MODERN PROBLEMS IN THE FIELD OF SMART SUBSTATIONS AND METHODS OF THEIR SOLUTIONS

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The article provides brief information related to the current situation in the field of smart substations and methods for solving them. The author also analyzes the basic functional characteristics associated with the phenomenon of the smart substation itself. Currently, smart substations use the IEC-61850 standard which is based on the International Electrotechnical Commission's (IEC) Technical Committee reference architecture for digitizing information and advanced applications for electric power systems. Although a smart substation offers many improvements in the design, manufacture of equipment, and construction, the smart devices used in this type of substation are expensive and also difficult to maintain because they are dispersed within a single unit. Thus, the optimization of functionality and the integration of devices have become important issues in the development of smart substations. Moreover, there are some problems associated with the activities of smart substations. The article describes both the problems and the solutions proposed to them. The author relies on scientific and methodological studies in the analysis of problems associated with smart substations, such as inaccurate synchronization, problems with cybersecurity, problems in the design and commissioning procedure, and also that IEC-61580 does not have a complete list of requirements for the experience required for personnel who have access to the design and commissioning of smart substations.

Keywords: smart substation, electric power industry, problems of smart substations, information management, digitalization of the power system

Currently, there is discussion of the trend towards universal digitalization of the global space: culture, health, education, finance, construction – all these and other areas have begun to attract IT technologies to their operating paradigm, allowing them to develop more quickly. In general, the world has become digital…and this includes the beginning of the era of digital electricity. Few modern specialists will remember the time when electrical relays were simple electromechanical devices without built-in software, communication interfaces, or multi-functionality. Despite the fact that providing electricity has always been a difficult task, new technologies have complicated this task in the transition from the twentieth century to the twenty-first century, as the industry had to bridge the gap between outdated analog devices and digital technologies which can help improve the operations of electrical substations, which underscores the relevance of the topic.

Today, there is not a single functional component in a modern substation that has not been improved, enriched, or supplemented with some form of embedded digital technology, which would allow it to work better, with higher performance and greater reliability, than ever before. However, the challenge now is to integrate all these elements into a fully digital substation and make it work in a demanding environment, as the demand for electricity increases globally every year, In 2018 alone, there was an increase in global electricity demand by 4%, or 900 TWh [1]. The entire concept of a digital substation is now moving much faster, in terms of industrial use, due to several factors. For example, in most developed countries, the power system operates at close to maximum capacity because consumers need not only more energy, but also better reliability. This is why when a fault occurs, it must be fixed as quickly as possible, and this is where modern digital technology offers so many advantages. On the client side, the digital technology counter is integrated, for example, into the Internet of Things (IOT). In short, an IOT is a network of devices, buildings, vehicles, and virtually any other physical object imaginable, equipped with sensors, connected networks, and computerized digital controllers. And, given the development of these digital technologies, the industrial phenomenon of a digital substation is the next logical development.

Purpose of research

Despite the fact that digital substations allow the electric power system to work much better and with a minimum number of interruptions there are certain problems associated with their operation which should be considered. In addition, each problem should have its own solution, which is what the theoretical component of the work suggests.

Material and methods of research

In this paper, we used scientific and methodological sources of both Russian and English-language nature for a broader understanding of the problems presented in the article. In the course of theoretical research, such research methods as ascend from the abstract to the concrete, analysis and synthesis, as well as induction and deduction, were used.

The results of the study and their discussion

Going directly to the study and analysis of the topic, you need to turn to the work of H. Li and L. Wang, who noted that a digital substation refers to a modern power system with information content, automation capabilities, and interactive characteristics [2].

The entire structure of the analyzed object is divided into three fundamental levels according to IEC 61850 [3]:

1. The first level is the process level;
2. The second level is the level of accession;
3. The third level is the station level.

As for the history of a digital substation, it must be mentioned that the first substation of this type in the world appeared on the basis of the IEC 61850 standard and was commissioned in Switzerland in 2005. It was the Winznauschachen substation, owned by Atel Versorgungs AG, a Swiss distribution network operator, part of Aare-Tessin AG, an independent electricity producer. The Swiss substation was transformed into a substation with a protection and control system based on IEC 61850, which included several digital sensors to improve control and feedback [4].

To implement the digitized substation information, network communication platform and standardized information exchange, the smart substation uses advanced, reliable, integrated, low-carbon and environmentally friendly intelligent equipment for automatic collection, measurement, control, protection, measurement, monitoring, and other basic operations. In addition, digital substations support a number of advanced functions, such as sequence management, intelligent signaling and analysis, comprehensive fault information analysis, intelligent operation order system, source-side maintenance, device status visualization, substation zone management, and others, which allows us to talk about the increasing digitalization of the power system. Moreover, compared to traditional substations, digital substations provide intelligent control of substation equipment using modern data analysis processing methods based on advanced sensor technologies. Integration of primary and secondary equipment is carried out by intelligent conversion of traditional primary equipment with electronic measuring transformers and digital monitoring technologies [2].

Key devices, such as transformers and switches with intelligent components, integrate all operations. In turn, Shageev S.R., Zakirov A.N. and Mullin F.F. noted to the fact that digital substations can help to minimize the level of electricity losses, maintenance costs, and also, if we refer to the experience of Russia, the implementation of digital substations will reduce losses in electric networks of all voltage classes by 25 % [5, p. 129].

Despite the fact that the system of digital substations is developing favorably, there are certain problems that partially offset the functional characteristics of such equipment, which is not a favorable development. A. Anoshin and A. Golovin, in their work, cited several problems related to the operation of digital substations, one of which is the design and commissioning procedure [6]. The authors note that if the digital protocol has been implemented, the network setup procedure will be completely different, which requires a new section in the project documentation, or even changes to the project documentation itself. All such documentation should include the design of the project itself, electrical diagrams of primary and secondary equipment, cable logs, etc., which leads to the conclusion that the documentation itself can be more than 1 thousand pages [paper format], even if it is a small substation with connections in the amount of 20 units. In this regard, to avoid problems, when developing digital substation projects, it is necessary to use specialized CAD systems with the ability to document all communications, which will greatly facilitate access to one or another part of the documentation, since everything will be in an electronically ordered form.

Teslenok A.I. reviews another problem, which consists in the content of some parts of the IEC-61850 standard – a standard whose main focus is the description of data flow formats, types of information, rules for describing elements of an energy object, etc. The author emphasizes that despite the fact that the standard has more than 20 chapters, which systematically provide information on the main parameters and thematic categories related to the operation of a digital substation, nevertheless, the standard is new and complex, adding also that the proper functioning of a digital substation depends on the design and commissioning staff, since to ensure operability, all equipment must not only be installed, but also configured so that there are no problems on the process bus. In this regard, he suggests more carefully prescribing requirements for the experience of personnel, which will determine how well the equipment of the digital substation will be debugged [3].

K. Wang and W. Li also analyzed several problems related to digital substation information protection in their work, noting that the relay protection of a digital substation faces very

high requirements in the power system in real time. Since the digital converter operates on a digital sample, it will be affected by the switch, for example, the receiver reception time increases, and other factors that affect data transmission. In this process, queuing in the switch and forwarding in it are one of the key factors for the temporary error of the digital transformer [7]. Therefore, the relevant operators need to develop a scientific and reasonable sampling scheme, before calculating possible errors, and then work on their selection. The calculation and sampling results should be organically combined to minimize errors and delays which contribute to improving the performance of real-time relay protection in a smart substation. Indeed, there are no problems with time synchronization in transformer equipment used in a traditional substation, so the protection of the power system in this aspect is relatively insufficient. A digital substation uses a digital method of collecting information, so its power distribution protection must be synchronously linked to time. Synchronization and reliability of digital substation relay protection can be guaranteed by the following methods:

First, it is the detection and practice of differential line protection during this period, because at the same time, the detection device and the circuit differential protection device must collect the amplitude and phase signal from two different substations. In addition to the data on the sideline, it also includes certain contralateral data – therefore, it is necessary to ensure proper and synchronous protection of the power system.

Second, the implementation of over-voltage and over-current protection. Over-voltage and over-current protection is very simple – you do not need to maintain a fully synchronous time, so only the appropriate operators must enter the correct amplitude into the relay protection system of a digital substation, which will help to eliminate problems associated with digital synchronization [7].

Third, the authors suggest that the use of an intelligent dual device in the relay protection system of a digital substation can implement a centralized backup protection configuration, which is a very effective measure to improve the relay protection of the interval level and the reliability of the system. The backup protection system can provide effective protection for the switch, backup equipment, adjacent terminal buses, and smart substation lines. In addition, it can accurately assess various problems and malfunctions in the power system and provide timely, correct and effective solutions to problems. In addition, within the controlled range of technical means, the voltage level of the digital substation can be centrally configured to allow it to adapt to the actual operation of the power system, which, again, will avoid problems with synchronization [7].

Given that the digital substation operates using IT technologies, cybersecurity can be a significant problem. For example, J. Cardenas, A.L. De Vinaspre, R. Argandona C. De Arriba noted in their work that the digital substation system should be protected from the point of view of cybersecurity. The high data rates of technology bus traffic and the requirement for very high availability of this data create problems for well-known cybersecurity vulnerabilities such as intrusion [hacking], detection, or encryption. If cybersecurity issues are not taken into account, they can either slow down the decision regarding the operation of the digital substation, causing it to be supplemented later for compliance, or they can create additional costs and efforts for the user during the deployment and startup of the system. The optimal solution is to develop an architecture that by its nature eliminates cybersecurity threats [8]. The architecture model was proposed by a team of authors led by Y. Yang. For example, they proposed a fuzzy testing method for detecting unauthorized embedded intelligent electronic devices based on the IEC-61850 standard. They also proposed a new intrusion detection system that combines physical knowledge, protocol specifications, and logical behavior to provide a comprehensive and effective solution that can mitigate various cyber attacks. The proposed approach includes access control detection, protocol whitelisting, model-based detection, and multi-parameter detection [specifically developed for each digital substation solution], which can help in situations where unauthorized access is detected that could hypothetically disable a digital substation [9].

Realizing the information imperfection of a digital substation and its vulnerability to cybersecurity problems, J. Cai, Y. Zheng and Z. Zhou found that since the volume of data transmission at a digital substation is larger, and various systems are directly related to the correct and stable operation of the substation, even the entire power system, cybersecurity, as a concept, becomes extremely important. They identified problems such as incorrect network and equipment configuration during substation testing, computer viruses, and network attacks, suggesting the following ways to minimize problems: using an Intranet system instead of the Internet to guarantee physical isolation

from it, to minimize the likelihood of network attacks. It is also suggested to install a firewall to prevent external unauthorized access and antivirus software to prevent virus infection. Moreover, the authors recommend configuring VLAN and ARP binding to prevent internal unauthorized access [10].

Conclusion

Thus, we can conclude that the modern power supply system is undergoing fundamental changes with the introduction of digital substation technology. Installing smart meters for end users, deploying distributed renewable energy generation, and interconnecting operating and information systems require new solutions that can intelligently monitor and manage infrastructure. In general, the digital substation is aimed at improving the operational efficiency of operators by increasing the flow of information and automation in order to make faster decisions, which reduces operating costs, as well as increases the reliability of the entire system. Of course, to achieve significant functionality and reliability, you need to face some problems, such as working synchronization, cybersecurity, and problems with data transmission systems, but there are already significant achievements in terms of solving them, so you need to be prepared for the fact that when working with a digital substation, there will be problems that need to be quickly and efficiently resolved.

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