Method for Realizing On-Line Condition Monitoring of Protective Device Based on Data of Information Processing System

Jiaqi Wang[a] and Yan Xu[b]

North China Electric Power University (Baoding), Hebei Baoding 071000, China

[a]wjqncepu@qq.com, [b]xy19761001@aliyun.com

Abstract. At present, the evaluation of relay status maintenance depends on a great deal of manpower, while the data source of relay protection device and fault recorder information system (hereinafter referred to as the guarantee system) has reached the basic requirement for online monitoring status evaluation. Based on the analysis of the internal structure of the system, the automatic extraction of abnormal operation information of the protection device is realized. According to the failure mode and reliability analysis method FMEA, the evaluation index of the risk of on-line status of the protection device is proposed. In the real-time status of relay protection devices and systems quantitative assessment, the final selection of actual operating data protection device as an example to show the effect of the method.

1. Introduction

Currently, the evaluation of relay protection status maintenance is mainly based on the provisions of the relay protection status maintenance evaluation regulations [1-2], manual collection of basic information on the operation status of reaction protection devices, it includes dynamic records of inspections, defects, overhaul and protection actions, and at the same time develop a corresponding relay protection status evaluation software system in order to improve the sharing of evaluation work information and uniformly collect data standards and evaluation standards [3-5]. Its characteristics are as follows: The work mainly depends on personnel participation, and there is a certain degree of difficulty in the work while having a large workload. With the expansion of the power grid scale, this mode of management-level evaluation requires a lot of manpower and capital, and it cannot guarantee that the performance of the protection device can be monitored in real time.

In this paper, the internal structure object information of the information processing system export file is used as the data source for online monitoring. According to meeting the maintenance requirements of relay protection status, the internal structure information of the two types of files of the data source is analyzed, and the automatic extraction and classification of the abnormal information of the protection device is completed. Using the failure mode and degree of impact reliability analysis method, the risk assessment indicators for on-line status of relay protection devices are presented as the results of quantitative assessment of the real-time status of relay protection devices and systems.

2. Information processing system data extraction

The information processing system provides two types of files to third-party application software development: real-time monitoring data files for protection device self-test or event configuration files and reaction history events [6].

2.1. Protection Device Self-Test or Event Profile

The protection device self-test or event configuration file provides information including: fixed value, fixed area code, soft platen, device parameter, protection measure, hard plate, action element, operation alarm, disturbance data description, fault information, etc. [7]. However, not all information is applicable to the research of relay protection devices and system condition maintenance. In order to make the data clearer, it is necessary to sort out the protection event information provided, filter out unnecessary information, and fail to respond to protection devices and system functions. Performance, reliability, etc., directly affect the recorded information, as the original feature of the relay protection device and system evaluation status.

The so-called direct response protection device and system function, performance, reliability and other information that directly affects the recording refer to the information that can directly reflect the status of the components in the protection device and the system functional structure diagram. The direct response protection device and system operation abnormal information included: 1. Relay protection device modulus A/D data monitoring information; 2. Relay protection device longitudinal channel monitoring information; 3. Protection relay temperature and humidity monitoring information; 4. Monitoring of operating voltage of relay protection devices; 5. Relay protection circuit module self-test and monitoring; 6. Relay Protection Device Central Processing Unit (CPU/DSP) Operation Monitoring; 7. Relay protection plug-in monitoring; 8. Relay protection switching input circuit monitoring; 9. Relay Protection Switching Output Circuit Monitoring; 10. Relay protection device activation element and action element abnormality monitoring; 11. Relay protection device background communication interface monitoring; 12. Relay Protection Device Interface Monitoring.

3. Based on FMEA to achieve protection device online status evaluation

3.1. Failure Mode and Failure Impact Reliability Analysis Method

Fault Mode and Failure Impact Degree Reliability Analysis Method FMEA is the English abbreviation of failure mode and impact analysis, and is an analysis method of pre-prevention in the production process [8]. FMEA is an analysis method to determine the cause of failure. When the subsystem or component that constitutes the system fails, the FMEA can be used to analyze the impact of the failure on the system and determine the components that have a significant impact [9].

3.2. FMEA model for online status evaluation of protective devices

The internal structure object information of the exported file of the information processing system is used as the data source for online monitoring. An on-line evaluation model of the protection device is established by using the FMEA method. Each protection device is a component of the system, and the collected self-inspection information is used as a failure mode. Different types of protection and different equipment manufacturers cause different self-identification of the protection device/event information naming. In order to ensure the universality of the protection real-time operating status evaluation, the failure mode information is classified according to the different parts of the reaction protection system and the same degree of influence. There are 22 failure mode classes. Hardware malfunction, Software failure, Electricity failure, Manual switch hardware failure, Device power on initialization, Fixed value error, Secondary control loop failure, Failure protection start exception, Configuration error, Abnormal start, Operation is confirmed, Abnormal quantity of output, Abnormal ambient temperature and humidity, Can't return for a long time, Clock synchronization failure, Communication failure, Measurement acquisition abnormality, Abnormal switch quantity collection,

Abnormal voltage measurement acquisition, Abnormal data, Optical signal abnormality, GOOSE network communication failure.

Through the analysis of the classified information impact types, we have determined: the influence of the protection device function, the influence of the protection system, the degree of influence of the protection device reliability, the degree of influence of the protection system reliability, and the influence of the protection system risk (safety) as are determined as the shadow loudness index of the FMEA reliability analysis method.

In combination with the actual operating conditions, the frequency of occurrence of each type of failure mode and the score of the FMEA impact index are shown in Table 1-2.

Table 1. Frequency of Failure Modes.

Failure mode class	Rating points	Failure frequency
Hardware malfunction, Software failure, Electricity failure, Manual switch hardware failure, Device power on initialization	2	Hardly happens
Fixed value error, Secondary control loop failure, Failure protection start exception, Configuration error, Abnormal start, Operation is confirmed	4	Rarely happen
Abnormal quantity of output, Abnormal ambient temperature and humidity, Can't return for a long time	6	Occurrence frequency is low
Clock synchronization failure, Communication failure, Measurement acquisition abnormality, Abnormal switch quantity collection, Abnormal voltage measurement acquisition	8	High frequency of occurrence
Abnormal data, Optical signal abnormality, GOOSE network communication failure	10	Occurrence is very high

Table 2. Influence degree.

Rating points	Failure impact
10	Fatal effects, loss of function, emergency defects
8	Major effects, loss of function, serious defects
6	Larger impact, degraded functional performance, emergency defects
4	Minor impact, functional performance degradation, serious defects
2	Minimal impact, functional performance degradation, general defects

Finally, the calculation formula of the risk degree of the FMEA analysis based on the abnormal alarm information of the information processing system is calculated.

For single failure mode risk calculation formula:

$$R_i = P_i * Q_i * \lambda_i = P_i * \sum (Qbzi + Qbsi + Qbksi + Qbfi) * \lambda_i \tag{1}$$

Where: R_i-specific failure mode risk; P_i- the frequency of occurrence of that particular failure mode; Q_i- the degree of influence of this particular failure mode; λ_i- the probability of detection of that particular failure mode, the probability of detection of a specific failure failure mode Is the number of occurrences of specific failure mode events in the history derived from the security system/statistical time T_0 or accumulated duration/statistic time T_0, if the specific failure mode event does not occur during the statistical period, the probability is zero; $Qbzi$- the specific failure Influence of the mode on the function of the protection device; $Qbsi$- the degree of influence of the specific failure mode on the protection system function; $Qbki$- the degree of influence of the specific failure mode on the reliability of the protection device; $Qbksi$- the degree of influence of the specific failure mode on the reliability

of the protection system; *Qbfi*- the degree of impact of this particular failure mode on the protection system's risk.

Protection device risk calculation formula:

$$R_s = \sum_{i=1}^{n} P_i * \lambda_i \tag{2}$$

Where: *n*- the number of all failure mode classes included in the protection device; *i*- the i-th failure mode is classified; *Pi*- the corresponding rank of protection device function, protection system function, safety, protection device reliability, and protection system reliability after the i-th classification occurs. *λi*- The degree of influence of the protection function, protection system function, safety, protection device reliability, and protection system reliability after the i-th classification occurs.

4. Example analysis

Take a substation line protection CSC101B as an example, the actual configuration of the failure modes are: current measurement and acquisition anomalies; communication failures; software failures; functional hardware failures; abnormal voltage measurement acquisition; configuration error; operation is not confirmed; Abnormal switch quantity collection; abnormal quantity of output; abnormal data. The abnormality information data exported by the information processing system is shown in Table 3.

Table 3. Abnormal information data occurs during statistics exported by the information processing system.

Abnormal information class name	The number of abnormal information occurrences	Abnormal accumulation of information (ms)	Abnormal risk calculation
Abnormal current measurement	1	100	0.0012
Communication failure	2	20	0.00045
Software failure	0	0	0
Functional hardware failure	0	0	0
Abnormal voltage measurement acquisition	1	120	0.00098
Configuration error	0	0	0
Operation not confirmed	0	0	0
Fixed value error	0	0	0
Abnormal switch quantity collection	3	500	0.0021
abnormal quantity of output	0	0	0
Abnormal data	5	5000	0.0078
Protection device statistics	12	5740	0.01253

The influence index of sub-items under the category of all failure modes included in the protection device is the effect of the protection device, the influence of the protection system, the influence of the reliability of the protection device, and the influence of the protection system reliability as shown in Figure 1-5.
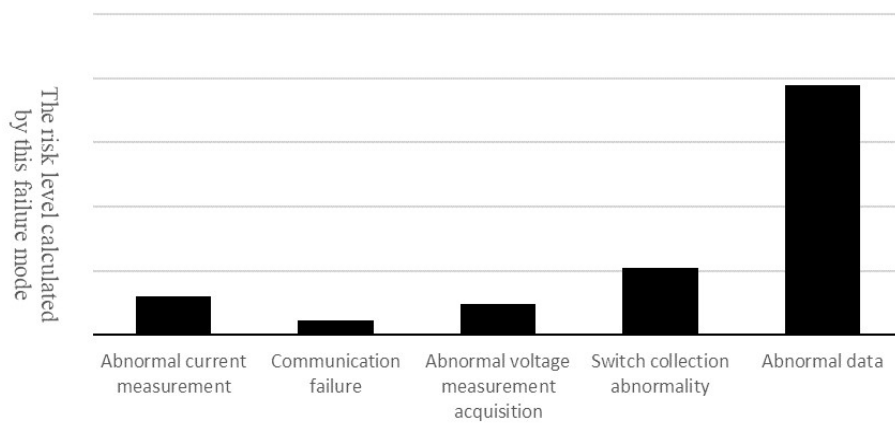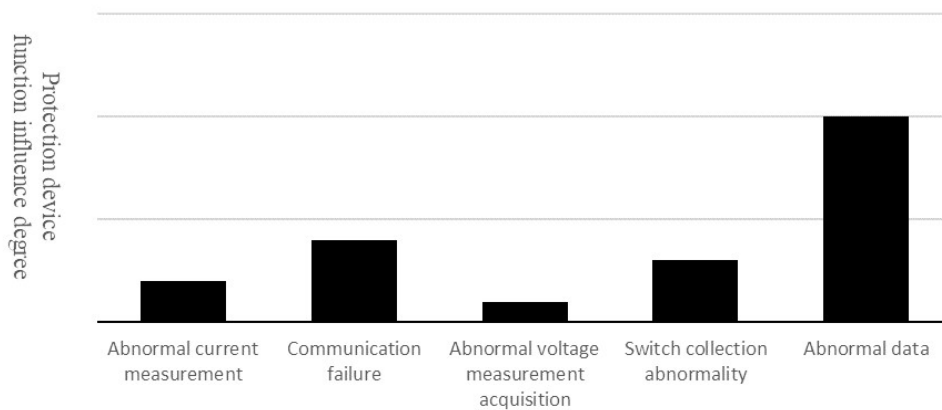
Figure 1. Effect of protection device function.

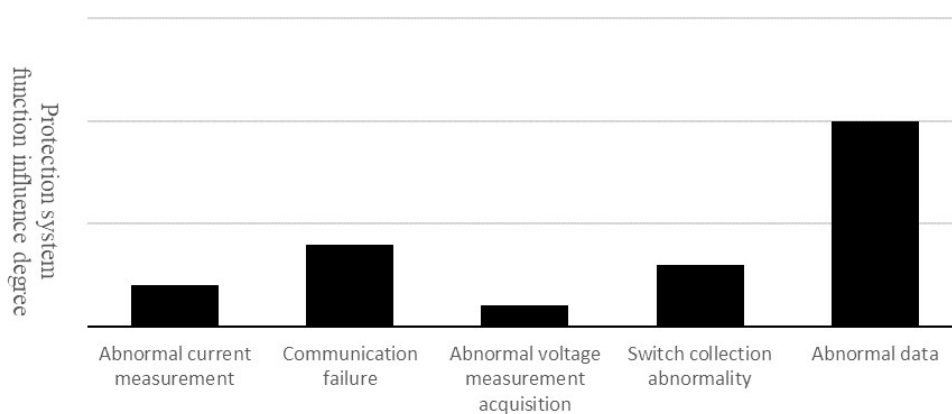**Figure 2.** The reliability of the protection device.

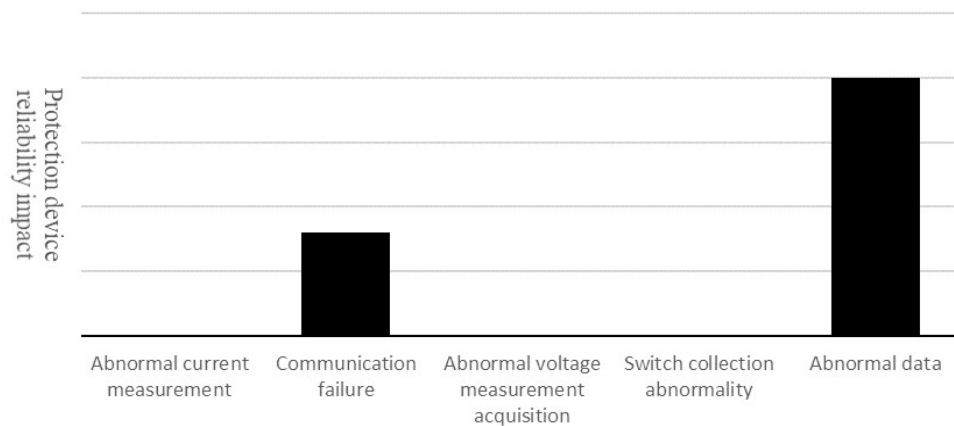**Figure 3.** Effect of protection system system function.

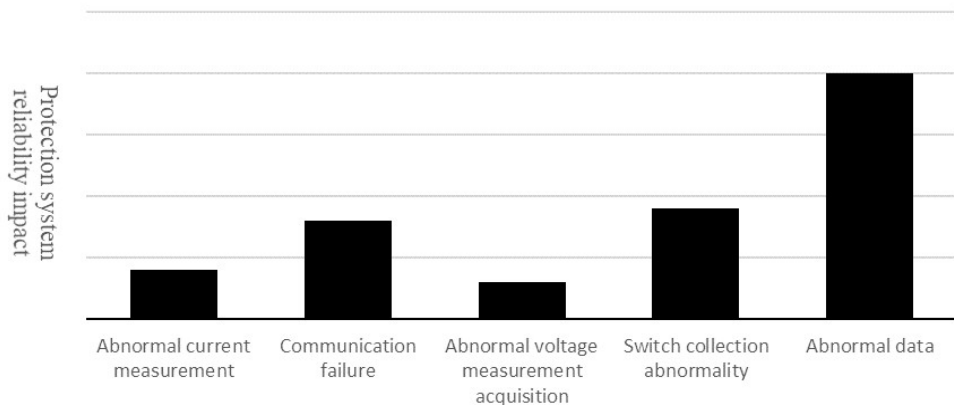**Figure 4.** The reliability of the protection system.

Figure 5. Impact of risk assessment on the protection system itself.

5. Conclusion

This paper is based on the FEMA classification of the information on the abnormality of the information processing system and the classification of the degree of influence, the risk assessment indicators and calculation methods for on-line status of relay protection devices are presented, which can be used to intuitively and accurately complete the online assessment of the risk of relay protection devices and find the abnormal operation status of relay protection devices in a timely manner. A new method for on-line monitoring and evaluation of relay protection is implemented, which provides status data support for real-time monitoring of the state of relay protection operation and improves the correctness of relay protection device operation and the reliability of power system operation.

References

[1]   Q GDW 1806-2013 Inspection code for condition based maintenance strategy of protective relay [S].
[2]   DL/T623-2010, Evaluation code of protection equipment and power system stability control devices [S].
[3]   XU Jing, WANG Jing, GAO Feng, et al. A survey of condition based maintenance technology for electric power equipment [J]. Power System Technology, 2000, 24(8): 48-52.
[4]   SONG Renjie, WANG Xiaodong. Research on assessment and analysis system of condition-based maintenance for power transformation and transformation equipment [J]. Relay, 2008, 36(9): 54-57.

[5]   GAO Xiang, Relay protection state maintenance application technology [M]. Beijing, China Electric Power Press, 2008

[6]   Feng Jun, Intelligent substation principle and test technology [M]. Beijing, China Electric Power Press, 2011.

[7]   CHEN Xiaoguo, WANG Junke, ZHANG Wei, et al. Structure Optimization and Data Modeling of IEC 61850 Based Online Equipment Monitoring System [J]. Southern Power System Technology, 2015, 9(07):95-99.

[8]   WANG Shaoyin. Failure modes and Effect Analysis (FMEA) [M]. Guangzhou, Sun Yat-sen University Press, 2003.

[9]   XIA Liang. Study on Condition Assessment Risk Management Technology of Power Transformer [D]. North China Electric Power University, 2014.