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Research on Development of Key Technologies for the Online Monitoring and Condition Assessment Expert System of Transmission Lines

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Abstract: Online monitoring and condition assessment expert system of transmission lines is an integrated system which integrates online monitoring, unified management of data and multi-dimensional assessment. This system can provide decision support for equipment operation, accident repairing and also improve the stability and reliability of the power grid operation. Based on analyzing the development status and problems of online monitoring and condition assessment of transmission lines, this study carry out the research of key technology including condition monitoring system of transmission lines, condition assessment guidelines, unified management platform for maintenance operation data, communication network model, integrated assessment model and software functional design and to build an online monitoring and condition assessment expert system of transmission lines to adapt to the development of smart grid.

Key words: Smart grid, transmission line, expert system, condition monitoring, synthetic evaluation

INTRODUCTION

In recent years, intelligent power grid has become a hot topic of research on the development trend of future power grid at home and abroad, which could meet the growing demand for high power load, ensure security, reliability and economical efficiency of electricity supply and improve the operation and management of power enterprise level (Hu, 2009). Intelligent power grid is built on the physical infrastructure of modern transmission and distribution power grid and established on the integration and high-speed bidirectional communication network platform. It supports the integrated application of advanced sensing and measurement technologies, as well as other techniques like computer, microelectronics, power electronics, control and intelligent decision-making. With grid real-time panorama information of power grid, it can conduct real-time monitoring, disaster and user interaction and realize the reliable, safe, economical, quality and highly efficient power grid operation and sustainable development. Transmission line online monitoring and condition assessment are key techniques in the power transmission of intelligent power grid and are important measures to achieve the operation and maintenance management of electric transmission and transformation equipment conditions, improving the streamline level of production and operation management. In this study, the relationship between transmission line online monitoring, condition assessment technology and the planning and construction of transmission part of intelligent power grid was discussed. The present situation of research on key techniques for online monitoring and condition assessment of transmission line and the existing problems were introduced. A basic thinking of establishing the online monitoring and condition assessment expert system for transmission lines was proposed.

CURRENT DEVELOPMENT OF TRANSMISSION LINE ONLINE MONITORING AND CONDITION ASSESSMENT KEY TECHNIQUES

Based on the features of intelligent power grid in China, key techniques of transmission line online monitoring and condition assessment primarily include the following aspects:

Online monitoring of transmission line device: Currently, transmission line online monitoring mainly includes line electric insulation monitoring, mechanical monitoring and line environment monitoring. In addition, the transmission line device online monitoring techniques also include

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electromagnetic compatibility, anti-interference, service life of monitoring device, reliability, data digitization and communication technology and other aspects that can improve the technological level of monitoring.

Online monitoring of insulator contamination: Normally, the insulator contamination level can be measured by equivalent salt density, contamination surface conductivity, leakage current and flashover and other indicators. Currently, the online monitoring of insulator contamination degree is mainly realized by leakage current of monitoring insulator (Wang *et al*., 2007).

Online monitoring of lightning and positioning technique: Lightning positioning system can realize real-time online telemetering of the high-power electromagnetic wave radiated by positive and negative charge during lightning. Besides, it could dynamically analyze and acquire lightning information like the discharge time to the ground, the discharge position, lightning current peak, the polarity and lightning return stroke number (Chen *et al*., 2008). Currently, the basic principles of lightning positioning include positioning method, time-difference method and combined positioning method. The combined positioning method is most widely used (Zhao, 1996).

Although lightning positioning technique can indicate relatively correct lightning strike fault points, its measured lightning current amplitude and waveform monitoring data remain incalculable error. Therefore, special lightning current monitoring devices are still needed to calibrate. The traditional lightning current measurement method is magnetic link method, which is still widely used now. But this method generates remarkable measurement error and can only measure the amplitude of lightning current. Besides, it is required that samples must be measured after lightning strike in a timely manner, showing poor operational efficiency. At present, Rogowski coil is often used as lightning current sensor coupling lightning current waveforms for lightning current monitoring (Li *et al*., 2012).

Conductor galloping monitoring of transmission line: Currently, video images method is often used in the online monitoring of conductor galloping track (Wang *et al*., 2010). However, low transmission rate and the low frame rate of images caused video signal distortion and it is difficult to reflect the conductor galloping track. Another thought of galloping monitoring is to directly install the conductor galloping capture unit on conductor-to-ground wire. According to the main wave number parameters during conductor galloping, the installing number on conductor-to-ground wire in a span length is determined (usually 2 to 7). The monitoring extension can be installed on the tower, which can transmit data of galloping unit and meteorological data surrounding towers to the data center by the integration of wireless transmission and cable transmission. Thus, the mathematical model of three degree of freedom of the conductor galloping can be used to clarify the line galloping.

Tower vibration and inclining online monitoring: Transmission tower is a tall large-space structure and may show remarkable vibration under the comprehensive effects of conductor load, wind load and other factors. Some serious cases would lead to instability of tower, even collapse. Tower vibration online monitoring acquires tower vibration amplitude, frequency and other dynamic response parameters through vibration sensor and analyzes the dynamic characteristics of towers and poles under the wind load based on considerations to meteorological parameters of lines, thus diagnosing the health of towers (Lv *et al*., 2012). If the system detects excessive levels of vibration, it will prompt the production and operation organizations to take timely anti-vibration measures and avoid the abrasion and fatigue fracture of tower components or welding parts, as well as other accidents like falling of tower screws and shear deformation.

Tower inclining is a phenomenon caused by the derivation of tower center from plumb position due to uneven foundation. In addition, when the conductors at both sides of tower are asymmetrical (like in the case of icing), the force balance will be destroyed and a tension difference will be formed between two sides. Towers will incline to the side with larger tension, leading to tower inclining, even tower collapse. Tower inclining monitoring can conduct real-time measurement of inclination along the fair line and the horizontal line by inclining sensors installed on tower (Bai *et al*., 2013).

Transmission line condition monitoring communications technology: In the transmission line condition monitoring system, online monitoring terminals distributed long the transmission lines collect condition information and transmit the information to the host monitoring station system through specific communication channels. In this way, it can centralize monitoring function. In most cases, online monitoring information is firstly merged to a condition monitoring agent device (CMA, Condition Monitoring Agent) and CMA gets access to the controller by the adjacent substation condition and the condition of host monitoring station is connected to the Condition Information Acquisition Gateway (CAG). In this

way, data transmission between monitor terminals and host monitoring stations is realized (Tao *et al*., 2012).

Communications technologies for transmission line condition monitoring mainly include GPRS, CDMA, 3G and other wireless public network technology, fiber optical communication technology including passive optical network and fiber industrial Ethernet and wireless private network like WiFi and WiMAX. In the transmission line online monitoring system, corresponding communication plan will be selected based on the instantaneity of monitoring data transmission and requirements of reliability.

Comprehensive evaluation of transmission line condition: The comprehensive evaluation of transmission line condition is based on the historic operation of transmission lines, maintenance and continuous online monitoring data. On the basis of the single device evaluation, it can assess and forecast the healthy condition of transmission lines, thereby arranging maintenance plans before the transmission line faults and realizing the maintenance of transmission line condition. Existing research on comprehensive evaluation of transmission line condition include: dynamic loads analysis and prediction of line and tower, insulator contamination and icing condition assessment, transmission line condition assessment models based on fuzzy theory, rough set theory, Monte Carlo and other methods with the integration of various artificial intelligent algorithms, models of risk probability evaluation for lightning, ice wind, landslides, forest fire and other dangers, reliability evaluation methods based on the fault tree model and Markov model, as well as assistant decision-making methods of condition maintenance based on fuzzy decision making, multi-objective decision-making and gray decision.

RESEARCH CONCEPT OF TRANSMISSION LINE ONLINE MONITORING AND CONDITION ASSESSMENT EXPERT SYSTEM

The intention of this research was to build up a set of standardized and intelligent online monitoring and condition assessment expert system for transmission lines and realize the overall comprehension of the overall operation situation of transmission lines and key device condition. In this way, the information isolated island can be eliminated and decision supports can be provided for device operation and maintenance, as well as accident repair. The research aimed at improving the stability and reliability of power grid operation. The research will be unfolded from the following 6 aspects:

Transmission line condition monitoring system: With full consideration of the topography of each transmission line section, natural environment and other actual situations, the composition, monitoring ways and methods of line monitoring condition will be studied. Besides, condition parameter weights, the mapping relations between condition parameter and line operation condition are also considered to identify the optimal combination of condition parameter and to form a complete and economically efficient set of standardized condition monitoring system.

Guide rules of transmission line condition assessment: According to characteristics of AC and DC transmission lines, condition parameters obtained in operating conditions, maintenance, quality family history, defects, online monitoring, manual inspection, the helicopter/UAV inspection of transmission line device, the condition grading of transmission line device unit and the transmission line condition partition method are analyzed to form a set of guide rules of transmission line condition assessment.

Research and development of unified management platform for transmission line operation and maintenance data: The research will realize the self-checking function of transmission line online monitoring data, which could effectively and accurately remove ill-conditioned data, thus improving the processing efficiency and judgment accuracy of transmission line condition information. The research of data storage of transmission line online monitoring and the highly efficient processing technology will lead to the establishment of a standardized unified management platform with high-capacity and high-performance, covering all-dimensional data of transmission lines. This could provide sufficient data for the online monitoring and condition assessment expert evaluation systems of transmission lines.

Communication network model of transmission line online monitoring: The multi-source heterogeneous characteristics of transmission line condition monitoring data, the integration criteria of transmission line condition monitoring information will be researched and developed. The communication network standards and interface standards needed by the information interaction of transmission line online monitoring will be developed based on IEC standard. Norms of communication technology of transmission line online monitoring are proposed. The research also involves communication technology of transmission line online monitoring and

communication network model, transmission of data acquired by transmission line online monitoring devices through cable and wireless communication networks. The communication networks should support the in situ sensor network, station level system network, substation network in regions of power supply administrations and network of host stations systems.

Scientific evaluation model based on multi-dimensional condition evaluation of transmission lines: The research will involve the modeling of transmission line operation condition assessment, modeling of risk evaluation and economic evaluation models, validity and correlation of evaluation results, the analysis of the intrinsic relevance, conditionality, coordination, etc. On this basis, integrated evaluation methods and decision support based on multi-dimensional evaluation of transmission lines can be provided.

Functional design of software for transmission line condition assessment expert system: The functional designs should follow the principles of openness, stability, safety, interoperability and handleability and realize the compatibility with other existing systems and information sharing. This can facilitate the gradual extension of the system (including hardware and software) and enable the sufficient use of hardware resources, providing a platform of condition detection, fault diagnosis, data analysis, display and information management for transmission line devices. The analysis conclusion and maintenance suggestions can be transmitted to the unified management platform of operation and maintenance data through the service bus, serving as the inquire references of information management system. Therefore, this will effectively support the specific implementation of condition maintenance.

CONCLUSION

In this study, the present situation of research on key techniques for transmission line online monitoring and condition assessment and existing problems were introduced. On this basis, a basic thinking of establishing the online monitoring and condition assessment expert system for transmission lines was proposed. Transmission line online monitoring and condition assessment expert system can address existing problems such as single monitoring system with poor connection, low utilization efficiency of monitoring data, extensive device evaluation methods and so on, showing promising prospects of extensive application.

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