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The Application of New Automatic Weather Station in Power System

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Abstract

Aiming at special demanding of weather monitoring in power system, an application project was designed basing on new type distributed and smart automatic weather station (AWS) Defects such as fixed hardware configuration and centralized data acquisition are overcome in new AWS. With distributed data acquisition node, AWS can extend and add new sensors for disaster forecasting of lightning, strong gale, icing of transmission line and insulators contamination flashover in power system and it is also convenient for evaluation of wind energy, solar energy and for power load forecasting. Using protective power supply to each node, AWS has high performance of lightning protection, which will not let system breakdown for any node crash. Three-stage automatic self-checking for node state is included, which can make failure diagnosis efficient. Data quality checking node is created in new AWS. It can provide data self-checking function and improve reliability of data from unattended AWS. Finally, application models of monitoring data are introduced. New type AWS is fit for system with many sensors or large amount of data flow. And this project can supply accurate, adequate and real-time data for weather disaster prevention and other applications in power system.

Keywords: automatic weather station, power system, weather monitoring, unattended operation, data quality checking

1. Introduction

Weather has been one of the important factors affecting construction,safe and stable running of power system. With the expanding size of power grids, complicating of loads structure and power structure. Disastrous weather will has severe effect on the stability of power system.

Now modernization in China embarked on a new level. Automatic weather station (AWS) network has been deployed and constructed according to China Meteorological Administration’s plan of meteorological observation automation.

Automatic weather station (AWS) is a device for meteorological observation above ground [1]. It can observe spatial environmental factors accurately, such as solar radiation, wind speed, wind direction, rainfall, air pressure, air temperature, relative humidity. And the data measured would be sent to remote central database to form a big meteorological observation network [2-3]. AWS is important to local environmental monitoring and to avoid meteorological disasters [4].

But most AWS produced in China are just only for data acquisition and data transmission of general meteorological factors. It’s the basic detection instrument and is lack of pertinence about power system. The vast majority of weather stations and AWS have been not aimed at the sensitive weather factors of meteorological disasters, electrical equipment investment and load forecast. Integrated unattended AWS, which can observe the icing of transmission line, lightning, gale, mountain fires, gradient wind, visibility and so on, is scarce in China.

When the domain of observation is expanding and requirement of automation and intelligence is rising, AWS demands higher stability and data quality [5-6]. In the remote

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mountainous regions and seaside, AWS would breakdown frequently for tough detection environment and even worse, its data is unreliable [7].

A new distributed and smart AWS has changed the central data acquisition structure into distributed node network. Three-stage self-checking system has been set up and data quality node has been created. Expansibility, stability and reliability have been improved. And fault location could be found quickly. This paper designed an application project for the distributed and smart AWS aiming at special demanding of weather monitoring in power system.

2. AWS Structure of Power System

Most of the running AWS have a central data acquisition structure, shown as figure 1. Different types of signals from far sensors are transmitted to the core module of AWS, and then they are sampled and processed in turn. The core module has sockets on the interface card for many sensors. When sensors are increasing, sockets are not enough now. When sensors are far enough from the core module, signals would attenuate fast and have interference signal. And there are some other questions such as lagging processing and data missed because of overload of core module.

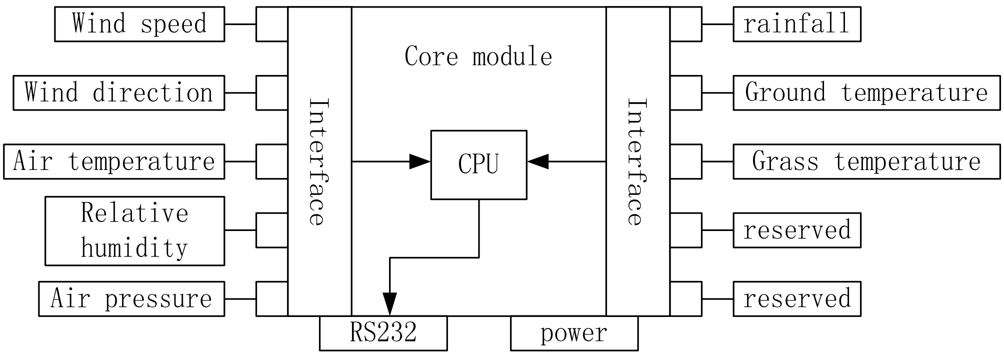

Figure1. Central Structure of Data Acquisition

High performance asks more CPU time and RAM, while a great variety of programs would disturb the order of data sampling. Distributed network is adopted here to avoid such questions. Different modules have different functions in the new AWS system, and all of the modules are connected to CAN Bus to form an AWS network. CAN is used for its network reliability, real-time ability and Bus flexibility [8].

The system structure of distributed and smart AWS is shown in figure 2 in power system. Main acquisition module sends commands on CAN Bus and collects data from distributed acquisition modules to form a long data frame. Then data frame is sent to remote central sever by wireless module or local area network. To avoid breakdown of the system caused by failure of main acquisition module, backup of main acquisition module is added. Because of non-destruction bus arbitration technology, main acquisition module has the supreme authority to use CAN Bus even command is sent on Bus at the same time by the backup module. Backup module receives clocked disable command from main acquisition module and sends nothing on Bus. When main acquisition module has failure and no clocked disable command is sent, backup module will control the Bus instead of the main acquisition module.

Distributed modules are different for different observation functions and requirement. They are independent to each other but they can communicate through CAN Bus. Different authorities of the Bus keep the system efficient from chaos.

In meteorological observation, general environmental factors include 6 elements of air temperature, relative humidity, air pressure, rainfall, wind speed and wind direction or 4 elements of air temperature, rainfall, wind speed and wind direction [9]. One distributed acquisition module is set to observe and make standard data frame.

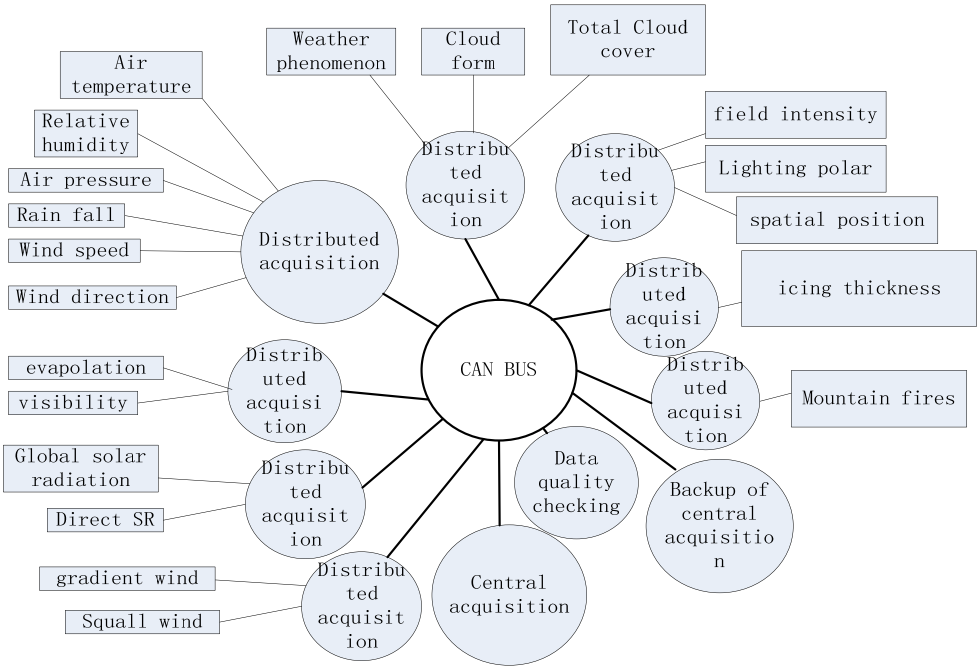

Figure 2. distributed structure of data acquisition

Pre-survey of wind resources is essential for the wind plant location and fan selection, so it is necessary to add gradient wind sensors to AWS. Photovoltaic (PV) power has direct and close relations with solar radiation and cloud cover. One distributed acquisition module monitors these factors in the system.

It is the same situation when gale or squall is needed to be observed in the transformer substation, coastal areas and wind region where line is located in.

Lightning warning system is important for large substations and plant and Ultra high power (UHP) transmission line. So distributed acquisition module with atmospheric electric field sensor is connected to AWS. It can comprehensively analyze the probability information of lightning integrated with the existing lightning stroke system.

Another visibility module is needed in the fog area, because fog will result in insulators contamination flashover.

While another module is needed for the icing of transmission line, which can warn the icing situation to avoid the tower collapse and line broken in power grid.

Mountain fires will cause power system trip. One distributed acquisition module with high-definition video and picture can monitor line’s environment in real time.

All of the standard data frames from distributed acquisition modules will assemble in main acquisition module and be sent out. Data quality checking module can find outlier in real time data. Its data self-checking function is very important under some special weather situation.

With simple functions of command sending and data transmission, main acquisition module will not slow down because of a big network or dozens of nodes. So smart AWS with CAN Bus has good adaptability for different environment. It is easy to add one node or to delete one node, while the network is operating normally. Baud rate of the Bus could be changed. The longest distance of communication could be 10 km when the baud rate is 5 kbps. Thus distributed acquisition nodes can be installed near the sensors and join in the AWS system through CAN Bus.

Node that is failure would withdraw from CAN Bus unless it is short. For more stability the system uses protective power supply for each module as figure 3. There are two grade protections in power system, including surge protection and leakage protection. When there is short failure in one module, leakage protection device will disconnect it from the system to protect other modules. When there is surge voltage from the system, surge protection device will protect the module. Response time of the first-grade should be longer than that of second-grade but should be less than withstand high voltage time of modules.

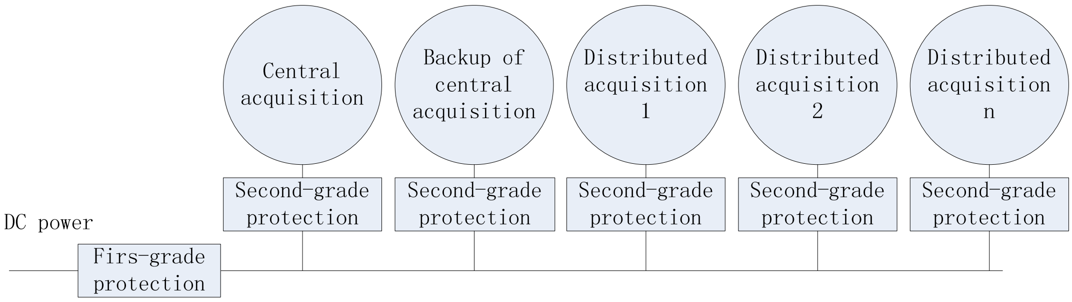

Figure 3. protective power supply system

3. Smart State Checking

State self-checking is one of the most important functions of smart AWS. To smart AWS system, both main acquisition module and distributed acquisition module are smart nodes with different Bus authorities. The state self-checking includes node state checking, node chips checking and sensors checking. Self-checking is created to find fault location quickly. Some AWS are installed in outlying areas, remote maintainers need detail failure information to make suitable repair plan.

Node state checking can find CAN Bus fault or node that is breaking down. Main acquisition node broadcasts self-checking command on the Bus and normal nodes return some factors such as operating voltage and time.

Node chips checking can find fault location on circuit. As show in figure 4, main acquisition node reboots the system and distributed nodes start to check the chips on circuit. The CPU initializes smart chips in order. Interruption function would be disabled first, and then RAM would be read and written. And the interface chip like 82C55 chip would be configured. Then ADC chip, CAN controller, COM chip are initialized. At last, interruption function would be enabled again and state information would be sent to main acquisition node. To reduce the dependence of fault information transmission on CAN bus, the RS485 ports of nodes can also compose an auxiliary bus network. So fault information will assemble in main acquisition module or the backup module by CAN bus also by RS485 bus at the same time.

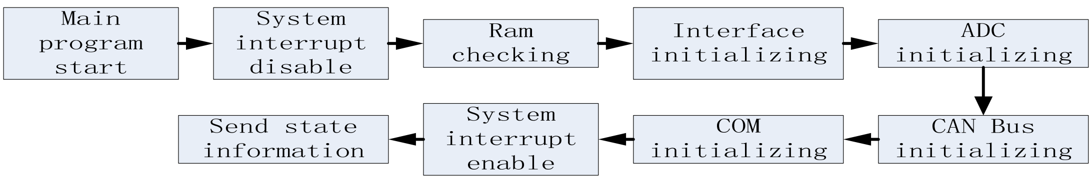

Figure 4. State Self-Checking In Node

Sensors checking can collect state information of sensors that connect to the node. For different sensors there are different signals. Special signal has special amplitude and signal range. Program can assess the state of sensors by data checking. For example, the signal range of relative humidity sensor produced by Vaisala Company, Finland, is 0~1 V. Sensor is out of order if 1.2 V signal is found. Nodes collect the sensors state information and report to the main acquisition node.

4. Data Acquisition

4.1. Data acquisition for general meteorological factors

New system has the same data acquisition function with old AWS. There are several methods for different signals. Proper hardware configuration and programs are set for signal sampling accurately. It is shown in figure 5. And one distributed acquisition module uses one or more methods according to the sensors it controls.

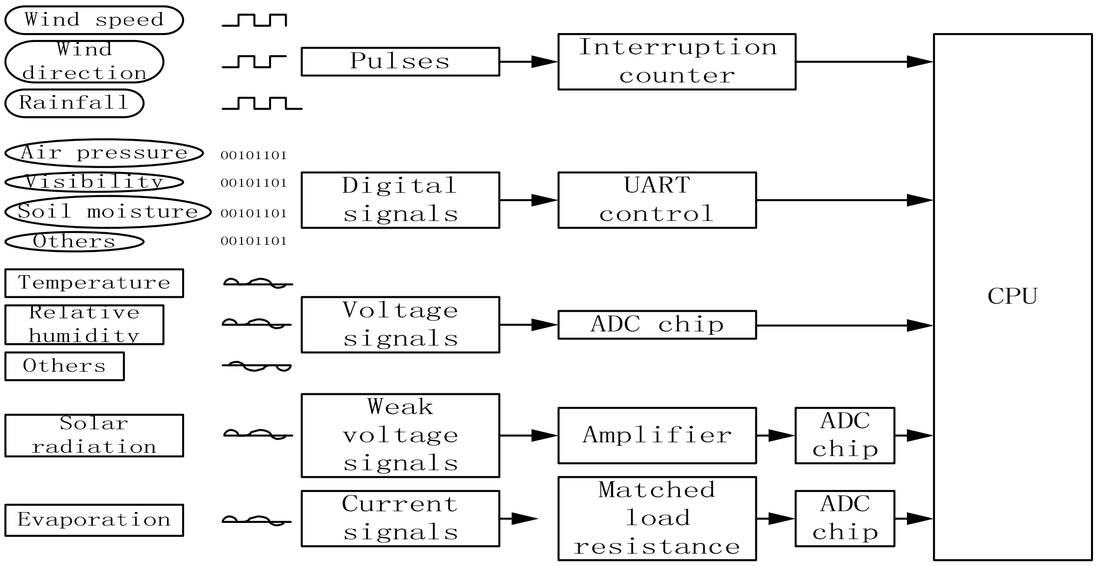

Figure 5. data collection methods for different signals

Wind speed, wind direction and rainfall sensors give pulse signals, so high frequent and clocked polling program is needed. It catches rising edge and falling edge of pulses and calculates period of the pulses. To read sampled data in ASCII character strings from smart sensors such as air pressure sensor, visibility sensor, software for UART control is programmed. Data would be read correctly after redundant check.

Sensors that output voltage signals should not be installed too far from acquisition module because resistance of the transmission line would make signals weak. Analog signal will be converted into 16-bit digital code through ADC chip. And then data processing will be started in CPU. For weak analog voltage signals, such as 0~20 mV signals from solar radiation sensors, a linear amplifier is necessary before ADC chip, and shield transmission line is necessary too. Analog current signal from ultrasonic wave evaporation sensor attenuates less even the sensor is installed in a long distance, but matched load resistance should be used before signal is converted.

The data collection for gradient wind, lightning, icing of transmission line, mountain fires is needed by power system except above sensors of general meteorological factors.

4.2. Data acquisition for gradient wind

The wind tower of 50 meters high , 70 meters high or 100 meters high is built up according to different terrain condition. It has the advantages of data stability and reliability. It needs investment less and is rightness for wind resource evaluation. Multilayer wind speed, wind direction sensors and ultrasonic wave sensor are used to improve the accuracy. All sensors communicate by RS485 bus to reduce the system complexity and failure rate.

4.3. Data acquisition for lightning

Lightning monitoring by lighting location system (LLS) is a detection systems of cloud to ground lightning. The spatial position of lighting is fixed on the measurement of electromagnetic pulse only after the charges in thundercloud accumulate to breakdown the air, so LLS can detect lighting but can not warn it.

The atmospheric electric field instrument, as shown in figure 6, can measure the atmospheric electric field and its change with a monitoring probe like windmill. When the electrical charges begin to separate in cloud, the ground field will correspondingly change. Rotor rotating of sensor converts electric charges on stator to voltage which is proportional to the atmospheric electric field, then the atmospheric electric field instrument will process the data and display the field value. When field intensity begins to change sharply to threshold, alarm will be triggered ahead of 10~30 minutes according to different lighting status.

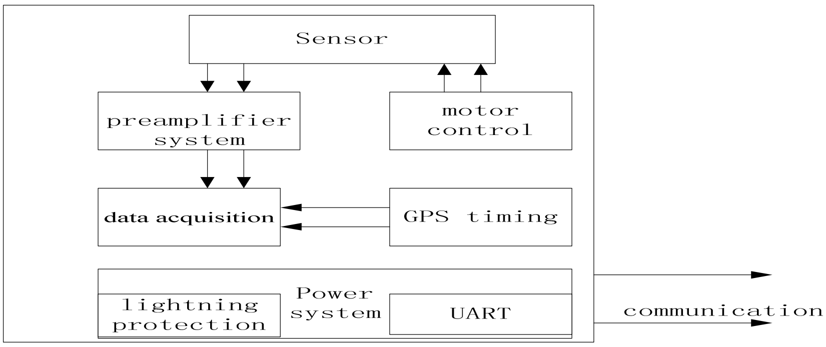

Figure 6. The structure of atmospheric electric field instrument

4.4. Data acquisition for icing of transmission line

Image analysis method about the icing of transmission line is simple, but its monitoring distance is limited and it cannot work normally under bad situation. Compared with the traditional resistance strain gauge, fiber bragg grating(FBG) is electro magnetically immune, and has good insulation properties and long life span, and it can be reliably applied in the ice monitoring [10].

Online monitoring system for icing of transmission line consists of fiber optic strain sensors, fiber optic temperature sensors, optical fiber composite overhead Ground Wire (OPGW), FBG regulating instrument [11]. All sensors are distributed on transmission line. Optical fiber sensors reflect different optical signal as wires become longer, expand with heat and contract with cold. Sensors are connected to FBG regulating instrument by OPGW, which can realize optical signal transmission among them. Then central wavelength of reflected signals will be modulated by FBG regulating instrument, and sent out to server. Server software calculates the ice thickness with mathematical model.

4.5. Data acquisition for mountain fires

Mountain fires has a serious influence on line safety, and will cause cascading trips. Monitoring system of transmission line consists of wireless image monitoring master, high-definition camera, power and server monitoring software. The system can achieve the goals of a real time online condition monitoring for transmission line, tower, insulator string, surrounding environment.

Image compression technology, digital signal processing technology, remote control technology, wireless communication technology, new energy and low-power applications technology are applied on this system. Monitoring extension receives commands from server at regular time or real time, such as adjusting of resolution ratio and focus, Yun tai camera rotating, sampling time interval, system time, viewing image and data at real time, and then starts up the camera. Video signal collected by camera is compressed into standard data frames and fed directly into computers by wireless communication module.

5. Data Self-checking

Data quality checking is an innovative function of new AWS. The extreme value detected under tough weather situation is meaningful and important. But electromagnetic interference, power fluctuation and other not natural reasons produce extreme value too. The extreme value must be confirmed before being referenced. In the situation of unattended operation, data quality self-checking node improves reliability of data from AWS. One or more data quality checking nodes could be set up in a distributed and smart AWS system.

Procedure of data quality checking is shown in figure 7. The node saves data from other distributed nodes and checks data according to three databases which are Limitation Database, Trends Regulation Database and Correlation Models Database.

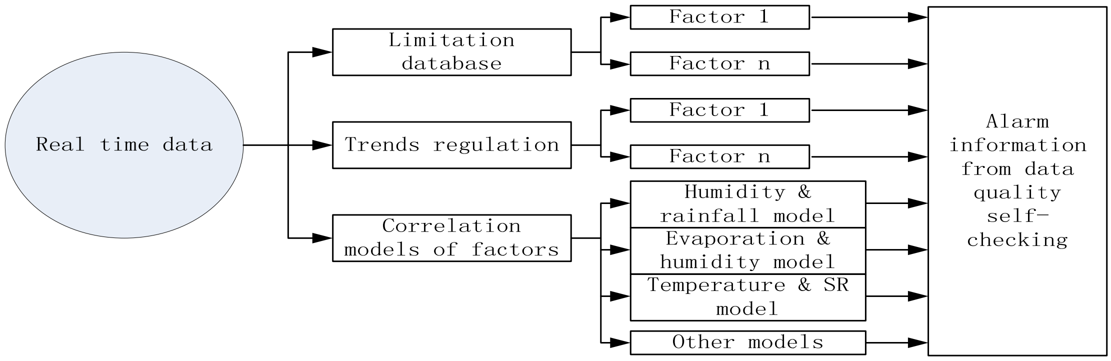

Figure 7. Real time data checking node

The upper limit value and lower limit value of every environmental factor are recorded in the Limitation Database, and the rate of change is recorded too. Because of the different local environments the same factor has different change rate. For example, relative humidity at seaside changes slower than that on hillside. And it will keep a high value at seaside. It is doubtful if the value jumps lower and data checking is necessary. Limitation Database in AWS is different, and it should be updated according to history data of local environment, so that data from AWS will be more typical. For example, Alarm threshold of lightning is different obviously for different regions, such as plain、hills、plateau and so on .So more intensive observation data and historic records are made to define the alarm threshold of lightning with local needs.

Trends regulation record curves of each factor, and a reversal of sampling data is doubtful. There are mathematical models of factors in Correlation Models Database. Data of one factor can be checked for its reliability by data of another factor. For example, there are correlation functions between relative humidity and rainfall. When air temperature and air pressure are stable, rainfall makes humidity rise easily. If humidity becomes saturated the correlation coefficient will be smaller. Ground temperature or black bulb temperature are relative to solar radiation. Ground temperature depends on infrared radiation in solar ray, so it has the same change curve with solar radiation. Extreme value of one factor can be checked with other data by such models and its reliability could be confirmed.

6. Data Application Models in Power System

Any meteorological disaster in power system is attributed to several meteorological factors. Kinds of data models should be established to process meteorological data. When the application index in power system has linear relation with several meteorological factors, it can be analyzed with multiple linear regression. Then multiple linear regression model is established. Large number of actual data is needed to determine the regression coefficient. This model is usually applied to electrical mid-long term load forecasting or PV power forecasting of solar energy.

In many cases, the application index has uncertainty relation with meteorological factors. Optimum regression equation through random seeking and flexibility of the genetic algorithm should be built then. The prediction and forecasting precision of such model are preferable than that of linear regression.

7. Conclusion

This application project makes full use of distributed network of new type AWS. In view of special needs of power system, special acquisition modules are added. They are connected by CAN bus and synchronized data acquisition of many factors is realized. Thus installation of sensors is convenient and the efficiency of data acquisition is improved.

On the other hand, three-stage automatic self-checking can help remote fault analysis, which makes maintenance of unattended AWS easier and efficient. Data quality checking function makes data acquisition reliable, especially when there is extreme value. Models can be updated by history data and supply more typical acquisition data. Then different and detailed application models can be established for weather disaster prevention, power load forecasting and evaluation of wind energy or solar energy, which help decision making in power system.

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