Research on Low Power Sensor Networking Technology of Transformer Equipment Based on Node Energy

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Abstract: With the development of smart grid and Internet of Things technology, the level of substation intellectualization is getting higher and higher. In order to monitor the substation equipment in real time and obtain the information of equipment operation status, a large number of monitoring sensors are installed on the equipment. Because of the complex internal environment and many dangerous factors in the substation, monitoring nodes usually use wireless communication and rely on their own batteries for power supply. Because the replacement of batteries is not convenient, node power consumption is very important for its lifetime. Traditional monitoring devices install SIM card, but according to this way, the power consumption of the device is large, so it needs to be connected separately to supply power for the device. At present, the main method is to form a network in the station, and the nodes gather information uniformly in the station. Because of the different transmission distance, each node sends information directly, which leads to its own battery consumption too fast, and the generation time of nodes is relatively short. In order to prolong working time and improve energy efficiency, a low-power sensor networking technology based on node energy for transformer equipment is proposed in this paper. The energy consumption of each node is balanced by considering the node energy in the process of information transmission, thus prolonging the node lifetime and monitoring the network lifetime.

1. Introduction

With the development of smart grid and Internet of Things technology, a large number of new technologies have been applied to monitor the operation status of substation equipment in order to obtain the real-time operation status of equipment[1].

Wireless sensor has considerable advantages in intelligent transportation, environmental monitoring, industrial control and other fields, but battery replacement is difficult. With the development of sensor technology, a large number of sensors have been installed in substations to monitor transformer oil, insulation resistance, arrester overcurrent and so on[2]. Because of the complex environment and many dangerous factors in substation, sensors usually use their own batteries to supply power. Because of the inconvenience of replacing batteries, in order to extend the working time to a greater extent, low-power sensor networking technology is needed to reduce the energy consumption of sensor nodes[3-4].

2. Current status of monitoring nodes for substation equipment

There are three stages in the development of wireless sensor networks: general sensors, intelligent sensors and wireless sensors. General sensors mainly collect data. Intelligent sensors not only have the
ability of collecting data, but also can process the collected data[5]. They have the ability of information processing and computing. Wireless sensors add wireless transmission and communication capabilities on the basis of the first two kinds, which enhances the application scope and coverage area of sensors. At the same time, without wiring, the project cost is greatly reduced.

Traditional transformer oil chromatographic monitoring device uses operator network to communicate and installs SIM card on each monitoring device. However, according to this method, the device consumes a lot of power and needs to be connected separately to supply power for the device. The original monitoring types and nodes are few, but with the improvement of power grid monitoring level, a large number of monitoring nodes are installed in all kinds of equipment, which requires the use of low-power sensor networking technology to minimize node energy consumption and prolong working time[6-8].

Wireless sensor network is an important part of the Internet of Things technology, which uses wireless sensors as nodes to connect multiple sensors so that they can communicate with each other[9]. In the network, the network node equipment must be able to detect the target data continuously or for a long time, so the efficiency of wireless sensor network operation is very important. To achieve this goal, we must solve the key technical problems such as the structure of the wireless network, the link of the network, data forwarding, the target location of the wireless sensor, distributed data management and the security of the wireless network[10].

3. Wireless Sensor Network Architecture

The structure of wireless sensor network can be divided into planar network and hierarchical network according to its organizational form. All nodes in the planar network communicate directly with the base station; the hierarchical network divides the nodes into ordinary nodes and cluster head nodes, and cluster head nodes communicate with the base station. Planar network has less application because of its high energy consumption and short lifetime. Low Energy Adaptive Clustering Hierarchy (LEACH) protocol is a representative networking protocol in layered networks.

LEACH protocol algorithm randomly chooses a node as cluster head and dynamically chooses neighboring nodes with a certain probability

Forming clusters, the algorithm makes the nodes in the network take turns as cluster heads and distribute the average energy consumption of communication, and finally achieves the goal of load balancing of nodes' energy and prolonging network lifetime. The working process of LEACH protocol is divided into many "wheels", each of which includes cluster establishment stage and stable operation stage.

4. Low Power Sensor Networking Protocol for Substation Equipment Based on Node Energy

Because of the complex environment of the substation, the above networking technology can not be fully applied in the substation. In view of this situation, this paper proposes a network scheme based on node energy.

The working process of low-power sensor networking technology for transformer equipment based on node energy can be divided into two stages: the establishment of cluster and the stabilization of data transmission. In general, the working time of the stable stage is longer than the duration of the establishment stage. The process of cluster establishment can be divided into four stages: the selection of cluster head nodes, the broadcasting of cluster head nodes, the establishment of cluster head nodes and the generation of scheduling mechanism.

The workflow of low-power sensor networking technology for transformer equipment based on node energy is as follows:

Cluster establishment stage:

Firstly, each node broadcasts its own serial number, node energy Eres (j), generates random values, broadcasting transmission energy consumption and other information.
After receiving the broadcast information, each node chooses three nodes with the most energy according to their energy and random value, then calculates the comprehensive energy consumption according to the distance from each node, and chooses the optimal cluster head node.

The node broadcasts the selected cluster head information and sends the join request to the cluster head.

The cluster head node receives the broadcast information and confirms that its node becomes the cluster head.

Stable phase of data transmission:
In the stable stage, the sensor node transmits the collected data to the cluster head node.
The cluster head node fuses the collected data and transmits the information to the sink node.
The sink node transmits the data to the monitoring center for data processing.

Figure 1. Workflow diagram
Figure 1 shows Workflow diagram of low-power sensor networking technology for transformer equipment based on node energy.
Cluster head node selection algorithm:
As shown in Figure 2, n(CH) is the assumed cluster head node when calculating energy consumption. n\(_2\)(CH\(_2\)) and n\(_3\)(CH\(_3\)) represent the assumed intra-cluster node, d(CH, n\(_2\)) is the distance from n\(_2\) node to cluster head n(CH), and d(n\(_2\),CH) is the distance from n\(_2\) node to sink node.

\[
F_{RN}(j) = E_{ri}(j) \frac{d(CH, j)}{d(j, BS)} \cos \phi_j \quad \forall j \in n \tag{1}
\]

From the above formula, we can get the assumed residual energy F\(_{RN}\)(j) of cluster head node after transmitting information to sink node. After calculation, it can be concluded that the node with the largest residual energy F\(_{RN}\)(j) is chosen as the actual cluster head.

The calculation method of \(\cos \phi_j\) is shown in equation (2).

\[
\cos \phi_j = \frac{d^2(CH, BS) + d^2(CH, n_j) - d^2(n_j, BS)}{2 \ast d(CH, BS) \ast d(CH, n_j)} \tag{2}
\]

As can be seen from the above formula, if \(\cos \phi_j > 0\) or \(\phi_j < 90\) routing should be selected, that is, if select \(\cos \phi_j < 0\) or \(\phi_j > 90\), it will extend the transmission distance and increase energy consumption.

As shown in Figure 3, in the routing process, if the relay node receives the information sent by different nodes, the received information will be compared. If the same information sent by different
nodes is received, the relay node will fuse the information, thus further reducing the energy consumption of each node.

5. performance evaluation

![Figure 4](image1.png) ![Figure 5](image2.png)

**Figure 4.** Number of dead nodes with rounds  
**Figure 5.** Network stable period

This paper simulates the working condition of nodes by simulation. Figure 4 is the proportion of nodes that can not work because of losing energy. Figure 5 is the lifetime of each network. From Figure 4, it can be seen that the low-power sensor networking technology of transformer equipment based on node energy proposed in this paper can prolong the lifetime of all nodes in the network. Figure 5 shows that the networking technology proposed in this paper is better than the common protocol. Prolonged working hours by nearly 20%.

6. Conclusion

The low-power sensor networking technology of transformer equipment based on node energy proposed in this paper can improve the energy utilization efficiency of nodes and prolong the lifetime of nodes by optimizing the selection and routing strategy of cluster head nodes. It can greatly prolong the working time of monitoring network when the power supply is not available directly in complex environment. In the follow-up research work, we can study the application of load balancing technology in wireless sensor node routing.

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