Research of the communication technologies for transmission line monitoring

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Abstract. Power transmission line monitoring systems are widely used in power grid in recent years. The communication bottleneck of the power transmission line monitoring systems focuses on the communication network of high definition video monitoring. This paper analyzes several communication solutions for the high definition video monitoring in power transmission line monitoring systems, including public wireless network, wireless mesh network, optical fiber network, and fiber-wireless hybrid network. Through technical comparison, this paper demonstrates that fiber-wireless hybrid network combines the advantages of optical fiber network and wireless mesh network, and it is the most suitable communication solution for power transmission line monitoring.

1. Introduction

With the development of power system, safe operation and stability of the power transmission lines are given more and more attention. Traditional power transmission line patrol and inspection methods mainly rely on manual operation. As the scale of the power transmission lines grows rapidly in recent years, manual patrol and inspection of the power transmission lines should be replaced by power transmission line monitoring technologies which can collect and monitor different kinds of operation information of the power transmission lines automatically in real time\(^1\).

The power transmission line monitoring information includes video surveillance, micro meteorology, tower tilt, icing, etc. The bitrates of most of these power transmission line monitoring information are below 1Mbps except high definition video monitoring (2Mbps in 720P, 4Mbps in 1080P). So the communication bottleneck of the power transmission line monitoring systems focuses on the communication network of high definition video monitoring.

This paper will analyze several communication solutions for the high definition video monitoring in power transmission line monitoring systems, including public wireless network, wireless mesh network, optical fiber network, and fiber-wireless hybrid network. Through technical comparison, this paper will choose the best communication solution to meet the communication requirements of transmission line monitoring.

2. Public wireless network

The high definition video cameras can use communication modules which are compatible with the public 2G/3G/4G cellular networks to send the video data to the power transmission line monitoring server. The communication modules can get power from the solar cells\(^2\) installed on the transmission line towers. The low bitrate monitoring services such as micro meteorology can also use NB-IOT\(^3\) modules with built-in batteries which only need to be replaced every few years.
Using Public wireless network is the cheapest communication solution. However, the power transmission line towers are usually located in desolate places where the public cellular network signal cannot cover, and the reliability of the public wireless network is difficult to meet the requirements of the power transmission line monitoring. So public wireless network is not a good choice for power transmission line monitoring.

3. Wireless mesh network

Wireless mesh network integrates WLAN and ad-hoc network[4], which has the advantages of rapid deployment, strong robustness and communication load balance ability. The combination of wireless Mesh network and IEEE 802.11n protocol makes the mesh network has the characteristics of high bandwidth, wide coverage and strong compatibility with all kinds of monitoring devices. It has a broad application prospect in the construction of wireless city, wireless campus, video monitoring and other aspects. Wireless mesh network has larger bandwidth and higher reliability than public wireless network.

The network diagram of the wireless mesh network on a power transmission line is showed in Figure 1. The wireless mesh AP devices on the tower are designed in accordance with the Ad Hoc network modes. The mesh AP equipment can get power from the solar cells installed on the transmission line towers. Each wireless mesh node has the ability to directly communicate with all neighboring nodes within the specific hops around it, and runs the routing protocol to select the appropriate neighbor node as the next forwarding node self-adaptively. The industrial switches on the towers of the substation at either end of the transmission line will forward the data packets of all the mesh AP devices to the transmission line monitoring server through the power grid private optical fiber network.

When the node k+1 fails (k is node number), node k can automatically adjust the route and send the information directly to the node k+2 or any next hop node which is available on transmission link with node k, so as to send video monitoring information back to the monitoring center across the fault node. For node k, the transmission link of monitoring information will be completely interrupted only when m nodes downstream or upstream of node k fail at the same time, m depends on the signal reception performance of the mesh AP devices. Compared with single node fault, the probability of this kind of event is very low, so the reliability of wireless mesh monitoring network as a whole is greatly enhanced.

![Figure 1. The network diagram of the wireless mesh network on a power transmission line.](image-url)
4. Optical fiber network

Almost all the high-voltage transmission lines above 110kV are equipped with power grid private optical cables, these optical cables are used for the transmission of the information of relay protection and automation. Power grid private optical cables are mainly optical fibre composite overhead ground wires (OPGW), and according to the actual using status, most of these optical cables have enough spare fiber cores for carrying transmission line monitoring information.

The network diagram of the optical fiber communication network on a power transmission line is showed in Figure 2. Each transmission line tower deploys an industrial switch to transmit the power transmission line monitoring information. These industrial switches are interconnected by spare fiber cores of the OPGW optical cables, and can get power from the solar cells installed on the transmission line towers. The industrial switches on the towers of the substation at either end of the transmission line forward the data packets of the monitoring information to the transmission line monitoring server through the power grid private optical fiber network. Switches on these towers can turn on the spanning tree protocol to isolate the layer 2 loops.

Optical fiber network can get best communication performance, but the optical cables are not always have spare fiber cores for carrying transmission line monitoring information. And the cable junction boxes are located on only a few towers, when the industrial switches on a tower without cable junction box access this monitoring network, the optical cable should be cut off to reassemble the cable junction box, this will seriously affect the reliability of relay protection and automation service the optical cable bearing.

5. Fiber-wireless hybrid network

To combine the advantages of optical fiber network and wireless mesh network, a communication solution of fiber-wireless hybrid network is presented to meet the communication requirements of transmission line monitoring. The network diagram of the fiber-wireless hybrid network on a power transmission line is showed in Figure 3. Mesh wireless nodes on the tower are grouped, and several adjacent nodes are grouped into a group. In each group, a tower with optical cable junction box is selected as the data aggregation node (like Tower4 and Tower7 in Figure 3). In addition to mesh AP device, an industrial switch is installed on the tower of the data aggregation node. Monitoring information of each tower is first transmitted to the nearest data aggregation node through wireless multi-hop, and then transmitted by the optical network of the industrial switches to the line monitoring server.
Fiber-wireless hybrid network has both the self-organizing characteristic of mesh network and the self-healing ability of industrial switch network based on spanning tree protocol, and it can effectively avoid the risk of the communication interruption of the relay protection and automation service when reassembling the optical cable junction box. So fiber-wireless hybrid network is the most suitable communication solution for power transmission line monitoring.

6. Conclusion

This paper makes a contrastive analysis of the technical characters of different communication technologies including public wireless network, wireless mesh network, optical fiber network and fiber-wireless hybrid network. Public wireless network has signal coverage restriction and low reliability. The wireless mesh network cannot be used in long distance relay transmission because the relay hops of the wireless mesh network is limited. Optical fiber network has the risk of the communication interruption when reassembling the optical cable junction box, which will affect the reliability of the relay protection and automation services. Fiber-wireless hybrid network combines the advantages of optical fiber network and wireless mesh network, and it is the most suitable communication solution for power transmission line monitoring.

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