Research on Regional Micro-meteorological Measurement System for the Operation Control of Distribution Network

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Abstract. With large number of wind power and grid-connected photovoltaic system, the ratios of renewable power greatly increase. However, random variations of the meteorological environment usually have a huge impact on the output of the renewable power, also the performance and stability of power grid. Hence, a local meteorology real-time monitoring technique is really needed. In this paper, a local micro-meteorological monitoring system is proposed, which takes temperature, wind speed, wind direction, and illumination intensity into account. The measurements would provide a reliable real-time meteorological data for power supply forecast and operation reference of distribution network. The hardware and software design are discussed. Finally, a prototype is developed.

1. Introduction
With the change of global climate, the deterioration of human ecological environment and the shortage of conventional energy resources, the new energy represented by wind power and photovoltaic power generation has been highly valued worldwide and developed rapidly in recent years. According to the national energy administration on June 6, China's installed photovoltaic power generation capacity reached 179.7 million kW by the end of March 2019, including 126.25 million kW of centralized power stations and 53.41 million kW of distributed photovoltaic power [1]. In the past decade, China's wind power technology has also achieved revolutionary development. In 2010, China surpassed the United States as the country with the largest installed wind power capacity [2]. However, photovoltaic and wind power production is heavily influenced by local weather. In cloudy weather, photovoltaic output fluctuates violently, when wind speed, direction and other factors change, wind power generation fluctuation is also very obvious, which will cause voltage fluctuation and power factor over accuracy of the power grid, leading to changes of frequently switched reactive power compensation equipment and main transformer, posing a threat to the safe and reliable operation of the local power grid.

By analysing the factors affecting photovoltaic power generation through the historical meteorological data set and forecast daily data, the daily feature vector is constructed, the historical daily data is selected as the training set, and the forecast daily data is used as the calibration set. LSSVM parameters are optimized by using the global optimization characteristics of the improved bat algorithm to construct a short-term photovoltaic power prediction model [3]. By analysing the
correlation between various meteorological factors and power grid load, the corresponding relationship between meteorological factors and power grid load is found. On the basis of the building method of the empirical correction model library, and according to factors such as humidity, rainfall, temperature, pressure, the corresponding correction model is established, the results show that the model has a good prediction accuracy [4]. Based on a numerical weather prediction, a prediction model considering the seasonal cycle and daily cycle of statistical is set up, and then points and application of three kinds of different time algorithm (median classification, classification, regression and classification clustering) to modify the original short-term forecast, and using minimum variance portfolio combination algorithm of the 3 kinds of monomer, so as to achieve the goal of the output prediction [5].

The above new energy power station output prediction methods have certain engineering significance, but most of them are based on the past historical meteorological data, and there will inevitably be some errors. Therefore, it is necessary to monitor the micro-meteorological factors affecting the output of photovoltaic, wind power and other new energy power stations, so as to provide accurate new energy output prediction for rational adjustment of distribution network. Foreign research on micrometeorological distribution network began in the late 1990s. Since 2000, the online micrometeorological monitoring technology of distribution network has attracted the attention of many countries in the world. In recent years, a major breakthrough in micrometeorological monitoring of distribution network in foreign countries is the realization of automation and nationalization of distribution network monitoring [6]. The early micrometeorological monitoring methods of distribution network in China were limited to single processor and could only measure single micrometeorological information. In addition, measurement data cannot be reflected to transmission line managers in real time, but can only be obtained by periodically outputting data from the processor [7-9]. In order to improve the problems existing in micrometeorological monitoring in the past, such as the simplification of monitoring meteorological factors, the complexity of sensor layout and so on, a remote real-time meteorological monitoring system based on general packet radio service (GPRS) is designed in this paper, to monitor the wind speed, wind direction, solar radiation, temperature and other meteorological factors, and to provide real-time meteorological basis for the prediction of the output of the renewable power and the regulation reference of distribution network.

This paper mainly includes three parts, the general design of micrometeorological monitoring system, hardware and software design, as well as the prototype design and overall deployment of micrometeorological monitoring system. The general design of micrometeorological monitoring system is introduced, including its system structure and network structure. Hardware and software design mainly includes hardware structure of meteorological monitoring station, monitoring data collection and processing process, appearance design and so on.

2. Construction of micrometeorological measurement system

The integrated micrometeorological monitoring system designed in this paper consists of meteorological monitoring stations and server clusters distributed around new energy power stations. Its overall system block diagram is shown in Fig. 1.

**Figure 1. System block diagram.**
The above figure shows the overall working process of the integrated micrometeorological monitoring system. First, the meteorological data monitored by distributed meteorological monitoring stations are sent to the data access area through virtual private network (VPN). After receiving the data, the meteorological data are pre-processed by the data access server, and then the corresponding application services are called. The data are calculated and stored in the big data analysis server. Users could view various applications of the system through interactive application services.

Figure 2. Configuration diagram of a micrometeorological monitoring system.

Micrometeorological monitoring system configuration diagram is shown in Fig. 2. System consists of the Infrastructure layer, Big data platform layer, and Application service layer. The infrastructure layer includes micrometeorological monitoring stations, servers and network equipment. The big data platform layer consists of Nginx server and Apache server. The view of the system business is realized through the service application in the application service layer.

3. Hardware and software design of regional micrometeorological measurement system

Hardware and software design of regional micrometeorological measurement system mainly includes hardware structure design, appearance design, collection and processing of monitoring data, communication scheme design and so on.

3.1. Hardware Design of Regional Micrometeorological Measurement System

The integrated micrometeorological monitoring system uses mainstream weather sensors, which can detect wind speed, wind direction, rainfall, illumination intensity, ultraviolet intensity, temperature, humidity, air pressure and other meteorological factors. Each module and the general control unit communicate through the IIC data bus [10]. The shortest time to complete the summary of each sensor information is every 16S. Then system could generate a message, which is then sent to the front data acquisition server through the GPRS module.

Figure 3. Hardware structure diagram of micrometeorological monitoring station.
As shown in Fig. 3, the micrometeorological monitoring station is equipped with temperature sensor, humidity sensor, illumination intensity sensor, wind direction sensor, rainfall sensor and other sensors. Each sensor communicates with the main processor STM32F103 through the IIC data bus, and generates messages according to the communication protocol, which are sent to the data access area through virtual private network [11]. The hardware watchdog is configured, power supply could restart when the system program run dead. The system is powered by energy storage batteries charged by solar panels. At the same time, in order to meet the requirements of working in the outdoor environment, the shell of the micro-meteorological monitoring station should also meet the requirements of waterproof and dustproof, as shown in Fig 4.

The Micrometeorological monitoring system design flow chart is presented in Fig. 5.

3.2. Software Design of Regional Micrometeorological Measurement System
In order to reduce the development cost of the system, Hadoop data analysis cluster is established by using several decommissioned servers to accept the scheduling of business servers for data analysis and operation [12], and its operation capacity can reach the operation level of high-end servers. The big data platform layer consists of Nginx server and Apache server. Nginx server is the only high performance server installed in the system. It is a load balancing server, responsible for data access and distribution, and overall scheduling of its connected server clusters. Apache server is installed on the decommissioned server of the company, and Hadoop framework is used. Through distributed file system, big data analysis algorithm is run on low-performance hardware, and the system has high fault tolerance. Hadoop is a basic framework of distributed systems developed by the Apache foundation, which enables users to develop distributed programs without knowing the underlying details of distributed systems and make full use of the power of clusters for high-speed computing and storage. The integrated micrometeorological monitoring system adopts STM32F103 controller as the main control chip. The system software mainly consists of the following procedures: main procedure, temperature acquisition procedure, solar radiation acquisition procedure, wind direction acquisition procedure, wind speed acquisition procedure, GPRS wireless data transceiver procedure.
The data is reasonable? 

Remeasure 

N 

Y 

Generate a message 

Message Upload 

END 

Figure 6. Meteorological monitoring data processing flow chart.

The data processing flow chart of the integrated micrometeorological monitoring system is shown in Fig. 6. After the data measured by the meteorological monitoring station is judged reasonable by the system, a message will be generated and uploaded to the server through GPRS module. Since the IP address of the public network of the Internet of things card is regularly redistributed by the operator, in order to ensure the stability of communication and reduce the burden of the weather station processor, the encapsulated HTTP pass-through module is used for communication. The processor only needs to send the data to the HTTP module through the serial port, and the module will automatically establish a connection with the server, and send the data to the server according to the HTTP communication protocol after packaging.

4. Prototype design and deployment of micrometeorological monitoring system

Based on the above analysis and design, combined with the structure design of waterproof and dustproof, a set of regional micrometeorological comprehensive monitoring system prototype is developed in this paper, which can realize the measurement of wind speed, wind direction, illumination radiation, temperature and humidity and other meteorological data. The prototype of a micrometeorological comprehensive monitoring station is shown in Fig. 7.

The grid deployment of regional micro-meteorological measurement system is shown in Fig. 8. Meteorological monitoring stations take new energy field stations as the radiation distribution at the center of the circle and divide the area into grids according to the geographical location. According to the meteorological data of grid monitored by each meteorological station, the trend of meteorological change could be forecasted through data analysis algorithm.

Figure 7. The prototype of micrometeorological comprehensive monitoring station. 

Figure 8. Grid deployment of regional micro-meteorological measurement system.
5. Sections, subsections and subsubsections
The micrometeorological monitoring system designed in this paper takes STM32F103 controller as the main control chip and develops microclimate and meteorological acquisition software, which can collect temperature, wind speed, wind direction and solar radiation information in the monitoring area. This design uses GPRS as the wireless data transmission unit, and Data communicates through the encapsulated HTTP passthrough module. In the big data comprehensive processing unit, Nginx server is responsible for data access and distribution, and coordinates the cluster of servers connected to the power grid dispatching. Apache server adopts Hadoop framework and can run big data analysis algorithm on low-performance hardware through distributed file system. The energy storage battery charged by solar panels can ensure the stable, reliable and durable operation of the system. The prototype of the regional micrometeorological measurement system is designed in this paper and the overall deployment scheme of the micrometeorological monitoring system is given. The monitoring system designed in this paper effectively improves the problems existing in past micrometeorological monitoring, such as the simplification of monitoring meteorological factors and complicated sensor layout. The system can monitor wind speed, direction, solar radiation and other meteorological factors in real time, providing real-time meteorological basis for renewable energy output prediction and distribution network dispatch.

6. References
[1] Y. XIE. “Design of Low Power Consumption and Real-Time Monitoring System of Micrometeorological for Power Transmission Line”, PROCESS AUTOMATION INSTRUMENTATION, Vol. 39 No. 4, Apr. 2018
[2] S. WANG, X. ZHANG. “The influence of microclimate on transmission line and its countermeasures”, Yunnan Electric Power, Vol. 6, 2005
[3] C. DENG. “The research and develope of Micro-meteorology Power Grid Real-time Monitoring System”, North China Electric Power University, 2008
[4] C. LIAO, R. LIANG, N, LI. “Study on influence of meteorological factors on load characteristics of power grid”, Science and Technology Innovation Herald, No. 17, 2010
[5] H. HOU, X. YIN, Q. CHEN, D. YOU, G. TONG, D. SHAO. “Analysis and consideration of the damage caused by snow and ice disaster in 2008 in the south part of 500 kV main network frame”, Automation of Electric Power System”, Vol. 32, No. 11, June 10, 2008
[6] T. SONG, C. QUAN, J. RAN, Y. LIU. “Analysis of micrometeorological monitoring technology in distribution networks”, Scientific and Technological Innovation, Vol. 4, 2008
[7] Z. WANG, X. ZHAO, G. WU, Y. HUANG. “Design and Realization of Micro-meteorological Disaster Mornitoring and Pre-warning System in Power Grid”, Power and Energy, Vol. 35, No. 6, 2014
[8] Y. JIN, W. ZHANG, Z. YU, W. ZHAO. “Research on Electric Micro-Meteorological Disaster Monitoring and Early Warning Technology”, ELECTRIC POWER ICT, Vol. 13, No. 4, 2015
[9] H. ZHAO, C. ZHU, Z. YU, Y. MEN, J. GUO. “Electric Micro-Meteorological monitoring and Early Warning System”, East China Electric Power, Vol. 42, No. 5, May, 2014
[10] D. DUAN, Y. ZHANG, X.GUO, K. YE, Y. LU, X. YU. “Statistical Law and Distribution Characteristic of the Impacts of Climate on Equipment of Beijing Power Network”, High Voltage Apparatus, Vol. 49, No. 7, July, 2013
[11] J. XU, W. ZHEN, X. HUANG, C. YANG. “Transmission Line Icing Prediction Model Under Micro-Meteorological Conditions”, ELECTRIC POWER, Vol. 47, No. 2, Feb, 2014
[12] J. ZHOU, C. LI, Y. ZUO. “Natural disaster risk assessment based on fuzzy number similarity”, Manufacturing Automation, Vol. 35, No. 8, 2013

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