Research on Informatization Construction of Digital Substation in Smart Grid

Yue Guo¹, Hui Yuan¹,*, Yan Zhuang¹, Jie Xu¹, Yintie Zhang²

¹State Grid Hubei Electric Power Information and Communication Company, China
²Information Systems Integration Branch, NARI Technology Co., Ltd, China

*Corresponding author email: huiyuan@sgcc.com.cn

Abstract. The thesis is based on the premise of the technological change of digital substations. Four key points in digital substation. On the basis of technology, the "smart" characteristics of smart substations in the smart grid system are proposed and the functional architecture of smart substations is built, which reflects the informatization, digitalization, automation and interaction of smart substations from multiple angles. The current problems in the research and construction of smart substations are put forward, and the resulting research topics are analysed. Aiming at the development trend of intelligence and integration of various equipment in substations, a new system integration architecture design concept is proposed, and the specific architecture and networking methods of smart substations are elaborated.

1. Introduction

With the rapid development of China’s economy, power consumption has also increased sharply, and the construction scale of China’s power grid has also continued to expand. Therefore, the requirements for the operation and maintenance of the power grid are getting higher and higher. The top priority. The digital substation under the smart grid is an important link of power transfer, conversion, transmission and distribution. It plays a safe and stable role in the operation of the power grid. It is the inevitable result of the development of modern technology in the power industry and is the safe operation and maintenance of power in the smart grid environment. Strong safeguard measures [1].

2. Key technologies and characteristics of smart substations

2.1. Key technologies of smart substation

The digital substation not only realizes the effective electrical isolation of the primary and secondary, but also expands the measurement range and accuracy of the digital voltage, current and electrical quantity collected and transmitted by the substation, which enables the substation to effectively share information.

2.1.1. The system layering is more reasonable. The digital substation applies the three-layer functional layered structure proposed by IEC61850, namely the process layer, the bay layer and the station control layer.
2.1.2. *The system structure is more compact.* Compact combination electrical appliances and primary equipment such as intelligent circuit breakers combine a larger number of components and functions and are relatively small in size, which effectively reduces the area occupied by the digital substation and the overall layout is more compact and reasonable.

2.1.3. *System modelling is more standard.* The unified modelling of the primary and secondary equipment of IEC61850 used in the modelling of digital substations. This modelling unified definition of the previous modelling language, equipment model, information model and information exchange model. And the global unified rules are used to name the resources in it, which enables information sharing and seamless connection between the substation and the control centre in a true sense [2].

2.2. *Network structure characteristics of smart substation*

The substation has the functions of current collection, voltage level conversion, power distribution and voltage adjustment in the grid. The continued application of traditional relay protection devices in smart substations will affect the performance of smart circuit breakers and electronic transformers. Therefore, it is necessary to improve the main protection algorithm of the station area to realize all intelligent substations. The intelligent substation adopts advanced communication technology, sensor technology, and computer technology to realize the digital and intelligent management of the power grid. According to the IEC61850 communication protocol, the smart substation is mainly composed of three parts: the station control layer, the bay layer and the process layer, as shown in Figure 1.

![Network structure of smart substation](image)

**Figure 1.** Network structure of smart substation

The main function of the station control layer in Figure 1 is to process the interval layer and the process layer to transmit data in real time, and forward the data to the power dispatching centre, and at the same time convey the adjustment instructions issued by the dispatching centre to the power grid. The bay layer mainly realizes the real-time data collection of the process layer and the communication function between the process layer and the station control layer. The process layer mainly integrates some primary equipment, secondary equipment, and intelligent electronic devices. This part is the foundation of the entire intelligent substation. Smart substations can collect current, voltage and other
parameters through measuring equipment such as electronic transformers and photoelectric transformers. The new measuring equipment improves measurement accuracy and expands the dynamic measurement area of smart substations, laying a foundation for the development of wide-area protection the foundation [3].

3. Informatization construction of digital substation under smart grid

3.1. Digital electrical information collection structure

The structure of digital electrical information collection mainly includes electronic transformer and merging unit. This article will briefly introduce the characteristics of the two in actual operation. Among them, electronic transformers can be divided into several different types according to different classification standards. According to the principle of division, it can be divided into active transformer and passive transformer; according to the application object, it can be divided into current transformer and voltage transformer. Among them, active electronic transformers can be mainly divided into resistance voltage divider transformers and current voltage divider transformers. Current electronic transformers mainly use air-core coils for current induction, that is, the air-core coil is wound in a magnetic skeleton. In the process of selecting the frame, it should be noted that the frame cannot be made of iron to avoid electromagnetic backlash. In addition, this type of transformer has high measurement performance for large currents in practical applications and can play a good protective role. Low-power electronic transformers can accurately measure small currents and have been well used in current measurement systems [4].

In the actual application process, the merging unit needs to connect the electronic transformer. At the same time, in this application mode, there are multiple combined unit signals in the electronic transformer. To improve the application quality of the merging unit, it is necessary to effectively manage the efficiency and operation synchronization in the system. At present, the main method used in the management of operation synchronization is the pulse signal in the GPS positioning system. This management method can ensure the synchronization of internal and external operations. In the process of managing the stability of the system, the PTP mode is mainly used for management, so as to realize the data synchronization in the system. Figure 2 shows the structure of the electronic transformer and the merging unit.

![Figure 2. Structure of electronic transformer and merging unit](image-url)
3.2. Design of main protection algorithm for digital substation

The current differential can judge the fault location according to the parameters of the two ends of the component, remove the fault reliably and quickly, and protect the safety of the component. Therefore, for important equipment such as generators, transformers, high-voltage bus bars, and large motors, differential protection is used as the main protection. This equipment has simple structure, convenient wiring, and easy access to electrical power at both ends. Since there are transformers in the station protection, take the transformer as an example to illustrate the differential protection. Figure 3 shows the simulation system diagram of the station protection.

![Figure 3. Station domain protection simulation system](image)

If a trip signal occurs in the CD1 area and the CD2 area at the same time, the fault point is located at the T transformer; if only the CD1 area has a trip signal, it means that bus 1 has failed; if only the CD2 area has a trip signal, it means that the bus 2 has failed. Since both the CD1 area and the CD2 area contain transformers, it is necessary to consider the impact of the inrush current on the protection. Traditional differential protection uses harmonic braking to prevent the relay protection system from malfunctioning. The calculation formula of the ratio differential protection current is:

\[
I_{2d} = \left| I_{2A} - I_{2C} - aI_{4a} \right|
\]  

(1)

Among them, \(I_{2A}\) is the A-phase current at CB02, A; \(I_{2C}\) is the C-phase current at CB02, A; \(I_{4a}\) is the A-phase secondary current at CB04, A; \(a\) is the transformer ratio. The braking current calculation formula is:

\[
I_{4d} = \left| \frac{I_{2A} - I_{2C} - aI_{4a}}{2} \right|
\]  

(2)

The differential protection action conditions are:
Among them, $I_{\text{offset}}$ is the bias current, A. The ratio-based differential protection algorithm organically combines the substation protection modules and functional modules, which simplifies the repeated setting of protection modules distributed to the transformer, bus 1 and bus 2. The method can use the collected data to judge the fault location and send out an isolation signal to ensure the safety and stability of the system. However, since the protection area contains transformer T, the magnetizing inrush current in the transformer can easily cause the differential protection to malfunction. When a fault occurs inside the transformer, there are more harmonic components in the current, and the differential protection system will block the protection, so there is a certain delay in isolation. Therefore, the protection algorithm needs to be improved to slow down the delay [5].

3.3. Changes and development directions brought by digitalization to the operation of power grids

3.3.1. There will be major changes in substation design. The main control room function will be gradually distributed to the intelligent terminals of the primary equipment in the station. The substation automation system composed of distributed intelligent equipment allows the control equipment such as the control panel and central signal panel of the conventional substation to be eliminated; the adoption of digital equipment makes the boundary between the primary and secondary equipment blurred, measuring, metering, protection, Control will tend to be integrated; with the development of network communication and interactive technology, the local area network inside the substation can be connected to the wide area network, and users can monitor the operation of the substation anywhere; after the integration of digital equipment, independent transformers will gradually be replaced or completely Disappear, so that the number of substation equipment is greatly reduced, and the substation design will be more compact [6].

3.3.2. Digital equipment will make the grid operation safer. Due to the intelligent diagnosis function, the main status is visible, therefore, the reliability of the equipment can be further improved, reducing the occurrence of accidents, thereby improving the reliability of the grid operation; because the abnormal warning can be given in advance, it is more sufficient for the safe operation of the system. The early warning time of the power grid; due to the realization of the digitization of the status information, a more scientific accident protection can be realized, and the power grid "self-healing" can be effectively promoted; because the status is visible, it is helpful to implement a more scientific grid dispatching A more scientific accident plan [7].

3.3.3. Digital equipment will make equipment management more scientific. Since the main status information is expressed in digital form, it provides scientific guidance for the transformation of equipment from regular maintenance to state maintenance and maintenance strategy based on risk assessment, and promotes the realization of state maintenance in the true sense; due to effective digital information Support, avoid blind replacement of equipment, and promote intelligent equipment management. In 2009, the State Grid Corporation of China proposed "measurement digitization, control motorization, status visualization, function integration, and information interaction" as its characteristics, and emphasized the integration of "measurement, control, metering, detection, and protection" integrated design of primary equipment intelligence The construction plan pointed out the development direction of the digitization of primary equipment and made domestic related research into the international leading ranks.

4. Conclusion
With the progress of the times and the development of technology, digital substations are gradually being built more and more perfect, and to a certain extent replace the original traditional substation working mode. Related technologies involve technological innovations at multiple levels. For this
technology in the current development process, further thinking and research on key technologies are needed. In terms of work effectiveness, it has played a certain role in enhancing the reliability of power supply and distribution and improving the development level of the power grid. Digital substations adopt advanced technology to broaden the effective development space of substation functions, play a great role in the safe, economic and stable operation of power grids, and become an important part of the construction of intelligent power systems.

References

[1] Li, H. Q. Zhang, X. F. Dong, W. J. & Zhang, G. Q. Optimum research on cooling and heat transmission and distribution pipe network in smart grid. Journal of Engineering Thermophilic, 35(7) (2014) 1275-1279.

[2] Cavalieri, S. & Realmuto, A. Integration of iec 61850 scl and opc ua to improve interoperability in smart grid environment. Computer standards & interfaces, 47(8) (2016) 77-99.

[3] Li, J. Li, T. & Han, L. Research on the evaluation model of a smart grid development level based on differentiation of development demand. Sustainability, 10(11) (2018) 55-59.

[4] Delfanti, M. Falabretti, D. Fiori, M. & Merlo, M. Smart grid on field application in the italian framework: the a.s.se.m. project. Electric Power Systems Research, 120(3) (2015) 56-69.

[5] Noguera-Oviedo, K. & Aga, D. S. Lessons learned from two decades of research on emerging contaminants in the environment. Journal of Hazardous Materials, 316(8) (2016) 242-251.

[6] Liu, Y. Tong, K. D. Mao, F. & Yang, J. Research on digital production technology for traditional manufacturing enterprises based on industrial internet of things in 5g era. The International Journal of Advanced Manufacturing Technology, 107(3) (2020) 1101-1114.

[7] Miyoshi, K. Tanaka, S. Yokoyama, S., Sanda, M., & Baba, K. Effects of different types of intraoral scanners and scanning ranges on the precision of digital implant impressions in edentulous maxilla: an in vitro study. Clinical Oral Implants Research, 31(1) (2020)59-69.