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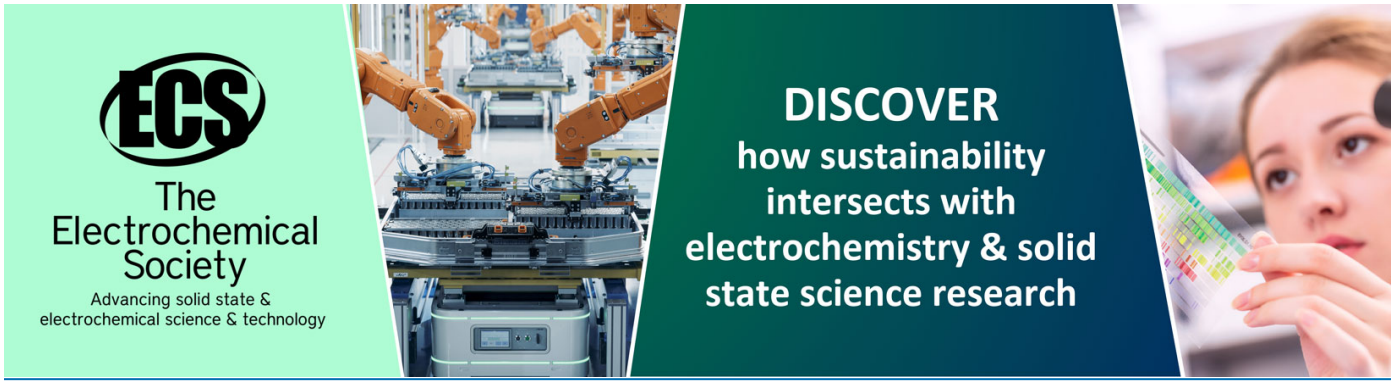

Review on Breaking-closing Position Monitoring Method for Intelligent Disconnecting Switches

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Abstract The reliability and intelligence of intelligent disconnecting switches breaking-closing is one of the key technologies for intelligent substation construction. The tasks of substation operation and maintenance have increased greatly due to the increasing requirements of security operation level and service quality. Only to enhance the intelligent and automatic level of power grid, reliability of smart substation devices operation can be improved. The research condition of breaking-closing position monitoring technology for intelligent disconnecting switches at home and abroad is summarized and the methods are illustrated respectively from the views of their basic idea, characteristics, and disadvantages, including image recognition method, optical sensing method, pressure sensor method, auxiliary contact principle method, attitude sensor method, and so on. Finally, the research tendency in the intelligent disconnecting switches position monitoring field is point out.

1. Introduction

With the rapid development of smart grid technology, intelligent substation construction and substation intelligent transformation have become an important direction for the development of the power industry [1]. There will be more than 7,700 new intelligent substations with a substation capacity of more than 2.6 billion kVA in China by 2020. As a key component of intelligent substation, intelligent disconnecting switches are used for information collection, transmission, processing and communication. The reliability and intelligence of intelligent disconnecting switches closing is one of the key technology for intelligent substation construction.

In recent years, due to the increasing requirements of security operation level and service quality, the tasks of the substation operation and maintenance have increased greatly. The traditional manual switching mode is no longer applicable due to various problems such as complex process, large duplication of work, low efficiency and safety risk. With the continuous penetration of sensing technology [2], information processing [3], condition monitoring and fault diagnosis [4] in the field of intelligent disconnecting switches, improving the automation and intelligence level of high voltage isolator has become an important means to improve effective productivity.

This paper reviews the research status of intelligent disconnecting switches technology at home and abroad. The techniques and methods of common opening and closing position monitoring are summarized including image recognition method, optical induction method, method based on pressure sensor, method based on auxiliary contact principle, method based on attitude sensor, etc. The

characteristics, basic ideas and shortcomings of different methods are discussed. The main research trends of intelligent disconnecting switches are prospected in the future.

2. Research status of intelligent disconnecting switches at home and abroad

At present, the rapid development of sensor technology has formed a combination of strong and weak electricity, and promoted the development of high-voltage isolating switchgear in the direction of intelligence. Research on intelligent disconnecting switches is progressing toward high voltage, large capacity, high mechanical reliability, and low maintenance.

Foreign research on intelligent disconnecting switches started in the 1950s. In [5], American South State Power, ALSTOM, SIEMENS, French MG, TAKAOKA TOKO and other companies applied new materials, technologies and processes to the mechanical transformation of high voltage isolating switches to improve its stability, reliability and durability. The contact system of the high voltage isolator designed by SIEMENS was made of copper alloy with special material which can ensure the good conductivity of the contact without pressing the spring. A high-life lubrication system was adopted by RUHRTAL in Germany to reduce maintenance costs. In [6], silver-plated contacts and double-bearing structure are used to improve the sensitivity and stability of operation by TAKAOKA TOKO.

In China, the manual operation mode is still adopted to switch on the high voltage isolator which is carried out by manual force. Although the operation mode is simple, poor contact, low operational reliability, low switch on speed and other issues are caused by mechanical problems [7]. With the application of one-click sequence control technology in intelligent substation, the traditional manual execution of the operation ticket mode is changed into a task ticket with predefined operational steps based on the correct switch acquisition information[8].In [9], the separation position of the isolator mainly depends on the auxiliary contact which is easy to cause the misalignment of the opening and closing position due to the long distance between the auxiliary contact and the contact. With the development of image application technology and sensor technology, laser measurement, pressure measurement, image recognition and other techniques are applied to discriminate the separation position of the isolator.

3. The monitoring methods of intelligent disconnecting switches

The one-click sequence control technology puts forward higher requirements on the accuracy of the opening and closing position of the isolator. The existing monitoring methods mainly include image recognition method, optical sensing method, method based on pressure sensor, method based on auxiliary contact principle, method based on attitude sensor, etc.

3.1. Image recognition method

In [10]-[12], image recognition technology mainly refers to the use of computer vision, pattern recognition and other technologies to extract features from image regions to meet the information and visual needs of users in different scenarios. In the method, the image features of the position are extracted. The information processing technology and the intelligent recognition algorithm are used to determine whether the isolating switch is opening or closing. The advantages are intuitive discriminating process and high degree of automation. The disadvantages are low recognition accuracy, affected by weather and high cost.

Research on image recognition technology in power equipment is extensive. In [13], with using image processing and pattern recognition technology, an intelligent robot suitable for the actual construction of 500kV intelligent substation is proposed. Based on Hough transform and scale-invariant feature transformation algorithms, the robot realizes the automatic identification and accurate transmission of switch position status information. The position information can be seamlessly transmitted to the monitoring platform to provide a basis for discrimination and process reproduction for the "one-button" sequential switching operation. In [14], the image recognition feature analysis technology combines with the template matching algorithm to remotely monitor the operating state of

the power transformer. This method can determine whether the device is overheated, but it cannot automatically identify the opening or closing position of the electrical device. On the basis of the literature [14], the literature [15] proposes a method for identifying the state of the switch from machine vision. The double-threshold change and spatial filtering are used to remove the interference factors in the image, and extracted the effective switch image, which greatly improves the state recognition rate. However, taking video surveillance devices, it is sometimes impossible to monitor the position of the switch in all directions and is susceptible to interference from magnetic fields and the environment.

3.2. Optical sensing method

The optical sensing method refers to that a laser sensor is installed on the moving contact of the isolating switch. The laser emitter and the laser mirror are used to emit and reflect back the laser beam to monitor the isolation switch in the fully open position or the closed position. The connection status between the output of the circuit and the auxiliary contact of the isolator analysed to determine whether the switch on is in place.

The research on optical sensing method applied to position detection starts earlier at home and abroad. In [16], an intelligent monitoring device is developed by using an infrared laser to detect the change of temperature difference in the open/close state of the isolating switch. In [17], a set of position detecting device suitable for high-voltage isolating switch is developed. The laser beam, mirror, sensor and other modules were used to realize the wireless sensing of the position of the moving contact of the laser beam, which can accurately monitor the separation switch. The laser beam, the mirror, the sensor and other modules are used to realize the wireless sensing of the position of the moving contact by the laser beam. The disadvantages of this method are highly accurate mounting position, difficult to adjust during actual installation on site, and limited by light transmission distance. Combined with laser sensor technology, a laser sensing detection system suitable for horizontal rotary isolation switch is designed in [18]. The optical signal is received by the photosensitive surface of the laser sensor and converted into an electrical signal. The split/close state of the moving contact is determined by the laser sensor output signal. The method is simple in measurement and strong anti-interference ability which is not interfered by strong electromagnetic fields. Due to the vulnerability to rain, snow, humidity and visibility, the scope of application is limited. As the low reliability of the detection process, its reliability and accuracy are low.

3.3. The method based on pressure sensor

A method for judging the opening and closing position of the isolating switch based on the pressure sensor is described. The pressure sensor is installed at the contact point or the spring of the isolating switch moving contact and the static touch. The change in pressure is measured during the switching action to determine the state of the isolating switch. Since the pressure sensor directly measures the finger jaw pressure, its reliability is affected by the life of the spring member.

The pressure sensor was applied to the condition monitoring of the circuit breaker [19]-[20] or the contact finger pressure detection of the isolation switch [21]. In [22], in order to solve the problem that the isolation switch is in a semi-closed position due to the failure of the contact switch spring or the contact failure of the contact, a set of software and hardware devices for visually monitoring the isolation switch in place is developed. The pressure sensor is bolted to the moving contact of the isolating switch. The advantage is that the determination result is reliable, and the disadvantage is that the use of imported long-lasting battery power supply greatly increases the design cost. In [23], a method for judging whether the contact state of the contact is good is proposed. The pressure sensor is used to measure the pressure of the compression spring. The action of the switch is judged by the magnitude of the sudden change in spring pressure. The infrared temperature sensor is used to measure the temperature of the contact part, and it is judged whether the contact state of the contact is good when the switch is in the joint position. The method is simple, reliable and high real-time performance, but it is only applicable to the type of isolating switch with a treatment spring.

3.4. The method based on auxiliary contact principle

The principle of the isolation switch position discrimination based on the principle of the auxiliary contact is simple. The auxiliary contact is installed at the opening and closing limit screw or the stop plate of the isolating switch. The on/off of the isolating switch is determined by the on and off of the contact. The auxiliary contacts can be mounted in a high or low pressure zone. When the auxiliary contact is installed in the high pressure zone (such as near the opening and closing limit screw), the mechanical force generated by the opening and closing of the isolating switch collides with the auxiliary contact, and the separation or combination of the isolating switch is reflected according to the action of the auxiliary contact. The advantage is that it can accurately reflect the opening and closing position of the isolating switch, and the disadvantage is that there is a problem of signal transmission and auxiliary switching function in a high voltage and strong magnetic environment. When the auxiliary contact is installed in the low pressure zone (such as the travel switch in the isolation switch mechanism box), the contact is driven by the movement of the relevant components in the mechanism box to realize the opening and closing operation of the isolating switch. The continuous action of the multi-stage transmission is used to reflect the movement of the switch contacts. When the transmission link is abnormal, the actual action of the isolation switch cannot be accurately reflected [24].

3.5. The method based on Attitude Sensor

Attitude sensor technology was developed abroad in the middle of the 20th century, and applied to national defense in developed countries such as the United States and Japan [25]. In the 1960s, sensor technology had initial development in design, research, and manufacturing in China [26]. The attitude sensor mainly detects the change of the posture (including motion, speed, and angle) of the carrier and converts it into a signal output for detecting the change of the body angle of the device.

The early attitude sensor uses the traditional inertial sensor as the core measurement component, which has the disadvantages of high cost, large volume, complicated structure and poor stability. With the comprehensive development of Micro-Electro-Mechanical Systems (MEMS) [27]-[28], MEMS attitude sensors such as MEMS gyroscopes, MEMS magnetoresistive sensors and MEMS accelerometers have become the development trends. Compared with traditional inertial measurement components, MEMS attitude sensors have the advantages of low price, simple structure, light weight, low power consumption, high stability, saving system resources, large measurement range, easy integration, etc. With the development of large industrial technology and sensor technology, attitude sensors have been widely used in aerospace [29], ocean [30], vehicle engineering [31], military [32], robot [33] and other fields in recent years. At present, the commonly motion attitude sensor is mainly composed of a three-axis MEMS accelerometer, a three-axis MEMS gyroscope and a three-axis MEMS magnetometer. Based on information fusion algorithm, the output of the gyro is corrected in real time by the output of the accelerometer and the magnetometer to obtain the optimal estimation of the carrier attitude information. This combination not only satisfies the requirements of the application, but also realizes the complementary advantages of the three devices, which constitutes the redundant configuration of the sensor and improves the reliability of the system.

The principle of two-confirmation position discrimination method for an isolator is to monitor the "attitude" (the position angle) of the components of the sensor body, and calculate the rotation angle to determine whether the isolator is opening or closing. The angle error of the isolator based on attitude sensor technology is less than 0.5° which is almost independent of external influences, and has self-calibration function. .

3.6. Other Methods

Other methods for monitoring the opening and closing position of the isolator include temperature measurement method, distance measuring method and so on. The temperature measurement method [34] uses infrared, fiber optic and sensor to measure the temperature of the position of the isolating switch contact, and judges its in-position state according to the temperature change in the split/close

state. It has the advantages of low cost and wide application range, but also has shortcomings such as short communication distance, high safety hazard, high temperature influence by environment, and low judgment accuracy. The distance measuring method determines the in-position state of the isolating switch according to the change of the distance between the two sides of the movable contact U-shaped groove. This method is because the sensor is installed near the moving contact of the isolating switch, and it is determined by measuring the change of the distance of the sensor that there is a positional deviation, so the reliability of the measurement result is not too high. Since the sensor is installed near the moving contact of the isolating switch, there is a positional deviation that makes the measurement result less reliable.

4. The tendency of intelligent disconnecting switches position monitoring

With the vigorous expansion and the continuous transformation of intelligent substation, the development of intelligent disconnecting switches that meet the requirements of one-button control has become one of the key points in the current development of smart grid. In this paper，five position monitoring methods of intelligent disconnecting switches are reviewed. Intelligent disconnecting switches based on optical sensing or auxiliary contact technology is currently only available for related patent applications, and there are no samples or end products. Research on intelligent disconnecting switches based on image recognition technology has just begun. Intelligent disconnecting switches based on pressure sensor and attitude sensor has developed some models of finished products or samples, which will become the main research trend in the future.

5. Conclusion

With the deepening of China's smart grid construction, grid companies have put forward higher requirements for safe operation level and service quality. The workload of substation equipment maintenance has increased significantly, and the safety situation has become increasingly severe.

Improving the automation and intelligence level of the power grid and realizing the one-button sequential control function have become an urgent problem in the current development of intelligent substation. In this paper, the commonly position monitoring methods of intelligent disconnecting switches are introduced, and the advantages and disadvantages of various methods are discussed. Through comparative analysis, the research on isolator position detection method based on pressure sensor or attitude sensor has become the main trend in the field of analysis of intelligent disconnecting switches one-button sequence control.

References

[1] LIU Z Y 2010 Smart grid technology (*Beijing: china power press*)
[2] ZOU J Y WANG Y 2000 Conception of intelligent switchgear and its relevant theoretical issues (*High Voltage Apparatus vol 36*) pp 43-46
[3] Q/GDW 383—2009 Technical guide for smart substation
[4] LIU Y W ZHOU H 2011 Information flow scheme designed for smart HV switchgear (*High Voltage Apparatus vol 47*) pp 1-4
[5] NIU H M 2008 The condition and trend for development of the high voltage isolator at home and abroad (*China Electrical Equipment Industry vol 02*) pp 24-30
[6] Runde M 2013 Failure Frequencies for High-Voltage Circuit Breakers, Disconnectors, Earthing Switches, Instrument Transformers, and Gas-Insulated Switchgear (*Power Delivery, vol 28*) pp 529-530
[7] HAN B LIN J M CHEN W J 2011 Analysis on the influence of the switching speed of disconnector on very fast transient overvoltage (*Proceedings of the CSEE vol 31*) pp 12-17
[8] WANG W L LIU Y DAI X X 2009 Influence of sequential operation on an expanded substation (*Automation of Electric Power Systems vol 33*) pp86-89
[9] YUAN S CUI W J 2004 Design and improvement of high voltage disconnector (*Beijing: China Electric Power Press*)
[10] Andreopoulos A Tsotsos J K 2013 50 years of object recognition: Directions forward (*Computer Vision and Image Understanding vol 117*) pp 827-891

[11] Russakovsky O Deng J Su H 2015 ImageNet: Large scale visual recognition challenge (International Journal of Computer Vision *vol* 115) pp 211-252
[12] JIANG S Q MIN W Q WANG S H 2016 Survey and prospect of intelligent interaction-oriented image recognition techniques (*Journal of Computer Research and Development vol 53*) pp 113-122
[13] CHEN A W LE Q M ZHANG Z Y 2012 An image recognition method of substation breakers state based on robot (*Power System Automation vol 36*) pp 101-105
[14] ZHANG H WANG W XU L J 2010 Application of image recognition technology in electrical equipment on-line monitoring (*Power System Protection and Control vol 38*) pp 88-91
[15] FANG SHU X H LI D W 2017 A Method based on machine vision for opening-closing status recognition of substation disconnecting switches (*Journal of Hunan University of Technology vol 31*) pp32-36
[16] ZHANG G C SU D Q 2012 Design and research on laser monitor fevice of intelligent high voltage disconnector position (*Automation Application vol 03*) pp 79-81
[17] LIU B SUN C C XIAO C 2014 Laser sensing technology based condition monitoring device of high-voltage disconnect switch (*Smart Grid vol 11*) pp 48-51
[18] FANG X G LIU N J CHEN W T 2015 On-line real-time monitoring device of moving contact position of the disconnect switch (*Heilongjiang Electric Power vol 02*) pp 144-146
[19] LEE W Y PARK K Y CHONG J K 2002 A method to decide the switching instants of controlled switching circuit breaker for shunt reactors (T*ransmission and Distribution Conference and Exhibition vol 3*) pp1760-1765
[20] LI G WANG X F ZHOU S B 2010 Design scheme of circuit breakers state monitoring in intelligent substation (*Power System Protection and Control vol 38*) pp 140-143
[21] Lin Y B Chang K C Chern J C 2004 The Health Monitoring of a Prepressureed Concrete Beam by Using Fiber Bragg Grating Sensors (*Smart Materials and Structures vol 13*) pp 712-718
[22] YANG C LI G AN Y S 2014 VLD- based position monitoring method foe intelligent disconnector (*High Voltage Apparatus vol 50*) pp 76-82
[23] WANG Y LIU F WANG T 2017 Research on method of breaking-closing position discrimination with contact condition recognition of disconnector and its application (*Hubei Electric Power vol 41*) pp 1-4
[24] JIANG P LI J 2009 The test on contact pressure of high voltage disconnector (*Sichuan Electric Technology*) pp 26-28
[25] WAMG Y 2011 MEMS technical development and its application (*Aerodynamic Missile Journal)* pp 85-89
[26] JIANG S S 2013 The development status and application prospect of sensor technology (*Electronic Technology & Software Engineering*) pp 23
[27] ZHANG L 2017 The research and design of a MEMS motion attitude sensor (*Modern Computer*) pp 12-13+24
[28] Xin T Li Z F Han G W 2018 Adaptive EKF based on HMM recognizer for attitude estimation using MEMS MARG sensors (*IEEE Sensors Journal vol 18*) pp 3299-3310
[29] Zhang L Wu Q S Gao R 013Design and Implementation of Vehicle Attitude Detection and 3D Dynamic Display System (*Applied Mechanics and Materials vol 397*) pp 1253-1257
[30] James C K Louis L 2007 Whitcomb. In situ alignment calibration of attitude and Doppler sensors for precision underwater vehicle navigation: theory and experiment (*IEEE Journal of oceanic engineering vol 32*) pp 286-299
[31] Hamad A , Muhammad T 2017 Accurate attitude estimation of a moving land vehicle using low-cost MEMS IMU sensors (*IEEE Transactions on Intelligent transportation system vol 18)* pp 1723-1739
[32] WU J 2004 Design and research for the dishing unmanned helicopter (*Nanjing, Nanjing University of Aeronautics and Astronautics*)
[33] QIANG C Z WU Z C SHEN F 2010 Application of attitude sensor in humanoid robot foot perception system (*Instrumentation Technology*) pp 68-70
[34] ZHANG Y TIAN J YE F C 2005 Development of temperature real-time monitoring network for high voltage switch cabinet based on IR Sensor (*High Voltage Apparatus vol 41*) pp 91-94