Research and Implementation of SCD Precision Decoupling in Intelligent Substation for Single Equipment Replacement

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Abstract: In the process of reconstruction and expansion of intelligent substation, it is difficult to accurately define the influence scope of SCD file upgrade. In the wake of each modification of SCD file, all configuration information contained in SCD needs to be re-verified, which greatly increases the workload of debugging, operation and maintenance of intelligent substation. Via decoupling SCD files, the problems of modification and re-verification of SCD files in the reconstruction and expansion stage can be tackled. In this paper, SCD precision decoupling method for smart substation with single equipment replacement is proposed, which makes SCD decoupling work more detailed, adaptable to various expansion and technical transformation of substation. The decoupling of SCD is refined from logical structure to physical link level, and the decoupling range of SCD is precisely determined, so as to minimize the modification and re-verification range of SCD files and reduce the change risk caused by SCD modification.

1. Introduction
The secondary system configuration of intelligent substation must comply with the requirements and procedures of IEC 61850 standard [1]. The SCD (Substation Configuration Description) file contains almost all the configuration information related to substation protection and automation. SCD files is susceptible to frequent modification in the stages of debugging and acceptance of newly-built intelligent substations, as well as the reconstruction and expansion of substations and daily operation and maintenance. Every time the SCD file is modified, all the configuration information contained in the SCD needs to be re-verified [2-3], which greatly increases the workload of debugging, operation and maintenance of intelligent substations.

In the process of reconstruction and expansion of intelligent substation, it is difficult to accurately define the influence range of SCD file upgrade. In order to ensure the reliability, the debugging range is often increased, and the SCD file of the whole substation needs to be modified when expanding one interval or even replacing one equipment. The moment the SCD file is modified, all the configuration information contained in the SCD is required to be reverified, greatly adding the workload of debugging, operation and maintenance of intelligent substations.

2. Research Status
In recent years, a method has emerged, which is used to generate sub-files through decoupling SCD files. When carrying out reconstruction and expansion projects, only the sub-files are modified
pertinently, instead of the whole SCD files, so as to narrow the scope of modification and re-verification of SCD files and reduce the risk of modification brought by SCD modification in the reconstruction and expansion stage.

At present, in the research of SCD file decoupling, the main decoupling methods can be divided into three categories: decoupling according to the service direction, decoupling according to the interval mode, and decoupling according to the topology relationship of primary and secondary devices.

1. The scheme of decoupling according to service direction is to decouple SCD files based on the protection service configuration, measurement and control service configuration, measurement service configuration, detection service configuration, stable service configuration and public configuration.

2. The scheme of decoupling according to interval mode is to decouple SCD files into only two BCD files. Among them, the first BCD file contains all intervals involved in the current operation, which is called “Related Interval BCD” file; the second BCD file contains all the intervals that are not covered and is called the “Independent Interval BCD” file. The above two BCD files are completely decoupled.

3. According to the topological relationship structure of primary and secondary equipment, the topological configuration relationship of primary and secondary systems is referred to the decoupling mode of topological relationship of primary and secondary equipment.

All the above three technical schemes have obvious shortcomings.

Decoupling for service direction is suitable for all equipment replacement in the whole business chain, but the reconstruction and expansion project of on-site substation basically does not encounter this situation. For interval expansion or single equipment replacement, this decoupling scheme is obviously unavailable.

Decoupling according to interval mode is suitable for interval expansion, but for the most common single equipment replacement in substation operation and maintenance, the decoupling range of this scheme includes all equipment in interval into the modification range, which obviously expands the modification and re-verification range of SCD files involved in actual work.

According to the topological relationship structure of primary and secondary equipment, there is no specific technical scheme for single equipment replacement in the secondary system of intelligent substation. This method still remains at the level of logical relationship for decoupling, and its application scope is limited. There is no effective response to the replacement of acquisition and convergence equipment such as switches, fault recording and acquisition units, or network analyzer acquisition units.

3. Research Ideas

The research idea of this paper is to study the SCD precise decoupling method, for the most common single equipment replacement in substation operation and maintenance, which refines the SCD decoupling from logical structure to physical link level, and accurately determines the SCD decoupling range, so as to minimize the modification and re-verification range of SCD files and reduce the change risk brought by SCD modification.

4. Implementation

The ultimate goal of accurate decoupling SCD of intelligent substation for single equipment replacement is to decompose a large and complete SCD file of the whole substation into Related Configuration Description (RCD) file and Unrelated Configuration Description (URCD) file according to the actual requirements of single equipment replacement. Related Configuration Description (RCD) denotes a configuration file describing all devices associated with the device being replaced this time. Unrelated Configuration Description (URCD) refers to a configuration file that describes all devices unrelated to the device being replaced this time. The RCD shall be provided to the undertaking unit of this equipment replacement work, and the staff of the undertaking unit may modify the RCD accordingly based on this work situation. The URCD file is stored in the file decoupling system after being decomposed, and is locked and prohibited from being modified, so that it can be finally merged with RCD and restored to SCD.
The implementation method of SCD precision decoupling in intelligent substation for single equipment replacement includes the following processes:

1. The transportation inspection unit downloads the latest SCD file and SPCD (Substation Physical Configuration Description) file from the SCD management and control system. It is needed to input substation SCD and SPCD files, input the SCD information of the replaced equipment (including VoltageLevel, Bay, LNode, LDevice, and IED), and input the SPCD information of the replaced equipment (including Substation, Region, Bay, Unit, Cubicle, Cable, Core, and Intcore).

2. Based on SPCD file, a physical link network topology centered on the input replacement device unit is constructed, and the device unit with a distance of 1 Cable from the replaced device is formed into a set R.

3. The IED in SCD is mapped to the Unit in SPCD, and the set M of IED mapped to the set R in SCD file is obtained.

4. Using set M of IED in SCD file as decoupling boundary, two decoupled files are obtained. One is a Related Configuration Description (RCD) file, and the other is an Unrelated Configuration Description (URCD) file.

5. The decoupled RCD file is returned to the undertaking unit of equipment replacement for modification, and the URCD file is stored in the file decoupling system and locked to prohibit modification.

6. After receiving the decoupled RCD file, the undertaking unit of equipment replacement modifies, debugs and verifies the file through configuration tools.

7. After the debugging and verification of RCD files are passed, the URCD files generated by this decoupling are merged with the set M as the boundary again to obtain a brand-new SCD file, and the process ends.

The flow chart is shown in Figure 1.
Figure 1. SCD precision decoupling implementation process.

1. **Initialization**
   - Substation Configuration Description (SCD) file
   - SPCD information of the replaced equipment

2. Based on the SPCD file, a physical link network topology centered on the input replacement device Unit is constructed.

3. The device unit with a distance of 1 Cable from the replaced equipment is formed into a set R.

4. The IED in SCD is mapped to the Unit in SPCD, and the set M of IED mapped to the set R in SCD file is obtained.

5. Using set M of IED in SCD file as decoupling boundary, two decoupled files are obtained:
   - RCD
   - URCD

6. Return to the undertaking unit of equipment replacement for modification, debugging and verification.
   - The file is locked to prohibit modification.

7. Merging with the set M as the boundary again, brand-new SCD file is obtained.
5. Conclusion
According to the current research status of SCD file decoupling in intelligent substations, this paper puts forward a precision decoupling method for SCD in intelligent substations with single equipment replacement, which makes SCD decoupling work more detailed and can adapt to various expansion and technical transformation of substations. The decoupling of SCD is refined from logical structure to physical link level, and the decoupling range of SCD is accurately determined, so as to minimize the modification and re-verification range of SCD files and reduce the change risk caused by SCD modification. The method can effectively solve the problems of SCD file control in the links of new construction, operation and maintenance, reconstruction and expansion in intelligent substations, improve the safety of upgrading and modifying SCD files and the efficiency of debugging and acceptance, and effectively optimize the technical management level of intelligent substations.

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References
[1] Gao, Z.Y., Huang, H.F., Xu, H.L. (2018) Application analysis and development discussion of IEC 61850. Power System Protection and Control, 46 (1): 162-169.
[2] Xu, P., Zhang, Z., Ding, X.B. (2016) Research on positioning the influence range of SCD upgrade on secondary circuit. Power System Protection and Control, 44 (18): 140-144.
[3] Wang, S., Xuan, X.H., Lu, C.Y. (2013) Version management method of smart substation configuration file. Power System Automation, 37 (17): 95-98.
[4] Xiong, H.Q., Wan, Y., Gui, X.Z. (2015) Design and implementation of SCD file visual management and analysis decision system for intelligent substation. Power Automation Equipment, 35 (5): 166-171.
[5] Wang, X., Yang, W.L., Wang, F.Y. (2017) Research on SCD management and control system in smart substation. Power Grid and Clean Energy, 33 (2): 68-74.
[6] Zou, Z.Y., Sun, Z.W., Xiu, L.M. (2018) Research on configuration decoupling technology of intelligent substation information model. China Electric Power, 51 (1): 78-82.
[7] Huang, S.B., Ni, Y.M., Zhang, H.D. (2016) Decoupling technology of multi-dimensional information section of smart substation configuration description model. Power System Automation, 40 (22): 15-21.
[8] Zhang, H.D., Huang, S.B., Yang, Q. (2017) Discussion on interval decoupling technology of substation configuration description model for expansion scenario. Power System Automation, 41 (10): 129-134.