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Fault Diagnosis Based on Internet of Things Technology for Electricity Supply Network

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Abstract: Fault diagnosis based on Internet of Things technology for electricity supply networks is proposed. The proposed diagnostic method monitors online changes in the three-phase zero-sequence voltage and current of fixed points on high-voltage transmission lines in real time. The proposed method also equally measures such voltage and current to evaluate the performance of the section and identify short circuits and ground malfunction. In fault diagnosis and line maintenance, the Internet of Things enables interflow and interaction among units, such as the detection terminal, signal relay, long-distance control centre and maintenance crew. The proposed detection method has a “self-learning” function; that is, it does not require multiple thresholds on transmission lines with different loads in advance. Performed online in real time, fault diagnosis based on the Internet of things for electricity supply networks is accurate and convenient.

Key words: Fault diagnosis, short circuit, ground malfunction, internet of things, online monitoring

INTRODUCTION

Fast, accurate fault diagnosis is of great significance to reduce power outage time and enhance the reliability of power supply. The most common power grid faults are the short circuit and the open circuit.

In recent years, many intelligent methods are used for the fault diagnosis of power system, such as artificial neural network, expert system etc. Bi *et al.* (2002) applied Radial Basis Function neural network (RBF NN) to the power supply fault diagnosis and optimized the parameters with the orthogonal least square method. The computer simulation on a 4-bus test system shows that the RBF NN is quite effective and superior to the back-propagation neural network system. Guo *et al.* (2010) presented a novel diagnosis method combining element-oriented artificial neural networks and fuzzy integral fusion, which models the transmission line, bus and transformer with element-oriented ANNs. When a fault occurs, a primary diagnosis is made by element-oriented ANNs and then the synthetic diagnosis fuses the primary diagnosis results with fuzzy integral. The method overcomes the Achilles heel of ANNs at getting training patterns and handling topology changes. And the simulation shows that this method improves the diagnosis accuracy, particularly suitable for the large scale real-time fault diagnosis. Zhu *et al.* (2007) presented a diagnosis method based on the Bayesian network. According to the internal logic relationships among the element fault, the protective relay action and the circuit breaker trip, the general fault diagnosis models of the transmission lines, busbars and transformers are respectively established to solve the information uncertainty problem in power system fault diagnosis, which organizes a special Bayesian network composed of Noisy-Or and Noisy-And nodes and uses back propagation algorithm in parameter learning. The Bayesian network for each element diagnosis is generated automatically according to the relationships among element, protective relays and circuit breakers. The instance simulation shows the feasibility and effectiveness of the proposed method for both simple and complex faults, even with a malfunction of the protective relay or the circuit breaker. Mansour *et al.* (2012) also established a model based on the Bayesian network for the real-time fault diagnosis of the high dam power station and its 500KV transmission grid. This method has many merits, such as rapid reasoning, less storage memory and processing time, strong adaptability, etc. Ma *et al.* (2013) combined the expert system and BP neural network and divided the whole network is into several sub networks, proposed the diagnosis method of multiple network expert system. The experiments show that this method improves the diagnostic accuracy of expert system. Wu *et al.* (2012) combined the fuzzy evaluation theory with the expert system, proposed the diagnosis method of the fuzzy expert system. In addition, the rough set (Ren, 2012), or the rough set combined with the evidence theory (Zhao *et al.*, 2009). or the rough set combined with the neural network (Zhou *et al.*, 2012), is also used to the

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diagnosis model of the power station or network. Fonseca *et al.* (2013) proposed a new approach to fault diagnosis in electrical power systems, which makes use of protective devices as well as information related to the protection philosophy. Initially, these data undergo a preprocessing step to convert the format of 0 and 1 to percentage values. The conversion to percentage values allows the use of artificial neural networks, whose numbers of inputs do not depend on the number of alarms of the protection philosophy, or the type of bus arrangement or the number of circuit breakers. The proposed system was tested in the IEEE 118-bus systems and Eletronorte 230-kV real power system. Dobakhshari and Ranjbar (2012) proposed a new diagnosis method, in which the fault point voltage and its current phasor after the fault occurs are obtained with the wide area measurement system in the power grid, then the fault point is located through the analysis of these phasor.

The technology of the Internet of things is trying to realize the interconnection, the intercommunication and the interaction among all kinds of the terminal equipment and the facilities everywhere, such as sensors, mobile terminal, industrial system, numerical control system, intelligent home facilities, video monitoring system, through a variety of wireless or wired, long distance or short distance communication network. The Internet of things technology is being rapidly applied to many realms. A novel method based on Internet of things technology for the transmission network fault diagnosis will be presented, which is suitable to the short circuit or the ground fault detection. It will monitor the changes of three-phase voltage and current of the fixed points on the high voltage transmission lines online in real-time, judge the fault type and locate its position rapidly and precisely.

MALFUNCTION DETECTION BASED ON INTERNET OF THINGS TECHNOLOGY

Malfunction detection based on Internet of Things technology for electricity supply networks with balanced measurements between three-phase zero-sequence voltage and current monitors online changes in such voltage and current in fixed points of high-voltage transmission lines in real time. This detection method determines malfunctions in high-voltage overhead lines according to the variation of voltage and current. The method can detect ground faults and short circuits.

System and structure of malfunction detection: The fault detection system consists of a detecting terminal and remote control centre coupled by wireless transmission (Fig. 1).

The fault-detecting terminal consists of machine tools and two sub-machines. These tools and sub-machines are hung on three high-pressure transmission lines. The structure and working mechanism of the sub-machines (Fig. 2) includes a signal acquisition module, fault detection module, microcontroller module, alarm indication, power supply module and short-distance wireless transmission module. The tools contain the sub-machine structures and remote wireless transmission module. Both sub-machines check faults in self-hanging power lines and transmit fault information to the machine tools via the short-range wireless transmission module. This module can be a wireless radio frequency module or a wireless ZigBee module. The machine tools detect information on self-hanging power lines, receive information from both sub-machines, synthetically identify faults and their type and send the information to the maintenance personnel phone and remote monitoring

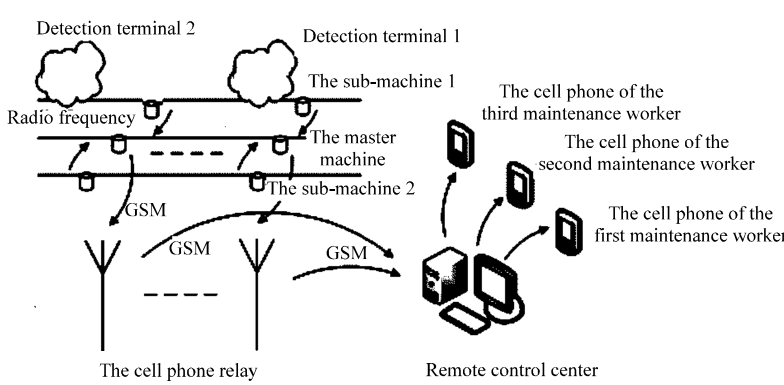

Fig. 1: Fault diagnosis system based on internet of things technology

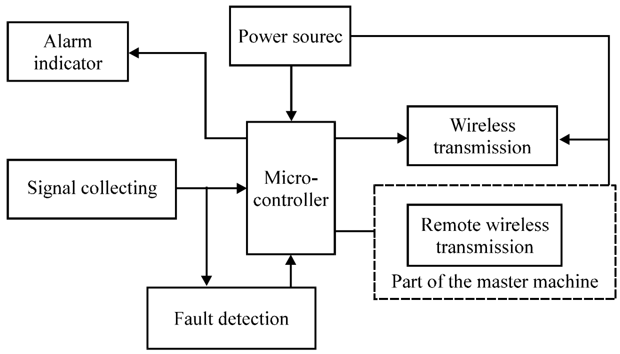

Fig. 2: Mechanism of the fault diagnosis terminal

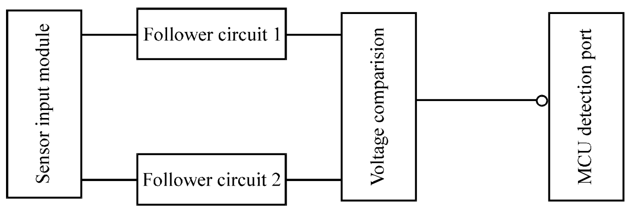

Fig. 3: Circuit for signal collection

centre through remote wireless transmission. Remote wireless transmission can use a GSM, GPRS, or 3G module to transmit the information over long distances through mobile base stations. The power supply module, which has a mode of mutual inductance self-created electric and supercapacitor combination, is used to supply electricity.

The signal acquisition module (Fig. 3) includes a sensor input module, follower circuit 1, follower circuit 2 and a voltage comparison module. One output signal of the sensor is connected to follower circuit 1 and the other connects to follower 2. Follower circuits 1 and 2 are connected to the voltage comparator module, the output of which is connected to the detection port of the Microcontroller Unit (MCU). The hollow cylindrical coil of the sensor detects the current signal on the side of the overhead lines as the sensor input signal. Follower circuit 1 receives the input current signal of the sensor and quickly changes with variations in input signals. Through the "self-learning" function, the current signal with normal operation is detected by follower circuit 2, converted to a voltage signal and recorded as a reference value of the voltage comparison module. When the input signal of the sensor changes, this reference value holds the last voltage within a certain period of time. The voltage comparison module receives the signals from follower circuits 1 and 2 and compares them in real time. The input voltage instantly transitions and the voltage comparison module generates a voltage difference and produces a certain delay pulse regarded as a detection signal of the microcontroller module.

Conditions of malfunction detection: Short circuit criterion conditions:

- **Sudden increase in line current:** A short circuit abruptly increases wire current. The rate of such an increase is related to circuit impedance. The mutational current of the malfunction indicator action is generally designated as 80-150 A
- **Mutant current duration:** To improve the accuracy of the fault indicator operation, mutational current duration ΔT should have a threshold width of 10 ms to 60 m sec$\leq\Delta T\leq$1.5-4.0 sec
- **Zero circuit current:** An online short circuit causes the short-circuit protection of the substation to turn on the trip switch to cause line outage. In this case, the current in the conductors is zero
- **Under these three conditions:** the fault indicator can identify short circuits online

Grounding criterion conditions:

- **Sudden voltage drop:** Single-phase grounding of the line abruptly reduces the voltage-to-ground of the fault phase. The varying nature of grounding indicates that voltage does not always drop to zero. However, increasing line load also reduces voltage and thus causes confusion. To avoid "false ground" owing to voltage reduction caused by load increase without losing voltage reduction owing to "true ground" caused by non-metallic ground, voltage is predetermined to vary by $\Delta U \leq 20\%$
- **Ground current multiplier:** Single-phase grounding of the line makes the grounding current that flows through the fault point equal to the single phase-to-ground capacitive current, which is three times that during normal grid operations. Ground current is related to line voltage, frequency, structure, length and many other factors.
- **Sudden increase in fifth harmonic current:** Single-phase grounding yields an electric arc with a high harmonic. If the fifth harmonic current $\Delta I5$ is greater than 35 mA, a ground fault may come in to being

Under these three conditions, the fault indicator can identify ground faults online.

The fault detection system works as follows:

- Fault-detection terminal monitors hung on the three high-pressure transmission lines track the operational status of the transmission grid and environmental parameters and provide real-time access to data
- The sub-machines with self-learning function record electrical signals under normal working conditions and use them as their own evaluation thresholds.
- To determine line abnormalities, the sub-machines compare their thresholds in real time with the electric signals acquired by each line. Abnormal information is sent to the machine tools via the short-range wireless transmission module.
- The machine tools receive fault signals from the sub-machines to determine the type of fault.
- The machine tools send the fault information to the control centre or maintenance staff by telephone

SIMULATION ANALYSES

Analysis of short circuit fault: In this experiment, a 50 Hz signal simulating a transmission line signal is created by a signal generator. After reasonable parameters are selected for the detection module, the device is used to analogue the output of the detecting circuit with different hopping voltages inputted.

When the input transition below the threshold voltage is 1 V, the output voltage of the detecting circuit is a constant 0 V. When the input transition above the threshold voltage is 10 V, the detection circuit outputs a negative pulse with an amplitude of 2.5 V. The circuit module determines the voltage transition threshold by setting suitable parameters for the capacitors and resistors, thereby can easily detected voltage mutations generated by short circuits in the high-voltage line.

Detecting circuits based on the amount of current mutation of the short circuit requires the current mutation of the high-voltage line to be 200-300 A and the sensor output voltage to be below 15 V to avoid exceeding the full scale of the analogue-to-digital converter of the MCU. The sensor uses a special hollow cylindrical coil. Considering the charge and discharge time constants, the capacitance of both follower circuits varies by at least one order of magnitude.

Grounding fault analysis: Fault detection terminals analyse the fifth harmonic of the line current voltage to identify ground fault. Single-phase ground fault varies the superposition of the harmonic components of the current and causes the non-fault phase voltage to generate harmonics. To verify the accuracy of the harmonic detection algorithm in the microcontroller, raw data are generated by MATLAB and the 64-point Fast Fourier Transform (FFT) is implemented by the grounding fault algorithm of the fault detection terminal with an STC MCU. The data are generated by the following analytical expression:

$$y = a_1 \sin(2\pi f_1 \times k \times \frac{1}{f_s}) + a_2 \sin(2\pi f_2 \times k \times \frac{1}{f_s}) \tag{1}$$

where, α_1 and α_2 are the amplitudes of the two signals (5 and 15, respectively), f_s is the sampling frequency (800 Hz), f_1 is the basic frequency (50 Hz) and f_2 is the fifth harmonic (250 Hz). In other words, the signal consists of a frequency signal and the fifth harmonic component and k is the sampling point sequence number. The raw data waveform generated by MATLAB is shown in Fig. 4 (a); the waveform generated by MCU operation is shown in Fig. 4b. The fundamental and higher harmonics of the signal in the original data waveform are

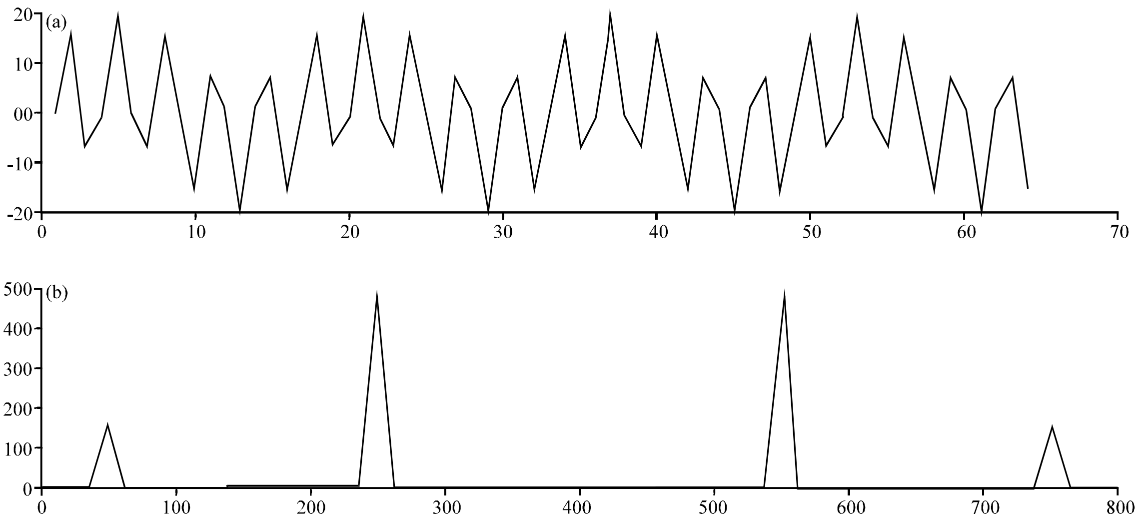

Fig. 4(a-b): (a) Wave pattern of primary data from MATLAB and (b) wave pattern after FFT

difficult to distinguish. FFT significantly increases the difference between the fundamental and higher harmonics.

SUMMARY

A novel fault diagnosis based on Internet of Things technology for electricity supply networks is proposed. The proposed diagnostic method monitors online changes in the three-phase zero-sequence voltage and current of fixed points on high-voltage transmission lines in real time. The proposed method also equally measures such voltage and current to evaluate the performance of the section and identify short circuits and ground malfunction. In fault diagnosis and line maintenance, the Internet of Things enables interflow and interaction among units, such as the detection terminal, signal relay, long-distance control centre and maintenance crew. The proposed detection method has a "self-learning" function; that is, it does not require multiple thresholds on transmission lines with different loads in advance. Performed online in real time, fault diagnosis based on the Internet of things for electricity supply networks is accurate and convenient.

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REFERENCES

Bi, T., Y. Ni, F.F. Wu and Q. Yang, 2002. A novel neural network approach for fault section estimation. Proc. Center Sci. Eng. Edu., 22: 73-78.

Dobakhshari, A.S. and A.M. Ranjbar, 2012. A circuit approach to fault diagnosis in power systems by wide area measurement system. Eur. Trans. Elect. Power, (In Press). 10.1002/etep.1654

Dos Santos Fonseca, W.A., U.H. Bezerra, M.V.A. Nunes, F.G.N. Barros and J.A.P. Moutinho, 2013. Simultaneous fault section estimation and protective device failure detection using percentage values of the protective devices alarms. Trans. Power Syst., 28: 170-180.

Guo, C., J. You, M. Peng, Y. Tang, Y. Liu and J. Chen, 2010. A fault intelligent diagnosis approach based on element-oriented artificial neural networks and fuzzy integral fusion. Trans. China Elect. Tech. Soc., 25: 183-190.

Ma, D., Y. Liang, X. Zhao, R. Guan and X. Shi, 2013. Multi-BP expert system for fault diagnosis of power system. Eng. Appl. Artif. Intell., 26: 937-944.

Mansour, M.M., A.A.W. Mohamed and W.M. Soliman, 2012. Bayesian networks for fault diagnosis of a large power station and its transmission lines. Elect. Power Compon. Syst., 40: 845-863.

Ren, D.J., 2012. Application attributes reduction of rough set in power system for fault diagnosis. J. Convergence Inform. Technol., 7: 300-308.

Wu, K., S. An, G. Ma and Y. Tao, 2012. Research and application of fuzzy expert system on transformer fault diagnosis. Proceedings of the International Conference on Computer Science and Electronics Engineering, March 23-25, 2012, Hangzhou, China, pp: 378-382.

Zhao, F. and H.S. Su, 2009. Application of evidence theory and rough sets in substation fault diagnosis. Proc. Chin. Soc. Univ. Electr. Power Syst. Automation, 21: 42-46.

Zhou, A.H., H. Song, H. Xiao and X.H. Zeng, 2012. Power transformer fault diagnosis based on integrated of rough set theory and neural network. Proceedings of 2012 International Conference on Intelligent Systems Design and Engineering Applications, January 6-7, 2012, Sanya, China, pp: 1463-1465.

Zhu, Y.L., Y. Wang, L.Q. Geng and D. Su, 2007. Power system fault diagnosis based on Bayesian network. Electr. Power Autom. Equip., 27: 33-36.