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Integrated Two-Level New Energy Monitoring and Big Data Centers: A Comprehensive Approach for Urban Sustainability

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Abstract: -This study examines the transition to green energy in Wenzhou City and suggests a novel plan for integrating an energy monitoring and data center. The aim is to improve the city's sustainability through the building of a large-scale wind-solar integrated energy monitoring system by a group in Wenzhou City. The solution uses the Internet of Things and intelligent data analysis technology to realize real-time data collection, processing and operation and maintenance decision support for distributed power stations. The system adopts storage-computer separation and data encryption technology to ensure data security and system stability and improves data processing efficiency through containerization and microservice architecture. In addition, the study also explores the application potential of this technical scheme in regional energy planning, which provides a new idea for Wenzhou to achieve green energy transformation and low-carbon development.

Keywords: new energy, monitoring and big data platform, architecture design, district energy planning

I. Introduction

Due to the escalating severity of global climate change and environmental degradation, there is a growing emphasis on sustainable urban development in both academics and practice. As a key factor in achieving sustainable development, the application of green energy in urban planning and construction is particularly important [1]. Taking Wenzhou City, Zhejiang Province, China as an example, this study explores the importance of green energy transition for sustainable urban development.

As a coastal city, Wenzhou is rich in renewable energy resources such as wind, solar, and tidal energy [2]. Full use of these resources is significant for Wenzhou to achieve low-carbon development and environmental protection. However, despite the city's immense potential in the field of green energy, the current development and utilization is still in its infancy, and according to the data in the Wenzhou Energy White Paper, the city's dependence on fossil fuels remained high at 91.3% in 2021 and it is completely dependent on external supplies. At the same time, non-fossil energy accounts for a small proportion of the city's energy supply, about 8.7%, and its green energy consumption ratio is lower than the average level of Zhejiang Province. In addition, the pace of development of strategic emerging industries is still slow, and the modernization level of the industrial chain must be improved. It can be said that Wenzhou is facing multiple challenges in the transition from traditional energy structure to green energy.

This study constructs an integrated scheme for monitoring and managing distributed energy power stations in real-time. The scheme utilizes the Internet of Things and intelligent data analysis technology to achieve this goal. The proposal focuses on innovation at the technical level and explores how these technologies can be applied in district energy planning to promote green energy planning and assumptions in Wenzhou. The purpose of this study is to provide theoretical basis and practical guidance for the planning and construction of green energy in Wenzhou and similar cities, and to help promote the optimization of regional energy structure, improve energy efficiency, reduce environmental pollution, and achieve the goal of green and low-carbon development of the city.

II. Related work

Urban green energy planning and construction has always been a topic that scholars at home and abroad have tried to study many times. Numerous studies have provided digital insights and technical support for energy planning and sustainable development through different perspectives and methods. For example, [3] based on the

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development law of the energy industry and the theory of Internet big data, a system architecture for energy big data planning and research has been developed, which provides new mechanisms and algorithms for the collection, management, and analysis of energy big data. [4] Focusing on improving the resolution of energy consumption, it provides new theoretical and practical suggestions for the spatial distribution of energy by collecting big data at the city level. [5] Based on the analysis of multi-source spatiotemporal big data, the spatial distribution characteristics of commuting links and carbon emissions are deeply discussed, which provides a new perspective for analyzing the impact of building environmental factors on energy consumption. [6] In terms of the construction of new energy big data platform, from the three perspectives of data fusion, intelligent computing and application services, key technologies are proposed for business objects such as new energy operators and power grid companies, and the construction of new energy big data application platforms in specific fields is promoted. [7] Through the application of big data analytics (BDA), it is revealed that it plays a significant role in solving energy network operation problems and creating intelligent and adaptable energy systems. [8] Comprehensive energy planning has been introduced into urban planning, and a low-carbon energy planning system from macro to micro has been established, which has promoted energy conservation, emission reduction and low-carbon city construction by adjusting the energy structure and optimizing urban energy utilization. [9] By constructing a multi-objective decision-making model, the issue of renewable energy investment planning is discussed, and a new decision-making support tool is provided for energy planning. [10] GE's digital wind farm strategy was discussed, demonstrating the potential of big data technology to improve wind energy efficiency.

Overall, these studies provide a wealth of theoretical basis and practical cases for the planning, management, and optimization of green energy, and point out the direction for future urban sustainable development and green energy transition. However, despite some progress, green energy planning and construction still face many practical challenges at the practical level, and further research and innovation are needed to achieve a more efficient and environmentally friendly energy system.

III. MONOLITHIC STRUCTURE

Using the construction project of a group in Wenzhou as an example, the main objective of the system design is to create a large-scale wind and solar integrated energy monitoring system. This system aims to have centralized monitoring and efficient operation and maintenance by relying on a digital cockpit management platform. The system will perform crucial functions such as data storage, operation monitoring, equipment management, statistical analysis, and maintenance scheduling. It will also collect, analyze, and secure real-time data to support intelligent decision-making and operation and maintenance.In regional planning, the adoption of the "carbon pinch point" method (CEPAP) has become a well-established and feasible planning strategy. This approach breaks through the traditional model of relying on increasing the supply of resources to meet energy demand and provides a comprehensive framework for district energy system planning to clarify the energy mix of buildings and optimize carbon emission targets. The main steps in implementing the CEPAP approach include setting clear energy consumption and environmental targets, assessing energy resources, forecasting energy loads, selecting appropriate energy systems and technology pathways, and comprehensively assessing energy efficiency and environmental impacts. Through these steps, the CEPAP approach provides an effective approach to energy planning and carbon emission optimization for regional planning [11].

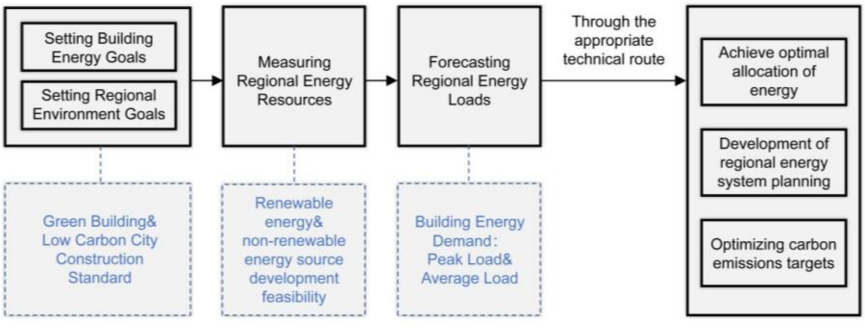

Figure 1 Flow chart of the CEPAP method

The system architecture of the energy monitoring system includes the data perception layer and the application service platform.

A. Data Perception Layer

The data perception layer primarily relies on third-party map services and Internet of Things technology to gather and analyze real-time production and operational data from scattered wind and solar power stations. Workflows at this tier encompass tasks such as identifying data sources, gathering, and transferring data, consolidating aggregates, establishing access rules, and conducting data preparation and visualization.Through IoT devices, the system collects real-time operation data of wind farms and photovoltaic power stations, including the operation status of transformers and booster stations, as well as multi-phase data resources such as power metering information. The collected data is transmitted via an API interface to the Energy IoT gateway following a specific transport protocol, where preliminary data processing such as acquisition, communication, labeling, and pre-processing takes place. The processed data is transferred to the distributor via the IoT-Hub, where it is streamed and batched for use by a centralized monitoring system. In addition, the system labels and aggregates these data on the map to form a panoramic view of the group's distributed new energy power stations, realizes real-time monitoring and visualization of the operation status of the power station, comprehensively displays the operation data of each wind and solar power station, and realizes real-time perception of the operation status of the wind and solar power station (Figure 2).

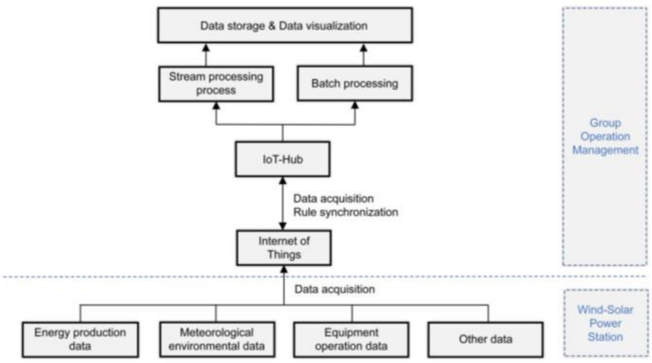

Figure 2 Flow diagram of the data-aware layer

While displaying data in real time, the system also integrates intelligent monitoring and early warning functions. Using simulation technology and a rule engine, the system can automatically determine and schedule distributed tasks. At the same time, the system can monitor the data throughout the process, and once the data anomaly is detected, the system will immediately start the linkage mechanism of message push and abnormal prompt.

Furthermore, the system is equipped with a versatile display mechanism that operates on the principle of service degradation. This mechanism can automatically and flexibly handle abnormal data and faults at the front end, based on predetermined threshold parameters, when an early warning is triggered. This ensures the digital cockpit maintains an important level of availability. At the same time, for key indicators, the system has an early warning and alarm mechanism, when the indicators exceed the warning value, the event will be automatically triggered to notify the relevant personnel, so that timely response measures can be taken.

B. Application Service Platform

The application service platform is a service function developed based on the data perception layer, which is the ultimate realization carrier of the new energy monitoring system scenario, and can provide centralized supervision, maintenance, and fast interaction functions for the new energy monitoring system. By adopting the popular containerization and microservice architecture in the market, the platform enables efficient integration and management of new energy services.

The system architecture uses containerization technology to integrate application functions and the environment on which they are based into a closed and self-contained ecosystem, helping the system achieve rapid application deployment and efficient operation and maintenance management. Containerization ensures consistent and controllable application operation, reduces the risk of environmental variability, and accelerates application iteration. The microservice architecture enables the development, deployment, and expansion of each application service in an autonomous manner, hence enhancing the system's flexibility and maintainability.The common component services in the platform also provide unified integration and O&M services for different applications, improving business efficiency through the reuse of business data. As the core of internal communication, the messaging service bus supports multiple communication protocols and enables seamless connection between different components and services. The application marketplace and platform operation based on the portal architecture provide users with a unified access portal to realize data integration and visualization of business management.

Furthermore, the platform incorporates features such as regional centralized control, equipment health monitoring, and power forecasting, offering robust capabilities for asset management, risk mitigation, and indicator analysis. The sophisticated monitoring and analysis system effectively addresses the monitoring requirements of new energy assets, enhances production and operation strategies, mitigates risks, and enhances power generating efficiency. The system can monitor wind power and photovoltaic units, substations, environmental data, power quality, wind/solar power prediction, energy saving and carbon reduction, etc., and provide data statistics, intelligent report generation, statistical index monitoring, fault analysis and other functions, providing comprehensive operation support for enterprises.

1. At present, the application services that have been completed and put into operation in the first phase include:

a. Wind power and photovoltaic power monitoring. Carry out unified power monitoring and management of the wind power and photovoltaic power generation facilities under the Group, so that the Group and its subordinate power stations can scientifically formulate safe production and operation strategies, to effectively reduce operational risks, improve power generation efficiency and the company's operation and management level.

b. Wind power and photovoltaic equipment failure warning. In-depth analysis of O&M and environmental data of wind and photovoltaic equipment enables early diagnosis and alert of inferior performance and potential faults. The system integrates multi-dimensional data, supports intelligent inspection, and combines it with manual inspection to improve the intelligent level of wind farm operation and maintenance, and achieve the goal of "unmanned duty, less attendance, intelligent operation and maintenance, cost reduction and efficiency increase" [12].

2. Overall, the technical architecture design effectively solves the problem of data islands, realizes the integration, consistency, and maintainability of the system, and at the same time, the visual management function of the platform also facilitates the operation of wind farm managers and improves management efficiency. The following expansion and transformation can be considered for the follow-up phase II project:

A. Meteorological resource monitoring and forecasting systems. The system can graphically present the distribution of solar and wind energy resources using a geographic graphical interface. This interface includes important indicators such as wind speed, wind direction, irradiance, air temperature, and air pressure. The system provides the day's wind and solar resource index data, as well as the corresponding power generation function forecast, planning and actual power generation performance. In addition, long-term assessment of new energy resources can be carried out, and daily, monthly, and annual trends in power generation and wind and solar resources can be analyzed, as well as year-on-year and month-on-month data. Wind speed or wind power density analysis can be used to predict the long-term trend of wind resources in wind farms or regions, and solar irradiance data can be used to analyze the trend of photovoltaic power plants or regional wind resources [13].

b. Data-driven decision-making and optimization. The vast amount of data collected by the system can provide valuable information to operators and managers to help them make more informed decisions to optimize equipment maintenance schedules, budget allocation, and more. By monitoring and analyzing data over time, the system can reveal long-term performance trends to support continuous improvement and optimization strategies to extend the life and performance of equipment.

c. Dynamically control the power utilization efficiency of the entire region and grasp the relevant indicators such as wind energy and carbon emissions and use them as the operation and evaluation standards in the region, to realize the rational use of electric energy in the region. Monitoring energy consumption involves carbon emission monitoring and energy consumption, energy consumption assessment and carbon audit. Compared with traditional energy consumption monitoring, data centers pay more attention to the application of solar energy and wind energy utilization and use them as one of the evaluation bases for data centers.

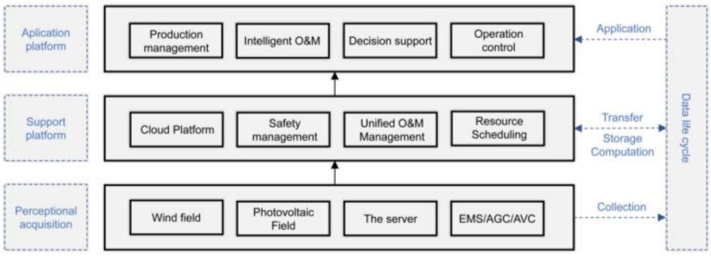

Figure 3: Flowchart of the platform operation based on the data lifecycle

IV. Information Security

To ensure the security of the system, storage and computing separation technology is used in data security, and the effective separation of the private domain and the public domain is realized through logical isolation. Under this architecture, the data and services of the digital cockpit are deployed in the government intranet area to ensure its security. Internet users will only be able to access the cockpit's front-end interface. At the same time, for the data transmission process, end-to-end full-link data encryption technology is adopted to minimize data leakage.

The platform is built with an advanced open framework and a trusted mutual recognition mechanism, which enables the platform to flexibly integrate systems and scenarios from multiple parties. At the same time, the platform relies on a strict identity authentication mechanism, targeted user group restrictions and careful organizational structure design to ensure that only trusted users can access and further enhance the security of the system.

Furthermore, by employing hierarchical authority isolation technology, the system has created a comprehensive authority control mechanism. This mechanism categorizes users, booths, and indicators into three levels, and the "trinity" permission management system ensures that managers can only access content that falls within their area of responsibility in the digital cockpit. This approach guarantees operational flexibility while upholding data security and confidentiality.Through these comprehensive security measures, the overall security of the system has been significantly improved, providing a solid guarantee for the security management of government data.

IV. App results

The platform was officially put into use in 2022 and has been connected to 11 distributed new energy power stations within the group, with a maximum distance of 110km between distributed power stations. A total of 37.14MW of wind turbines and 28.3MW of photovoltaic modules will be connected to the actual power generation of 80,854,199 kWh in 2023, with an average monthly power generation of 6,737,800 kWh, the active power of wind farms will be maintained at 6.7-6.9MW, the active power of photovoltaic farms will be maintained at 0.5MW-0.6MW, the average annual equivalent full-load utilization hours will be 1090.19h, and about 831 background monitoring points will be established, with nearly 200,000 daily processing data. It has become a large-scale centralized monitoring and management system for new energy data in Wenzhou. The distributed new energy power station has contributed a total of 18,849.28 tons of CO_2 emission reduction and 7,638.13 tons of coal savings to Wenzhou, and it is predicted that the average annual power generation of two wind farms will be about 60,337,421 KWh, and the average power generation of nine photovoltaic farms will be about 26,496,600 KWh. Calculated based on the benchmark price of 0.4153 yuan/KWh (RMB) in Zhejiang Province[14] The annual direct economic benefits of wind farms are about 25,058,100 yuan, which is 3,508,100 U.S. dollars at the exchange rate of about 0.14 yuan per 1 yuan (the same below), an increase of about 501 million yuan (70,162,800 U.S. dollars) in a 20-year operation cycle, and a direct economic benefit of about 11,004,038 yuan (1,540,600 U.S. dollars) per year for photovoltaic farms, an increase of 220 million yuan (30,811,300 U.S. dollars) in a 20-year operation cycle. If it is fully extended to wind and solar fields in the entire Wenzhou area, its annual economic benefits are estimated to exceed 200 million US dollars.

V. Enlightenment of the path of promotion to Wenzhou's new energy planning

According to the experience of the above project construction, we can try to explore the path of low-carbon energy planning at the regional level of Wenzhou city.

Initially, the evaluation and forecasting of dispersed renewable energy sources in the area. Utilizing big data analysis, the assessment and forecasting of distributed energy resources in the area, such as distributed solar and wind power, aids in the logical design of regional energy distribution. The first step is to conduct a topographic assessment. By analyzing topographic features, such as the mountains, oceans or plains of Wenzhou, the impact of topography on new energy resources is assessed. This will help cities to more accurately grasp the potential of new energy resource development when selecting new energy projects. The second is to carry out new energy data measurement and analysis. For example, Wenzhou's onshore wind energy resources have a theoretical reserve of 1.5 million kilowatts, which has great wind energy development value [2], collect historical wind energy, solar energy and other new energy measurement data, use meteorological models, ocean models, etc., to conduct in-depth analysis of the collected new energy resource data, and explore the distribution characteristics and laws of new energy resources and predict the spatial and temporal distribution of new energy resources in the future, so as to provide cities with more targeted new energy planning strategies and carry out reasonable and efficient planning and development of new energy projects.

Second, the forecast of new energy power generation in the region. According to the distribution of new energy resources, machine learning and artificial intelligence algorithms can be combined to predict the power generation of new energy power stations at the urban regional level. This function can help cities more accurately predict the power generation and economic benefits when planning new energy power generation projects, providing a basis for investment decisions. After the evaluation of the power generation project is feasible and the construction is put into use, the enterprise can also compare the actual power generation situation with the planned and predicted power generation, so as to better monitor the actual production of the new energy project, find and solve the problem in time, and improve the production efficiency.

Third, the optimal scheduling of regional source-grid-load-storage. Evaluate the power load of the plot in the planning area and evaluate the distribution and change trend of the electricity load according to the scale and power intensity characteristics of different land functional plots (such as industrial land, commercial land, and residential land). Through data analysis, it is possible to predict future power demand and changes, optimize power dispatching, and plan corresponding power storage facilities such as land for energy storage power stations as to improve the reliability of power supply [15].

VI. Conclusion

This study implemented a two-level scheme for integrating a new energy monitoring system and a big data center, specifically designed for Wenzhou City. The scheme successfully achieved real-time monitoring and data analysis of the wind-solar integrated energy system. The implementation of the system has significantly improved the efficiency and safety of energy management and provided strong technical support for the green energy transition and sustainable development of Wenzhou. In the future, the scheme is expected to play a key role in broader regional energy planning and promote the development of a low-carbon economy.

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