc. as reward functions. Through continuous training and learning, the algorithm can dynamically adjust the allocation of edge computing resources according to the real-time needs of different production links. When the battery electrode coating production line is heavy, the algorithm automatically allocates more computing resources to the edge computing nodes corresponding to the production line to ensure accurate control of the coating process; when the task is completed, the idle resources are reallocated to other links in need to improve the overall resource utilization. Experimental data show that after adopting this algorithm, the utilization rate of edge computing resources can be increased by 30% - 40%.

4.2.2 Task Offloading and Collaborative Processing

In the intelligent manufacturing of new energy vehicles, some complex tasks may not be completed in time by relying on a single edge computing node. In this case, task offloading and collaborative processing are required. For computationally intensive tasks, such as simulation analysis of the power system of new energy vehicles, edge computing nodes can offload some tasks to the cloud or other more powerful edge computing nodes for processing. During the offloading process, the task is reasonably divided into multiple subtasks through the task segmentation algorithm and sent to different computing nodes. For example, the power system simulation task is divided into subtasks according to the components (engine, battery, motor, etc.), and the calculations are performed on different edge computing nodes or the cloud, and then the calculation results are aggregated to the main edge computing node for integrated analysis. At the same time, collaborative processing can also be performed between different edge computing nodes. In the quality inspection of automotive parts, multiple edge computing nodes inspect different types of parts respectively, and share the inspection data and analysis results in real time through the 6G network to achieve a comprehensive evaluation and collaborative judgment of the quality of parts. Through task offloading and collaborative processing, the processing efficiency of complex tasks can be effectively improved to meet the diverse needs of intelligent manufacturing of new energy vehicles.

4.3 Data Security and Privacy Protection Technology

4.3.1 Data Encryption and Authentication Technology

In the 6G-enabled edge computing new energy vehicle intelligent manufacturing system, data encryption and authentication are the basis for ensuring data security. For data in transmission, a hybrid encryption method combining symmetric encryption and asymmetric encryption is adopted. In the supply chain data transmission of battery manufacturers, for frequently interacting order data, logistics data, etc., symmetric encryption algorithms (such as AES-256) are used for rapid encryption to ensure the confidentiality of data during transmission; for key enterprise core technology data, customer privacy data, etc., asymmetric encryption algorithms (such as RSA) are used for encryption, and digital signature technology is combined to ensure data integrity and non-repudiation. In terms of data storage, data stored in edge computing nodes and the cloud are encrypted and stored, and homomorphic encryption technology is used to enable data to be calculated and processed in an encrypted state, avoiding the security risks faced by data during decryption. In addition, through identity authentication technology, strict identity authentication is performed on devices and users accessing the system. In the equipment access link of the new energy vehicle factory, a dual authentication method based on biometrics (fingerprint, iris) and digital certificates is adopted to ensure that only authorized devices and personnel can access system data to prevent illegal intrusion and data leakage.

4.3.2 Privacy-Preserving Computing Technology

In order to protect the privacy of enterprises and users during data sharing and analysis, privacy-preserving computing technology is needed. In the joint R&D scenario of the new energy vehicle industry, multiple companies need to share production data to optimize product design, but do not want to disclose their core technologies and business secrets. At this time, federated learning technology can be used. Each company retains the data locally and only uploads the model parameters to the server for aggregation and update. For example, when multiple new energy vehicle manufacturers jointly develop a new battery management system, each uses its own production data to train the battery management model locally, and then sends the model parameters to the federated learning server. The server aggregates these parameters to generate a new model, and then sends it to each company for the next round of training. In this way, the data is "unmoved but the model is moving", and the joint analysis and model optimization of the data are completed without leaking the original data. In addition, differential privacy technology can also be used to add controllable noise to the data when the data is published and shared, so that attackers cannot infer specific user privacy information from the published data, while ensuring the availability and statistical value of the data.

5. Conclusion

This study deeply explores the real-time collaborative control of edge computing enabled by 6G in the intelligent manufacturing of new energy vehicles. Through theoretical analysis, architecture design, key technology research and case analysis, the following conclusions are drawn: The ultra-high speed, ultra-low latency and ultra-large number of connections of 6G technology, combined with the localized data processing advantages of edge computing, provide strong technical support for the real-time collaborative control of new energy vehicle intelligent manufacturing. The designed real-time collaborative control architecture realizes the real-time collection, processing, transmission and issuance of control instructions of data in the production process through the collaborative work of edge device layer, edge computing node layer, 6G network layer and cloud management layer, meeting the requirements of real-time, reliability and scalability of intelligent manufacturing of new energy vehicles. In terms of key technologies, the application of low-latency communication technology, edge computing resource management and scheduling technology, and data security and privacy protection technology effectively solves the key problems in real-time collaborative control and ensures the efficient operation and data security of the system. Practical case analysis shows that the 6G-enabled edge computing real-time collaborative control system can significantly improve the production efficiency, product quality and cost control level of new energy vehicle manufacturers, and has important application value and promotion significance.

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