Online Verification method of Relay Protection Settings Based on ETAP software

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Abstract. In order to solve the limitations of the “pre-set, real-time action, and regular check” working mode of traditional relay protection in offshore oil field platform grids, an online verification method of relay protection settings based on ETAP software was proposed. The real-time operating status of the current power system is obtained through the EMS system, then short-circuit calculation of various faults performed automatically under the current operation mode. The protection cooperation analysis module of ETAP software is used to realize the real-time online verification of relay protection settings. According to the matching principle of the time-current characteristic (TCC) curve, the TCC curve is graphically adjusted to meet the current protection cooperation requirements. Finally, the validity of the method is verified by engineering example simulation of a platform grid in the Bohai Sea.

1. Introduction
As the power demand of offshore oilfield platforms continues to increase, their power grids is becoming larger. The structures are more complex and operating methods are changing frequently. The limitations of the “pre-set, real-time action, and regular check” working mode of traditional relay protection have also become increasingly prominent. Inadequate coordination of protection in various areas can easily lead to hazards such as protection refuse action and misoperation, which poses great challenges to the safe and reliable operation and production of offshore power grids. Realizing the real-time online check of the relay protection settings can greatly improve the reliability and safety of power grid operation.

At present, more and more scholars pay attention to the research of online verification of relay protection settings [1-3]. References [4-5] verify protection settings online according to the order of importance, but the real-time operating status of the system is not considered and the verification process is not objective. Reference [6] proposed a multi-level protection coordination mode for the distribution network. Although it can effectively increase the protection range under the special operating mode of the system, it does not have timeliness. Reference [7] realized online verification through the analysis of relay protection setting path analysis, load current and fault current calculation and coordination of protection settings. Reference [8] established an online verification system of protection settings based on the calculation method of dynamic short-circuit current. The above studies are mainly aimed at large power grids, as well as the proposed online verification methods of relay protection settings are all more theoretical, which is not conducive to solving the actual engineering problems that offshore power grid checking protection settings. The relay protection cooperation module of ETAP is the mainstream
mature international relay protection cooperation simulation software. This paper proposes to realize the online verification of relay protection by matching the real-time data of the EMS system and applying the protection cooperation module of ETAP. This method is more feasible for solving the engineering problems of online verification of offshore power grid protection, moreover, improves the operational reliability of and provides technical support for the intelligence of offshore power grids.

2. Relay protection cooperation analysis module of ETAP
The relay protection coordination module of ETAP is the mainstream international simulation software for relay protection cooperation. This module can be effectively used in the calculation of relay protection settings and verify easily. In addition it can generate time-current characteristic curves (referred to as TCC Curve) for any branch and simulates the action sequence and action time of the relay when any point of the fault, also can simulate the action of the fault insertion protection device after the fault and give a sequence of equipment actions. The protection cooperation module of ETAP can check the cooperation of protection equipment and adjust the cooperation scheme of protection equipment to make it more reasonable and effective.

ETAP puts the electrical, logical, mechanical and physical attributes of system equipment in a database. Data integration provides consistency of data throughout the system and avoids multiple entries of the same data. Combined with ETAP’s powerful database, it is easy to realize the protection equipment coordination analysis of different cases (different operating methods, different system parameters) for large systems, so that the protection coordination scheme can adapt to all possible system conditions. At the same time, ETAP also has a real-time online function. By acquiring real-time data of the power system, it can also achieve online verification of the relay protection settings.

3. Real-time data matching and state estimation
Matching the real-time data of the EMS system needs to be realized through the real-time online function of ETAP. The real-time online expansion of the ETAP software can be connected to the data interface with any combination of computer workstations, historical databases, smart meters and EMS systems. According to the preset refresh rate, ETAP periodically reads the real-time electrical data of the system and the equipment opening and closing status from the EMS system, and displays it on the one-line diagram. At the same time, real-time data is used to perform topology analysis and various simulation calculations, such as load flow calculation, short circuit calculation, transient stability calculation and protection coordination analysis.

The ETAP real-time server is an OPC client that can communicate simultaneously with multiple systems. The ETAP software can be connected to the field acquisition device or SCADA system via the OPC server to obtain the required real-time data on demand and distribute the real-time data to all ETAP consoles.

The basic process of real-time data matching of EMS system based on ETAP software is shown in Figure 1. The basic steps include:

1. Build the electrical model of the power system in ETAP software, then set the basic parameters of the equipment and determine that the model can perform load flow calculations, short circuit calculations, etc.
2. ETAP real-time components are added to the device that needs to update real-time data, such as current transformers, voltage transformers, multi-function meters, etc.
3. Import the model into ETAP SCADA integrator.
4. Utilize device model library to create a general device model, then link the device components imported into the ETAP SCADA integrator to the general device model and update specific properties of the device model.
Figure 1. Flow chart of the real-time data matching and state estimation.

(5) Apply final modification and submit the program after confirming that the model and parameters are set correctly.

(6) After realizing ETAP real-time online, the system will automatically complete the power network state estimation. At the same time, the state estimation results and real-time data will be displayed on the software interface.

4. Online verification of relay protection settings

4.1. Criteria for starting verification
When the power grid changes, it will affect the relay protection setting. On the one hand, it is the on / off operation of the unit, main transformer and other equipment, and perhaps the trip due to a failure. Such reasons are mainly reflected in the change of the opening / closing state of the switch / knife. On the other hand, the change of load and unit flow. Therefore, the criteria for starting the online verification of relay protection settings are switch displacement and line current change.

4.2. Process for implement verification
When it is necessary to perform online verification of the relay protection settings in the power system, the process is shown in Figure 2. The specific steps are as follows:

(1) Use ETAP to create a project corresponding to the structure of the actual power grid to create the corresponding one-line diagram model, and then enter the basic parameters of the component, including comprehensive insurance parameters, etc.

(2) Use the real-time online function in ETAP software to read real-time grid data from the EMS system and map it to the corresponding components on the model diagram.

(3) Estimating the state of the power grid. If the state estimation is correct, proceed to step (4), otherwise perform step (2) again.

(4) Through the real-time fault simulation calculation of the power grid, parameters such as the equivalent impedance of each bus bar, the branch coefficients and the short-circuit current can be obtained to provide the required parameters for the verification of protection settings.

(5) Click on the protection cooperation module in the ETAP software, then choose to add the related branches and relays to generate the STAR view. It is checked whether the operation of the protective device is reasonable by judging whether the TCC curve is at the lower left of the equipment damage curve and the upper right of the equipment operating curve at the same time. If it is not reasonable, adjust the TCC curve to obtain a reasonable protection setting value and feed it back to the EMS system.
Figure 2. Flow chart of online verification of protection settings.

5. Simulation and discussion
An actual offshore platform group power grid in a certain area of the Bohai Sea was selected as an example to verify the effectiveness of the proposed method. As shown in Figure 3, after the ETAP software obtains the current real-time data of the power grid, it performs a real-time power grid simulation to complete the state estimation.
After completing state estimation, real-time fault simulation are performed on the grid under the current operation mode of the grid to simulate the behavior of the power system under various fault conditions. Calculate the equivalent impedance of each bus, branch coefficient and short-circuit current, which provide the required parameters for real-time tuning and calculation. After inserting the simulated fault, check whether the operation of the protection device meets the requirements of reliability and selectivity on the one-line diagram and the switching action sequence reader.

In the event of protection misoperation and refusal, use the protection area viewer to select all device elements within the corresponding protection range to generate a STAR view TCC curve. Adjust the protection setting and trip time according to the TCC curve of each device. As shown in the transformer protection in Figure 4, the TCC curve of the protection equipment is at the lower left of the transformer damage curve.

6. Conclusion
This paper proposes an online verification method of relay protection settings based on ETAP software. The real-time operating status of the current power system is obtained through the EMS system, then short-circuit calculation of various faults performed automatically under the current operation mode. The protection cooperation analysis module of ETAP software is used to realize the real-time online verification of relay protection settings. According to the matching principle of the time-current characteristic (TCC) curve, the TCC curve is graphically adjusted to meet the current protection
cooperation requirements. Finally, simulation results show that the method is simple, effective, and easy to apply. It can realize the real-time online verification of the adaptability of the relay protection setting value of the offshore platform power grid, which greatly improves the safety and reliability of the offshore power grid operation.

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