Research on Variable Topological Structure and Flexible Networking Mode of Remote Monitoring System for Wind Farm

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Abstract. The requirements of the modern wind power development on the monitoring system networking mode are analyzed, and the wireless sensor network based on ZigBee protocol and the remote monitoring network scheme of wind farm based on 3G network are designed. The system has the advantages of variable topology and flexible networking, and realizes a two-layer and three-layer variable topology networking scheme for the self-organizing network, easy expansion and remote monitoring system of the wireless sensor network. A wind farm video surveillance solution based on 3G network is designed for unattended wind farms. The system has the advantages of strong scalability, high reliability, strong real-time performance, safety and reliability, and low operating cost. It is especially suitable for online monitoring of remote wind farms.

Introduction

For a period of time, the development of renewable energy such as wind power will receive further attention and attention. Wind power generation is increasing year by year due to its renewable, clean environment, low development cost, and no danger of nuclear leakage [1].

The research and application of wind power condition monitoring system is of great significance for ensuring the normal operation of wind power equipment and avoiding huge economic losses. However, from the related research on wind power in recent years, it is mainly concentrated on the main body of wind turbines and the problems related to access to the power grid. For the networking mode of wind farm monitoring, the networking mode of general industrial monitoring is basically followed, and little research is concerned. The networking mode of wind farm monitoring determines the reliability, real-time, flexibility, security and even economy of on-site data transmission and control. Different management methods and geographical characteristics have different requirements for them. Inappropriate ways will not only affect the monitoring and control capabilities of wind farms, especially when wind power systems are connected to the grid for dispatching and peak shaving, which may cause serious accidents. At present, scholars and researchers at home and abroad have just begun to recognize this problem and have carried out certain research and development work [2-4].

Requirements for the Development of Monitoring Systems by Modern Wind Power Development

Due to the randomness of the wind, the wind turbine generates a large number of random parameters during operation, which directly affects its safe and stable operation. These status parameters need to be monitored in real time and reliably fed back to the control system and associated operators. Requirements for the development of monitoring systems are as follows:

(1) Network transmission is strong in real time. Wind power generation is greatly affected by the natural environment, and its related system operating parameters change frequently and rapidly.
(2) The networking reliability is high. Most traditional SCADA systems use wired networks to network wind farm monitoring systems. When a line fails, the small field monitoring parameters are not comprehensive, and the large-scale impact on the normal operation of the entire wind farm monitoring system.

(3) Networking flexibility. Most of the central control centers of wind farms are unattended, sometimes with failures, and data cannot be transmitted to remote monitoring centers. Moreover, wind farms sometimes need to be rebuilt and expanded.

(4) Network security is high. The data collected and transmitted by the monitoring system and the monitoring commands are crucial to ensure the normal operation of the wind farm.

(5) Network economy. The economic networking should reduce the system networking cost while ensuring that the same function or even more functions are completed [5].

Design of Wireless Sensor Network Based on ZigBee Protocol

Design of Wireless Sensor Network Topology

The network coordinator and router in the ZigBee protocol belong to the FFD (full function device), and the terminal node belongs to the RFD (reduced function device). The network coordinator is the highest-ranking node in the network, responsible for setting up the network, selecting the network communication channel, and managing the network nodes to enter and exit the network. The router has a lower level than the network coordinator and acts as a data relay. The terminal node has the lowest level and is responsible for connecting to the sensor [6-8].

![ZigBee Network Topologies](image)

Figure 1. Network topology supported by the ZigBee protocol.

The ZigBee protocol mainly supports three forms of network topology. As shown in Figure 1. Figure 1 (a) is a star network, Figure 1 (b) is a cluster tree network, and Figure 1 (c) is a mesh network. The three network topologies have their own advantages and disadvantages and can be applied to different environments [9-10]. This system selects a cluster tree network as the wireless sensor network topology.

Design of Wireless Sensor Network Based on ZigBee Protocol

**ZigBee Self-organizing Network Strategy.** The terminal node in this system is a wireless sensor node. In a cluster tree network, each sensor node communicates with other sensor nodes and strictly follows the path from parent to child or child to parent. Routing has the function of self-healing ZigBee network, that is, a wireless connection is disconnected, and the routing function can automatically avoid the disconnected network and find a new path, which greatly improves the reliability of the network. Most importantly, the router allows the sensor node to join the network outside of the RF range, and does not require the sensor node to be within the RF range of the coordinator. Therefore, the cluster tree network can extend the communication range of the ZigBee node. Figure 2 is a topological diagram of a wireless sensor network based on the ZigBee protocol.
Expansion of Wireless Sensor Networks. After the coordinator establishes a new network, it will assign itself a network address 0, network depth 0. When a sensor node joins the network, the router needs to assign a network address to it. Suppose a NODE_01 of a new sensor node RFD is to join the network, and is connected to the coordinator as a child node through the routing node ROUT_01. The process of address allocation is as follows: First, the router parent node is sub-different according to its depth d. Node NODE_01 assigns a network address:

\[
\text{Add}_\text{-NODE}_01 = \text{Add}_\text{-ROUT}_01 + C_{skip}(d) \cdot R_n + n, 1 \leq n \leq (C_n - R_n)
\]  

(1)

If the newly added child node is ROUT_02 and has routing capability, the parent node ROUT_01 will assign it a network address:

\[
\text{Add}_\text{-ROUT}_02 = \text{Add}_\text{-ROUT}_01 + 1 + C_{skip}(d) \cdot (n - 1)
\]  

(2)

The address offset \(C_{skip}(d)\) indicates that the parent node whose depth is d assigns an offset of the network address to its child node, and the calculation formula is shown in the formula (3):

\[
C_{skip} = \begin{cases} 
1 + C_m (L_m - d - 1), R_m = 1 \\
1 + C_m - R_m - C_m R_m^{L_m-d-1} \\
1 - R_m 
\end{cases}
\]

(3)

when the router ROUT_01 sends a packet to the destination node NODE_03 with the network address Add_DES, assuming the router's network address is Add_SRC and the network depth is d, the router will first pass the expression: Add_SRC < Add_DES < Add_SRC + C_{skip}(d-1) Determine if the destination node is its own child node, and the address of the next information forwarding node is:

\[
\text{Next}_\text{-add} = \begin{cases} 
\text{Add}_\text{-DES, Sensor node} \\
\text{Add}_{\text{SRC}+1} + \left[ \frac{\text{Add}_\text{-DES} - (\text{Add}_\text{-SRC} + 1)}{C_{skip}(d)} \right] C_{skip}(d)
\end{cases}
\]

(4)

The parent node of the router is used as the destination node for the transfer. After the address is allocated, it is transferred to the application layer, and the routing information and application layer data are processed. The expansion of a simple wireless sensor network is successful.

System Remote Monitoring Networking Scheme Design

Flexible Networking Scheme for Variable Topology Structure of Wind Farm Remote Monitoring System Based on 3G Network

The wind farm monitoring system generally includes a three-layer monitoring platform: an in-situ monitoring center, a central centralized control center, and a remote monitoring center. The wind farm has the characteristics of distributed layout. For a regional power grid, there may be multiple wind farms that are separately concentrated. A central centralized control center is set up at each of the separately concentrated wind farms, and a remote monitoring center is set up at the regional...
power grid or further to perform overall monitoring and dispatching of the entire wind farm. After the coordinator and the 3G data transmission module in the ZigBee wireless sensor network are connected, the data packet is transmitted to the central centralized control center, and then transmitted to the remote monitoring center by the central centralized control center. However, most of the central control centers of wind farms are unattended, and often fail, resulting in data not being transmitted to remote monitoring centers. Therefore, the wind farm monitoring networking framework needs to support a flexible topology, that is, a backup 2-layer topology. When the central control center fails, the system can automatically change the topology into a two-layer mode. Figure 3 is a two-layer network structure diagram of a wind farm remote monitoring system based on a 3G network. Figure 4 is a three-layer networking diagram of a wind farm remote monitoring system based on a 3G network.

Wind Farm Variable Topology Structure Networking Process

The 3G data transmission module receives the data packet sent by the coordinator. Since the 3G module node is not the destination node of the data packet, the specific processing procedure of the data packet is as follows:

1. The 3G data transmission module receives the data packet sent by the coordinator, and decapsulates the data packet to extract its topology number information.
2. According to the current topology number, read the forwarding table of the corresponding topology and find the next hop forwarding node.
3. Read the status information of the adjacent link of the 3G node, and determine whether the link connecting the next hop node on the transmission path is invalid. If it fails, go to step 5, otherwise go to step 4.
4. The packet enters the transmitter queue in the node forwarding module.
5. Since the link connecting the next hop node fails, the packet is transferred from step 3 to this step. Determines the topology number used by this packet for the current transmission path. If you are currently using the original topology, go to step 6. Otherwise, the current topology number is the backup topology number, indicating that the path has been switched over the topology during the forwarding process. Go to step 4.
6. Entering this step is the next hop node of the working path on the original topology that cannot reach the packet. Query the backup topology number of the failed link and rewrite the number to the topology number field of the packet. Go to step 7.
7. Find the next hop according to the destination node in the forwarding table of the backup topology. Go to step 2 to further determine whether the backup next hop node is reachable.
Wind Farm Video Surveillance Solution Based on 3G Network

The wind farm has the characteristics of wide geographical distribution and more operating equipment. Moreover, most of the wind farms are in remote and sparsely populated areas. The video surveillance subsystem is used as a supplement to the wind farm remote monitoring system, which can complete the comprehensive monitoring and management of the operation of the wind farm, and truly realize the unmanned or small number of wind farms.

The wind farm video surveillance subsystem based on 3G networks requires several embedded video servers with USIM card slots. The remote monitoring personnel can view the wind farm video surveillance information on the PC through the 3G network. The wind farm video information can also be viewed in real time through a mobile phone with a USIM card outside the monitoring center.

Conclusion

Considering the different requirements of wind power operation, according to the characteristics of wireless networking, this paper proposes the concept of flexible topology of variable topology, and discusses and determines the topology of wireless sensor network. The self-organizing network strategy and capacity expansion process of the wireless sensor network are analyzed in detail. The remote monitoring system of wind farm with variable topology capability was designed, and the process of variable topology networking was analyzed in detail. In addition, a wind farm video surveillance subsystem based on 3G network is designed for the situation that no or few people are on duty in the wind farm. The system caters to the requirements of wind power development and has good expandability, which is easy to expand and smooth the system in the future.

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