Research on Intelligent Substation Simulation Modelling Technology Based on Data Acquisition Technology

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Abstract. The introduction of intelligent substation process layer network has caused great changes in the data source and transmission method of relay protection, and its action performance and reliability are increasingly dependent on the communication network. The data flow of the relay protection in the intelligent substation and the communication mechanism of each message are analysed. Based on the IEC61850 standard, the process layer network and the relay protection IED device are modelled on the OPNET simulation software to realize the MU of the relay protection in the intelligent substation the whole process simulation of data collection, SV message, GOOSE message, protection algorithm and protection export. Combined with the example of current protection, the principle and realization mechanism of modelling and simulation are explained, and its feasibility and effectiveness are verified, which provides a new effective research tool for the quantitative analysis of relay protection in smart substations.

1. Introduction

According to China's digital standards and corresponding implementation methods, artificial intelligence technology has been well used in substation systems. Under the restraint mechanism of the secondary cable loop, various devices in the substation system can be effectively connected together through the function of Ethernet and optical fibre. In the intelligent substation, only the reliability of message transmission and command transmission in the system can be protected, and in this process, the connected equipment must be tested to see whether it can meet a certain sensitivity and reliability, and then according to the test The situation adjusts the substation intelligent protection system accordingly. According to different substation systems, different intelligent relay protection systems are designed by simulation to protect the entire intelligent substation layer by layer. With the support of OPNET simulation technology, the system can be designed and simulated, and the system can be designed according to the results of the simulation. Improvements are made in order to better protect the intelligent substation, and the simulation technology enables the entire intelligent substation system to control the nodes and the relay protection of the system, making the entire system more perfect for the relay protection of the intelligent substation [1].
2. The overall structure and function of the system

2.1. Overall structure design
This paper has designed a set of simulation test equipment (hereinafter referred to as "device") suitable for the whole station level testing of intelligent substations, and at the same time simulates the various operating states of the whole station's primary system, merger unit and intelligent terminal, and can receive and respond Trip and close commands to achieve closed loop testing. Because the intelligent substation uses SV messages to transmit analogy information, and the sampling rate is only 4 kHz, the device uses a steady-state simulation technology that is easier to implement and apply. The overall structure of the device is shown in Figure 1, including human-computer interaction unit, steady-state simulation unit, data acquisition unit and real-time data output unit. The functions of each part are as follows.

![Figure 1. The overall structure of the intelligent substation simulation test device](image)

1) Human-computer interaction unit. Provide human-computer interaction interface, establish and manage simulation models (including primary wiring diagram and component parameters), and control the simulation test process and other functions. 2) Steady state simulation unit. The principle of steady-state simulation is used to simulate the operation of the power network, output power data such as voltage, current, and switch position, and update the power data in real time according to the feedback of the system under test. 3) Data collection unit. Collect the feedback data of the system to be tested, extract tripping, closing and other information from it, and send it to the steady-state simulation unit. 4) Real-time data output unit. The power data generated by the steady-state simulation unit is converted into SV and GOOSE messages and output in real time.

2.2. OPENET model under the network
In this paper, the established OPENET simulation model combines the design process of the actual 500kV substation relay protection system, establishes the data link between device control and relay
protection, and then truly establishes the network relay protection model of the intelligent substation. In this process, in addition to using the intelligent relay protection system to protect the entire system, the traditional wiring method is also used to achieve relay protection, so as to establish a double insurance mechanism for the intelligent protection system of the substation. Establish a data path between the relay protection circuits, and use this form as the main form of relay protection. In this process, both the independence of the network and the interconnection between the networks must be considered. In the design process of the entire relay protection system, it was found that the use of a bus-type network to achieve the entire process is not very reliable, and the resulting network also has security problems, so other types of networks should be used to The reliability in the process is simulated, and the corresponding primary wiring network should be properly defined during the establishment of the entire network model.

2.2.1. The OPENET model under the network. The construction of the OPNET model is generally completed by decomposing into multiple different levels, including the network model, node model and process model. Through the analysis of the wiring process, two networking methods can be used: single string networking method and interval networking method. In the process of the first networking mode, the equipment in the entire string should be handed over to the router for management, and the data connection between the bus protection and the switch should be implemented to finally manage the entire data; and in the second In this way, it is necessary to analyse the relationship between the circuit breaker and the transformer and the entire line, and then connect it to the corresponding switch through the analysis. In the process of simulation, it is especially important to note the connection of the simulation system, as shown in Figure 2.

![Network model](image)

**Figure 2.** Network model

2.2.2. Node model. The OPNET simulation technology assists in the process of data reception and transmission through the connection of different nodes, which makes the simulation operation under the advanced node mode more systematic and standard, and realizes the timely communication effect of different nodes. Regarding the dual realization level of the intelligent contact operation and protection function of the merging unit and circuit breaker to carry out the organic cooperation between the port and the switch, the internal 2-port node definition needs to be sufficiently clear [2].

3
3. The structure and characteristics of the intelligent substation relay protection

3.1. Basic communication connection of relay protection in smart substation

In the intelligent substation communication network, the logical node is the basic unit of communication. Figure 3 is the communication structure of the protection function logical node given by IEC61850. The figure includes the protection input and output signals. The input signals include the control information from the station control layer, other function signals on the same layer, the voltage / current SV from the process layer MU, and the switching status of the intelligent operation box. The output signals include the switch trip signal and protection blocking signal. Most of the intelligent substation relay protection is designed based on this communication structure, and its main IEDs include: process level transformer, MU, intelligent operation box, bay level relay protection device, station control layer background host, etc.

![Figure 3. Communication structure of protection function logical nodes](image)

3.2. Basic data flow of the relay protection process layer of the smart substation

MU samples the voltage and current in the transformer according to the set sampling rate, packs it into a data frame format, that is, SV message, and transmits it to the relay protection device through the switched Ethernet; the relay protection device is based on Publisher / subscriber agreement, receive and process corresponding data, form an export command based on protection criteria, and send GOOSE messages (including switch opening and closing, equipment switching, gear switching, etc.) to the intelligent operation box. After the operation of the intelligent operation box is implemented the switch state quantity is fed back to the protection device in the form of GOOSE message [3].

3.3. Smart substation 3-layer communication protocol

Conventional industrial Ethernet generally adopts TCP / IP7 layer protocol to encapsulate and parse messages to ensure its reliability. However, in the process-layer network of intelligent substations, due to the high real-time requirements of applications such as relay protection, IEC 61850 supports direct mapping to the data link layer. The periodic message (such as SV message) and fast message (such as GOOSE message) in the substation adopt a three-layer structure, which effectively shortens the packet encapsulation and parsing delay.

3.4. Relay protection simulation requirements for smart substations

The introduction of the intelligent substation process layer network has caused great changes in the data collection, transmission, processing and output processes of relay protection. At the same time,
combined with the current status of existing software modelling, this paper will Modelling of electrical protection [4].

a. Data source and MU. The generation of data can be achieved by function generator or by importing fault recorder (or numerical simulation) data according to the analytic expression of electrical quantity; MU will package the original sampling data according to IEC61850-9-1/2. b. SV and GOOSE messages. The two specific fields of the message should be defined according to IEC61850, and the transmission mechanism is different: SV messages are sent periodically, and GOOSE is subject to the retransmission mechanism of heartbeat messages. c. Process layer network and its communication protocol. Including process layer network physical links, switches and other equipment modelling and IEC61850 related protocol modelling. d. Process-level network optimization mechanism. Due to the large data traffic in the process layer network, in order to ensure the real-time and reliability of key message transmission, optimization mechanisms such as priority setting and virtual local area network (VLAN) division are often used. e. Relay protection algorithm and logic. The IED modelling of the relay protection device mainly reflects the protection principle, algorithm, criterion and logic.

4. OPENET simulation application
This article takes the overcurrent protection of smart substations as an example and uses OPNET to establish the corresponding relay protection model and simulation of the substation. This article introduces the process-oriented network modelling for relay protection analysis. The data source can be obtained through sampling points. Electrical sampling volume [5]. Suppose, for example, that a fault occurs in a circuit of constant potential, the voltage at the protection installation and the corresponding current value are as follows:

\[ u = E_m \sin(\omega t + \alpha) \]
\[ i = I_m \sin(\omega t - \alpha - \varphi) \]

Where: \( \varphi \) is the power factor before the fault. Then, after establishing all the failure models of the power system, the OPNET function generator is used to write related functions. The calculation of the effective value in the current protection process is obtained by the corresponding half-wave integration method.

\[ S = \int_0^{\pi/2} \sqrt{2} I \left| \sin(\omega t + \alpha) \right| dt = 2\sqrt{2}TI / \pi \]  

Then the effective value of the current can be calculated as follows:

\[ I = \sqrt{2\pi S (2T)} \]

The results of the simulation are shown in Table 1:

| Sender device | Receiver equipment | Message transmission delay |
|---------------|--------------------|----------------------------|
|               | protection         | switch                     | Smart unit |
| MU            | -                  | 0.01890                    | -          |
| protection    | 0.0350             | 0.00672                    | -          |
| switch        | 0.0189             | 0.00200                    | 0.010      |
| Smart unit    | -                  | 0.01890                    | 0.016      |
However, in the substation system, there is no corresponding message transmission mechanism between various levels. The entire network is divided through VLANs to achieve the corresponding protection mechanism of the network, reducing the number of information broadcasts and greatly reducing the information. The degree of accumulation, so that the congestion of network information has been effectively avoided, effectively improving the efficiency of data and command transmission throughout the network. In the entire network, data packets are constantly undergoing data conversion between networks at all levels. Through simulation, the entire model is put into operation, and then the relay protection function of the entire substation system is tested accordingly, and the corresponding analogy input signal is given to perform corresponding data collection on the system messages. In this process, the switch is used as the basis for dividing the hierarchy. The purpose of this is to ensure the realization of a unified protection function [6].

The device will monitor the user input and the response of the system under test in real time during the simulation test. When there is a change in switch position (user operation or receiving a GOOSE message for tripping or closing), a change in the fault position or a change in the fault type, the software will restart Calculate and output the network status to form a closed-loop test. The response time of the device to tripping and closing GOOSE messages (from GOOSE message input to the new state of SV, GOOSE message output) is within 20 ms, and the actual smart terminal response time (from GOOSE input to output) The hard contact output is about 7 ms) and the circuit breaker opening and closing time (10 ~ 20 ms) is equivalent, and the real-time performance can meet the requirements of intelligent substation simulation testing [7].

5. Conclusion
Under the environment of the overall digital processing technology, the research work on the simulation processing effect of the substation relay protection device to achieve the pre-simulation model has achieved the necessary quality level, while determining the protection secondary circuit information exchange, pay attention to the process layer network The digital definition of the standard ensures that the conflict of actual data is minimized, the level of the LAN width is maintained, the timeliness level of message transmission is achieved, the maintenance efficiency of the entire power equipment in different links is effectively guaranteed, and the economic benefit under the overall control is guaranteed. It can be maintained and promote the continuous improvement of the transformation technology of China’s electric power industry to meet the operational requirements of various types of machinery and equipment in the modernization construction.

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