

Research Article

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Research on electric energy measurement system based on intelligent sensor data in artificial intelligence environment

<https://doi.org/10.1515/htmp-2022-0300>

received August 23, 2023; accepted November 07, 2023

Abstract: Electric power resources are the core energy for a country's economic development and growth. China is at the peak of electric energy consumption at this stage. Improving the accuracy and integrity of electric energy metering technology is of great significance for evaluating the use and consumption of resources in China. Under the background of artificial intelligence, this research analyzes and studies the integrated module, demand status, performance optimization, and coupling degree of the electric energy metering system (hereinafter referred to as EES) through the application of two different types of sensors. The results show that the application of intelligent sensors has a better integration effect with the system management of electric energy metering, which plays a very important role in promoting the sustainable development of automation and informatization of the EES.

Keywords: artificial intelligence, Intelligent sensor, EES, Internet of Things

1 Introduction

As the primary resource for social development, energy covers a wide range and types, including coal, natural gas, solar energy, etc. In the development of social life, the application scope of electric power energy is wide, and people cannot live without electricity; to cope with the diversified power consumption groups, the development of the State Grid and the future grid also needs to

change from traditional manpower to more intelligent and automatic power statistics and measurement methods. Junqi will establish a new information system based on the Internet of Things to collect, transmit, process, and apply information of the smart grid under the condition of Internet development; popularize the application of the smart grid; and solve the problems in electric energy measurement [1]. Precision, data collecting, security, big data volumes, energy theft detection, metering integration, environmental factors, regulatory compliance, grid integration, load balancing, infrastructure improvements, and privacy issues are some of the obstacles that electric energy measurement and management confront. Yuepeng, by studying the error causes of modern electric energy metering system (EES), elaborated the main components of the EES, the error mechanism of components, and the main causes and obtained the error definition of electric energy metering, providing a theoretical basis for the subsequent improvement of the EES [2]. Gang and others found that the advantages of electronic transformers in electric energy measurement are more accurate than traditional transformers in calculation and wider application fields by studying the application and advantages of electric energy metering devices in intelligent substations [3]. Xiaojun discussed the sensor technology, communication technology, information security, and artificial intelligence that need to be used in the construction of smart grids by studying the development direction of intelligent perception technology in smart grids [4]. Xiao designed a new intelligent electric energy metering method based on the problem of insufficient management of the asset warehouse of electric energy metering, incorporating the Internet of Things, big data, and automation technology, and realized the periodic management model of electric energy metering information from data collection to transmission to calculation and application [5]. Liping analyzed the application effect of the new technology of intelligent substation electric energy metering and made the system stability gradually increase through the new technology intelligence and automation improvement [6]. Wei, faced with the diversified demands of urban

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construction and residents' electricity consumption, the traditional EES cannot meet the needs of people's lives. While intelligent sensors, which are included in smartphones, smart homes, and IoT devices, offer sophisticated capabilities, connections, and real-time data for certain applications, traditional sensors are more affordable and often utilized in the automotive, industrial automation, and environmental monitoring industries. On this basis, the intelligent construction of the national grid continues to be upgraded, and the use of intelligent substations has improved the stability efficiency of the EES, which puts forward new ideas for the future development of electric energy metering technology [7]. Rui, with the introduction of a new store system, intelligent electric energy meters should also meet the functions of communication, load control, legal measurement, and isolation of nonmetering parts in addition to the electric energy metering functions and have more strict requirements for intelligence and automation. Therefore, based on the combination of artificial intelligence, they will make higher requirements and development directions for the future EES [8]. Due to the increasing demand for electricity and diversified characteristics, the traditional EES cannot meet the needs of the development of modern society. This article analyzes the EES based on intelligent sensor data based on artificial intelligence, improves the intelligence and automation of the EES, strengthens the power calculation method, and establishes an effective EES, which will help the management and development of the national grid. This study proposes a model for managing household energy use and expenses that takes into account a variety of energy sources and makes use of modern metering infrastructure. Additionally, it covers the potential uses for artificial intelligence [9]. This article covers current artificial intelligence (AI) applications in building management systems and demand response programs, presents a methodology for assessment, considers outstanding difficulties and potential future paths, and introduces an evaluation framework for research on energy, comfort, design, and maintenance [10]. Energy waste results in higher CO₂ emissions, which is a serious concern when it comes to climate change. 20% of these emissions might be avoided by using energy more efficiently, which accounts for 40% of these emissions. Future developments of intelligent energy management systems in residential, commercial, and educational buildings are being researched [11].

2 Construction of EES and electricity metering law model

The EES is used to measure the electric energy of the power plant on grid, off-grid, and tie line gateway, store, collect,

and process it in different periods, and provide basic data for electricity analysis and settlement. In the application of the national power market, only by stabilizing the power metering of power suppliers and users can the order of the power market be maintained. The development of China's power metering system has gone through two historical stages: The first stage is the acquisition and statistical processing of electric energy in the 1970s and 1980s. However, due to the limitations of equipment and capabilities, the acquisition accuracy and data reliability can be achieved wirelessly. From the 1990s to today, with the progress of science and technology, the progress of Internet and electronic communication technology, the development of EESs has also been improved. China's self-developed EESs, such as PBS-2000, DF-6000, the independent master station system, professional electricity collection terminal or electric energy meter, and special communication channels are used for electric energy collection, calculation, and statistical assessment, realizing the stable demand of commercialization and marketization. Qingqing EES is composed of hardware and software, and software refers to meter reading technology, metering algorithms, etc. Hardware includes a voltage transformer, electric energy meter, and current transformer. In daily life, as the information source of electricity calculation assessment, the accuracy and safety of the EES are of great concern [12]. Hechan, to meet the personalized electricity demand of many electricity users, and analyze the customer's differentiation and service demand, built the model of the EES through a clustering algorithm, date matching algorithm, curve similarity algorithm, and so on to analyze the user's electricity law; the effectiveness of the power analysis model is verified [13]. The analysis of the power consumption law of users needs to analyze and process the historical data of power consumption through various analysis and calculation methods of power data, such as the expectation-maximization (EM) clustering algorithm. To analyze patterns of power use, the EM clustering algorithm groups data points with comparable features. Although it is helpful for load assessment, anomaly detection, and grid management, high-dimensional data and fluctuating cluster sizes provide difficulties. This algorithm is used to evaluate the power consumption law, minimize the performance consumption, and optimize the effect of power consumption behavior.

3 Design and implementation of EES

The EES needs to follow certain design principles. Its design should be an independent and complete system.

Electric power companies need to use electric energy as the reference data value for billing and assessment. The independence of the system can ensure the reliability, uniqueness, and accuracy of the collection and transmission of electric energy, and the processing process. The acquisition of electric energy has a lower requirement for real time, but a higher requirement for simultaneity. The EES is a quasi-real-time system. The freezing period shall meet the requirements of time division metering accuracy, set as 5–30 min, and the shortest transmission period shall meet the requirements of settlement and statistical statements. In addition, the design of EES should be based on the principle of high acquisition accuracy and unique data source; the high-reliability principle of software; and setting principle of billing gateway. Dongyang uses the Internet of Things and artificial intelligence technology to establish an online troubleshooting system for power metering faults in the cloud. It is composed of handheld test terminals, handheld APPs, and cloud servers, which improves the troubleshooting ability of field maintenance personnel and reduces the technical requirements of technicians [14]. Through the research and development of the dynamic identification and processing system for abnormal data of electric energy metering devices, we have found and handled abnormal data problems promptly through the collection of electricity data, the establishment of metering files, and the dynamic monitoring and judgment rule base for data abnormalities, reducing the complaint rate of users, and improving the marketing operation and maintenance management ability [15,16].

4 Application of artificial intelligence intelligent sensor and EES

With the development and progress of computer technology and artificial intelligence technology, the functions of data transmission, detection and alarm, background data statistics and analysis, calculation, etc., required by the power system in operation are to meet the needs of personalized power consumption services and automatic meter reading tasks for user groups; avoid electricity theft and other acts. By predicting demand, examining user behavior, optimizing usage, taking part in energy markets, and offering user-friendly data visualization, AI technology improves energy management, customer happiness, and resource allocation. The development of EES

has approached the development of artificial intelligence technology. EES has had a tremendous impact on AI technology, enhancing grid effectiveness, forecasting, resilience, and energy storage optimization. For efficient, dependable, and sustainable energy systems, AI's capacity to analyze EES data is essential. A future that is greener and more effective is possible because of the interaction between EES and AI. In power system faults, artificial intelligence technology can quickly find out the causes of faults, avoid large-scale power outages, and increase the recovery speed of the system. Through improving predictive maintenance, load forecasting, defect detection, grid optimization, and asset management, AI solutions reduce power outages and hasten recovery. They provide real-time decision-making, micro-grid integration, fault identification, and restoration planning. Line faults, component faults, and signal faults can be found and handled promptly. Artificial intelligence technology not only improves maintenance efficiency but also reduces enterprise operating costs. The combination of IoT and AI in the collection of data on electricity consumption allows for real-time data collection, customized energy efficiency recommendations, load prediction, demand response, identifying anomalies, grid administration, customized tariffs, decreased energy waste, and flexibility, all of which support the development of a future that uses less energy. AI technology lowers operational costs by automating monotonous jobs, predicting maintenance, streamlining supply chains, managing energy, boosting employee productivity, spotting fraud, developing targeted marketing strategies, enhancing quality control, and automating compliance. AI increases the effectiveness of power company maintenance and lowers costs by maximizing energy efficiency, minimizing manual inspections, and boosting data-driven decision-making, which results in cost savings and enhanced performance. The power quality monitoring and early warning system of the cloud platform can also realize real-time monitoring of power quality indicators. Through the combination of software and hardware, the data can be stored in a distributed way, and the system's ability to analyze the detected data can be improved. In the background management platform of EES, artificial intelligence technology can also solve the problem of data processing and analysis efficiency and change and display data information according to different demand indicators of enterprises and users. Assuring privacy and effective data processing, AI improves data processing through cleaning, pattern recognition, natural language processing, picture and audio analysis, data compression, automatic labeling, protection, and adaptability. In the collection of users' electricity data, the Internet of Things technology and artificial intelligence technology are combined to achieve mobile terminal online

query, information acquisition, download, web browsing, and other services and improve user satisfaction and intelligent identification management.

5 Evaluation and verification of EES

5.1 Comprehensive module analysis of EES under different types of sensors

Electric energy measurement is related to the economic benefits of power supply enterprises and also has a significant impact on the satisfaction of users. For power supply businesses, accurate energy measurement is essential for generating income, assuring customer happiness, operational efficiency, recovering costs, allocating resources, complying with regulations, and maintaining long-term financial health. At present, there are many problems in the measurement management of electric energy, which directly leads to the inability to ensure the accuracy of electric energy measurement. For accurate invoicing, effective grid management, and trustworthy data analysis in the energy sector, electric energy measurement precision is essential. Regular maintenance, cutting-edge metering technology, power quality correction, data validation, and strong cybersecurity measures are some solutions. In the artificial intelligence environment, through the analysis and comparison of the integrated modules of the EES under two groups of different types of sensors, the results show that the application of intelligent sensors in the analysis of the integrated modules of the EES is higher than that of conventional sensors in the application of each module. Conventional sensors are dependable, economical, and long-lasting, but the criteria of the application determine whether they are appropriate. For real-time data processing or remote monitoring, intelligent sensors are more appropriate. While intelligent sensors offer enhanced functionality and accuracy, conventional sensors in EES can result in decreased efficiency, predictive capacities, and cost inefficiencies. Intelligent sensors' real-time data, precise energy measurement, predictive analytics, fault detection, and interaction with smart

grids considerably enhance the performance of EES. Through data-driven decision-making, resource allocation, and dependability, they improve energy efficiency, lower operating costs, and increase customer satisfaction. According to the EES system, the comparative data under the application of two groups of different types of sensors are analyzed and compared; Table 1 is obtained.

In Table 1, through the comparative data of the comprehensive module analysis of the EES under the two groups of different types of sensors in the above table, and from the analysis and comparison of automation, fairness, security, and accuracy in the system, the EES system under the application of intelligent sensors is far superior to the application of conventional sensors in terms of each module. With real-time data processing, advanced analytics, self-diagnosis, energy efficiency, remote updates, integration with energy management software, data validation, predictive maintenance, grid interaction, remote monitoring, and fault detection, intelligent sensors improve EES. It shows that the EES system under the application of intelligent sensors is more consistent with the current application and research of EES.

To reflect the analysis and comparison results of the integrated modules of the system more intuitively under two different types of sensors, the data comparison results in Table 1 are visualized and Figure 1 is obtained.

Figure 1 shows the data analysis and comparison results of the integrated module of the EES under the application of two different types of sensors. It is believed that the EES under the application of intelligent sensors has significantly improved compared with the system under the application of conventional sensors, which can better improve the construction of the EES, and make the electric energy value under the system more accurate and unified, it can effectively ensure the continuity of power supply, make metering fairer and more honest, and better comply with operating rules, thus ensuring the safety of power system. EES with intelligent sensors offers accurate measurements and monitoring of vital parameters including energy consumption, battery security operations center (SOC), electrical parameters, climate, humidity, grid conditions, energy flow, effectiveness, fault detection, preventative upkeep, security development, and grid integration and control. Intelligent

Table 1: Comprehensive module analysis data of EES under different types of sensors

Group	Information acquisition (%)	Information integration (%)	Data management (%)	Repair and maintenance (%)
Conventional sensors	61.27	63.57	60.91	64.83
Intelligent sensor	88.57	88.34	89.09	87.38

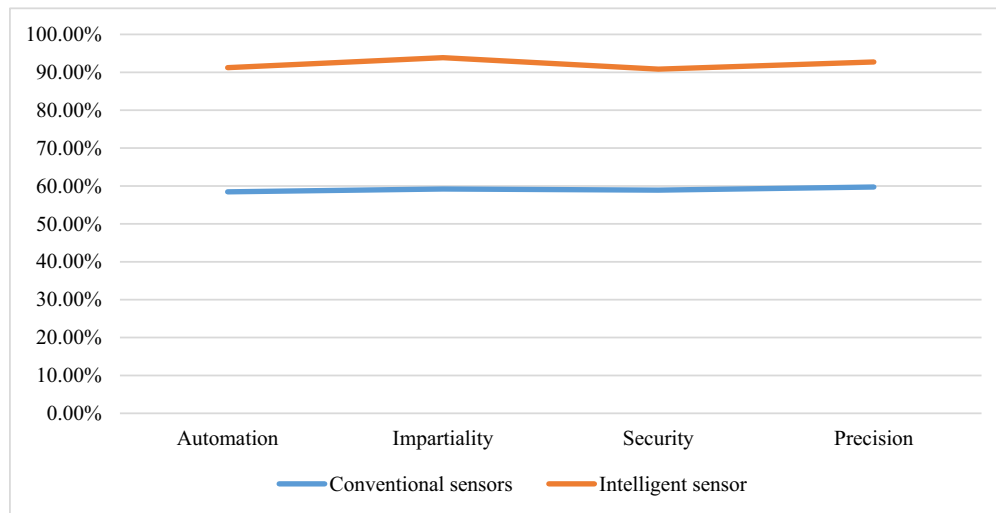


Figure 1: Visualization diagram of comprehensive module analysis data of EES under different types of sensors.

sensors improve the performance of EES by tracking SOC, and SOH, managing batteries, maximizing energy, spotting problems, balancing loads, providing proactive upkeep, assisting with data analytics, and improving security.

5.2 Current demand analysis of EES under different types of sensors

According to the comparison results of the analysis data of the demand status quo of the EES under different types of sensors, to better reflect the status quo of the current electric energy metering method and metering accuracy, the information collection, information integration, data management, repair and maintenance, and other aspects in the current demand status of the EES were analyzed and studied under the artificial intelligence environment from different types of sensors, and Table 2 is obtained. EES demand status analysis data must be presented using visualization techniques including line charts, bar charts, heatmaps, and Sankey diagrams to facilitate comprehension and decision-making.

In Table 2, through the research and analysis of the current demand analysis data of the EES under different

types of sensors, the data analysis of the EES under the application of conventional sensors is below 65%, while the analysis data of the EES using intelligent sensors are above 85%. The demand for data of intelligent sensor applications is higher than that of conventional sensors. Depending on the complexity and requirements of the application, intelligent sensors provide enhanced data processing, communication capabilities, flexibility, and integration possibilities whereas conventional sensors relay raw data for external processing. The EES under intelligent sensors can better meet the current demand for electric energy metering. With proper design, intelligent sensor integration in EES may enable improved performance and data-driven decision-making despite difficulties including expensive initial investment, complicated data handling, and environmental conditions.

To analyze and study the demand status analysis of the EES system under different types of sensors, the demand status analysis data of the EES under different types of sensors are visualized, and Figure 2 is obtained: more intuitively.

In Figure 2, the comparison of the current demand analysis data of the EES under two different types of sensors more intuitively shows that the application of intelligent sensors has a better effect on information collection,

Table 2: Analysis data of current demand of EES under different types of sensors

Group	Anti-electric larceny (%)	High-speed communication (%)	Mass storage (%)
Conventional sensors	62.71	63.84	64.93
Intelligent sensor	90.47	91.26	90.85

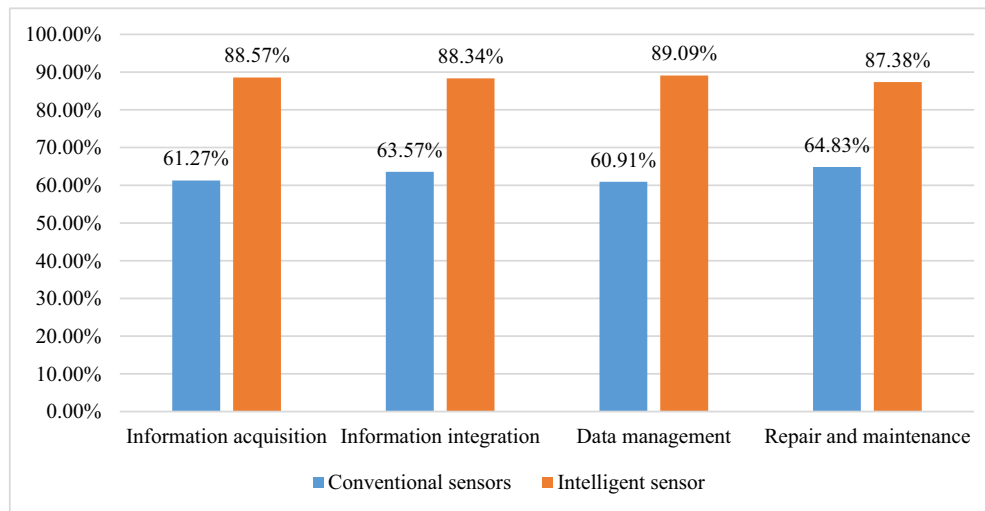


Figure 2: Data visualization diagram of demand status analysis of EES under different types of sensors.

information integration, data management, repair, and maintenance in the EES, which shows that the EES under the application of intelligent sensors can more accurately measure and monitor electric energy consumption according to various factors. By optimizing resources, lowering emergency responses, and prolonging equipment lifespan through real-time data monitoring, scheduled service, and tracking the environment, intelligent sensors improve the operation of EES. It helps to integrate information and data, to provide more flexible and convenient services.

5.3 Performance optimization analysis of EES under different types of sensors

Based on conventional sensors, intelligent sensors integrate the important results of artificial intelligence for improvement. This research analyzes and compares the performance optimization effects of EESs under two groups of different types of sensors. Defining goals, choosing variations, gathering data, analyzing, testing, utilizing machine learning, modeling situations, offering suggestions, verifying modifications, and documenting results are part of the

technique for assessing and optimizing EESs with a variety of sensors. According to the evaluation and analysis of the performance optimization effect under the application of conventional sensors and intelligent sensors, the comparative data of the two groups of systems are obtained, as shown in Table 3.

In Table 3, it can be seen from the analysis and comparison results of the performance optimization of the EES under the two groups of different types of sensors in the above table that the application of intelligent sensors has a more obvious effect on the performance optimization of the EES than the application of conventional sensors. In the EES, the application of intelligent sensors has more advantages for the optimization of the performance of related resources such as anti-power theft, high-speed communication, and mass storage.

According to the analysis of the optimization effect of various aspects of the performance of the EES under different types of sensors in Table 3, data visualization is carried out, and Figure 3 is obtained.

In Figure 3, the comparison between the application of conventional sensors and the application of intelligent sensors in the resource performance and other related performance optimization of the EES is shown. The application of intelligent sensors can better optimize the resource

Table 3: Performance optimization analysis data of EES under different types of sensors

Group	Automation (%)	Impartiality (%)	Security (%)	Precision (%)
Conventional sensors	58.45	59.21	58.92	59.73
Intelligent sensor	91.23	93.86	90.83	92.74

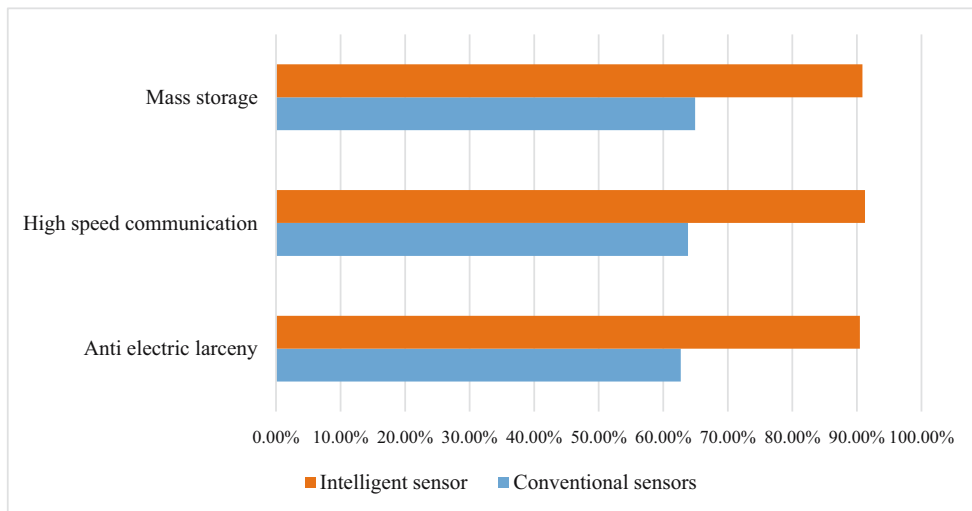


Figure 3: Data visualization diagram for performance optimization analysis of EES under different types of sensors.

performance of the EES than the application of conventional sensors, which also indirectly shows that the application of intelligent sensors has more advantages for measuring electric energy. It can effectively reduce the cost of manual application, greatly improve the work efficiency of workers, and improve the application and research of EES. Intelligent sensors are used in many different sectors to automate work, improve processes, eliminate downtime, increase energy efficiency, improve inventory management, find faults, assure data correctness, enable remote monitoring, cut waste, enhance customer service, and assist environmental monitoring.

5.4 Coupling degree analysis of EES under different types of sensors

In the process of application and research on the EES, analyzing the problems arising from the current measurement of electric energy in China can better propose the corresponding countermeasures to solve the problems, which can help the development of electric energy metering management faster. When determining the coupling strength of an energy storage system, it is important to take system objectives, sensor types, and intended results into account as well as other performance indicators including energy efficiency, SOC accuracy, and user happiness. Based on artificial intelligence, the coupling degree of application and research of EES is analyzed and compared under two groups of different types of sensors, and Table 4 is obtained.

In Table 4, it can be seen from the analysis results of the coupling degree of the EES under different types of

sensors in the above table that the coupling degree of the application of the EES system under the application of intelligent sensors is higher than that of the application of the EES system under the application of conventional sensors, and the mutual fusion effect of the coupling degree is also better, which is conducive to optimizing the application and research of the EES system. In the data of each row, it was found that $t < 10.000$ and $P < 0.05$, there was a significant statistical difference, which was more statistically significant.

Depending on the data and goals, several correlation algorithms are used in EES research. Common methods include cross-correlation, Canonical Correlation Analysis, partial correlation controls, Dynamic Time Warping, machine learning, and visual aids. They also include Pearson, Spearman, Kendall Tau, and other correlation coefficients. It aids in evaluating the connections between battery characteristics, seeing errors in sensor data, directing resource allocation, enhancing load forecasts, optimizing maintenance schedules, and spotting chances for cost savings. In the research of EES based on artificial intelligence intelligent sensors, correlation algorithm shall be applied:

Table 4: Coupling analysis data of EES under different types of sensors

Group	Coupling degree	
	Before use	After use
Conventional sensors	54.72%	78.29%
Intelligent sensor	57.63%	89.45%
t value	7.846	8.967
P value	0.037	0.046

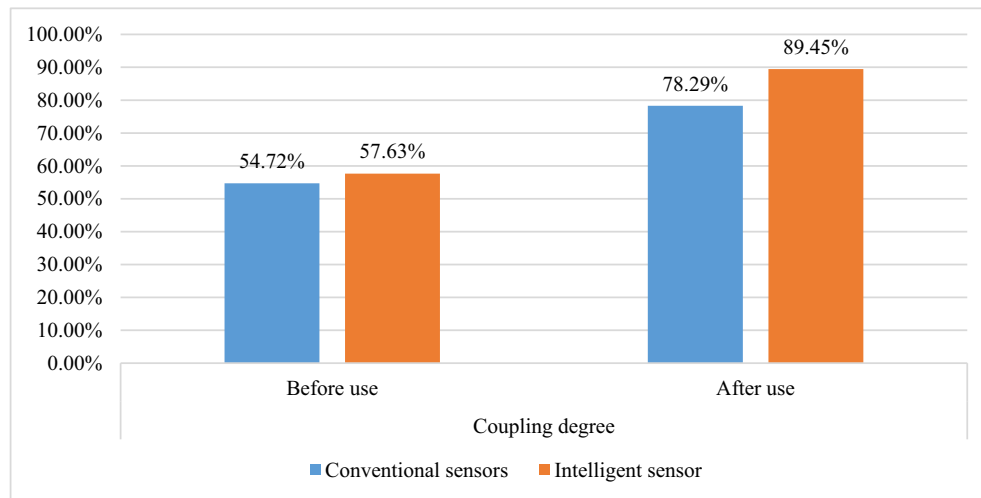


Figure 4: Visualization diagram of coupling analysis data of EES under different types of sensors.

$$\rho_s = \frac{\sum_{i=1}^N (R_i - \bar{R})(S_i - \bar{S})}{\left[\sum_{i=1}^N (R_i - \bar{R})^2 \sum_{i=1}^N (S_i - \bar{S})^2 \right]^{\frac{1}{2}}}. \quad (1)$$

Among R_i and S_i are the values of observation values; $\bar{R}$ and $\bar{S}$ are the average grades of variables x and y , respectively; N is the total number of observations.

To reflect the analysis and comparison results of the coupling degree of the application more intuitively of the EES system under different types of sensors, the comparison results of the coupling degree of the EES under two groups of different types of sensors in Table 4 are visualized, and Figure 4 is obtained:

Figure 4 shows the analysis and comparison results of the coupling degree of the EES under two different types of sensors. It is believed that the coupling degree of the EES system under the application of intelligent sensors is significantly higher than that of the EES system under the application of conventional sensors. The intelligent sensors can better enhance the coupling degree between the construction and application of the EES management system. Intelligent sensors are essential for contemporary energy management solutions because they improve EES organizational structures with real-time data processing, interaction, flexibility, data analysis, self-diagnostics, cost-effectiveness, adaptability, remote developments, security of information, and easy integration with vitality administration applications. The system of electric energy metering can be better optimized, and the management level of electric energy metering can be further improved, to promote and develop the standardization and standardization of metering.

6 Summary

In the development of modern society, artificial intelligence technology has been widely used in most industries. In urban development, rural life, and industrial production, diversified electricity demand is more large scale; The use of advanced science and technology such as artificial intelligence and Internet of Things technology can add more functions to the design and application of EES, meet the needs of most people's lives and the development of social enterprises, and play a more positive role in promoting the development of national data economy and harmonious construction. It also provides more technical support and convenience for the management and service of the national grid, reduces the difficulty and risk of front-line staff, and accelerates the development of electric power enterprises.

Acknowledgments: Not Applicable.

Funding information: Authors did not receive any funding.

Author contributions: All authors contributed to the design and methodology of this study, the assessment of the outcomes, and the writing of the manuscript.

Conflict of interest: The authors state no conflict of interest.

Data availability statement: No datasets were generated or analyzed during the current study.

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