Some issues and implementation problems for digital substations in Mongolia

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***Abstract*— Digital substations, based on technologies like IEC 61850, are at the forefront of modern power grid advancements, offering enhanced automation, communication, and control capabilities. Mongolia's Ministry of Energy initiated efforts to transition to digital substations as part of their "Smart Energy" project. However, the implementation of these advanced systems in Mongolia is not without challenges. This paper explores key implementation problems encountered during the transition to a digital substation in Mongolia, with a focus on IEC 61850 and IEC 60870 protocols, time synchronization, fiber optic devices, intelligent devices, telemechanic, SCADA, and Wide-Area Monitoring Systems (WAMS). The paper aims to identify these challenges and offer potential solutions to ensure the successful deployment and operation of digital substations in Mongolia.**

Keywords*— *IEC61850, IEC60870, time synchronization, fiber optic device, intelligent device, telemechanic, SCADA, WAMS.

I. Introduction

Due to the non-stop and increasing consumption of electricity, the need to deliver more reliable and quality energy to consumers is increasing day by day. In this requirement, the quality of the model increases the proper use and operation of electrical equipment introduction of microprocessor-based relay protection system, telemechanic, control, and automation [6, 7].

Globally, projects of power and energy are focused on digital substations. International engineers believe that the digital substation has many advantages [2], [5], [12], [14, 15]. One of the significant advantages of digital substation is the elimination of electrical connections between high-voltage equipment and protection and control systems. This reduction in electrical connection points minimized the risk of worker exposure to electrical current. By lowering the potential risks, digital substations can contribute to reducing labor costs associated with hazardous work environments [8-11]. However, this digital substation project hasn't yet been implemented in Mongolia. For Mongolia, digital substation research has been explored several times before. However, this research was not focused on digital substations based on remote control substations.

There is only one remote-controlled substation in Mongolia. As mentioned above, a digital substation has many advantages, so we need to implement this project in Mongolia. We divide the reasons that have not been implemented into two general groups. Firstly, we don't have enough experience in implementing digital substations, due to engineers usually work on conventional substations. Secondly, the project is based on capital-intensive, and we need a lot of funding to convert a simple substation into a digital substation.

II. The current state of the Mongolian electric systems, its relay protection, and automation

Mongolia has a strongly continental climate, with four fluctuations of temperatures, low precipitation, and marked regional variations depending on latitude and altitude. In summer, depending on the region, it heats up to 30-40^{0}C and it rains a lot. In winter, it gets cold to minus 35-40^{0}C and it snows a lot. It is related to global warming. Electrical circuit equipment is equipped according to this climate.

Mongolia has 2024 km of 220 kV, 5500.7km of 110km, 10167.5km of 35kV, 4357km of 15-20kV, 15250.1km of 6-10kV and 20899.1km of 0.22-0.4kV power transmission and distribution lines. Total is 58188.4km. There are 8709 substations in total [1], [13].

Mongolia's energy relay protection and automated system was started in 1916 with a 20kW power generator in the capital. It was based on an electromechanical base. During this century, the electromechanical base evolved into the microprocessor-based. Now, the existing substations are equipped with modern equipment.

SF6 and oil circuit breakers are used in combination. Existing conventional substations have been electromagnetic current and voltage transformers, connecting them to intelligent relay protection and automation equipment. Thus, many power cables and conduits are used for primary and secondary circuits. The manufacturers of smart devices are usually “Schweitzer Engineering Laboratories”, “Siemens”, “Schneider” and “ABB Group”.

In Mongolian conditions, we calculate the value of relay protection after calculating the short-circuit equation. The PowerFactory-digSilent licensed software is used for the Mongolian energy system to calculate the short circuit at each point of the substation. A microprocessor-based relay instruction manual is used for the calculation of substation's protection. And the characteristics of the relay's function are adjusted correctly. We use differential, gas, overcurrent, overload, and ground protection on transformers, differential protection of buses, and arc protection in closed switchgear.

The length of high-voltage overhead lines varies greatly from the effective value. For example, the document states that 110kV overhead lines are most efficient at 50-150km, but in our country, this length is doubled. Thus, the resistance of the length of the lines is relatively high in the short-circuit calculation.

In Mongolia, the maximum short-circuit value is 2-3.5kA at 110kV, and this value is used for relay protection and automation layout calculations.

Relay protection and automation devices are the latest models of this manufacturer, and these models support IEC61850 standard protocols [3], [4], [14, 15]. But we can't use this standard. When connecting between a measuring transformer and an intelligent device, a merging unit is used at a digital substation, but in our country, the direct analog input is transmitted to the smart device without the merging unit.

For this work, transformer protection calculations were made on the SEL-487E relay with the SEL TiDL merging unit and fiber optic measuring transformers. The manufacturer of fiber optic measuring transformers is "Prophetic". We used ANSI 87 differential protection as our primary protection for the transformer.

First, the primary current of the transformer is found at each voltage level.

$$TAP = \frac{MVA \cdot 1000 \cdot C}{\sqrt{3} \cdot VTERM \cdot CTR} \quad (1)$$

TAP_S=0.669, TAP_T=0.857 and TAP_U=0.84 in 110/35/10kV transformer with 40MVA power by this formula. The current transformers are directly star-connected, so there is a need for compensation. Because the connection of the power transformer is Y/Y/D. It was solved $TSCTS_s$=5, $TSTS_S$=5, $TSCTS_U$=0. And formula for finding the minimum operating value of the differential element:

$$087P \geq \frac{0.02 \cdot I_{nom}}{TAP_{MAX}} \quad (2)$$

Considering Inom=0.84, the answer to the above equation was decided as 1. Also when finding a differential element that will work without restriction:

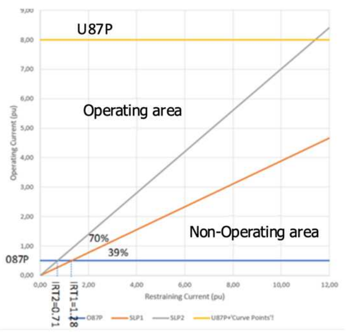
$$U87P < \frac{31 \cdot I_{HOM}}{TAP_{MAX}} \quad (3)$$

The answer is solved U87P=31. But we got 8 as suggested in the relay documentation. Then the characteristics of the relay were established, the formula of which is:

$$I_{dmax} = (1 + e) - \frac{1-e}{1+a} = \frac{(2 \cdot e) + a + (e \cdot a)}{1+a} \quad (4)$$

When making this calculation, the error of the current transformer is 10 percent. The transformer's tap changer error was considered to be 16 percent.

FIGURE I. CHARACTERISTICS OF DIFFERENTIAL PROTECTION

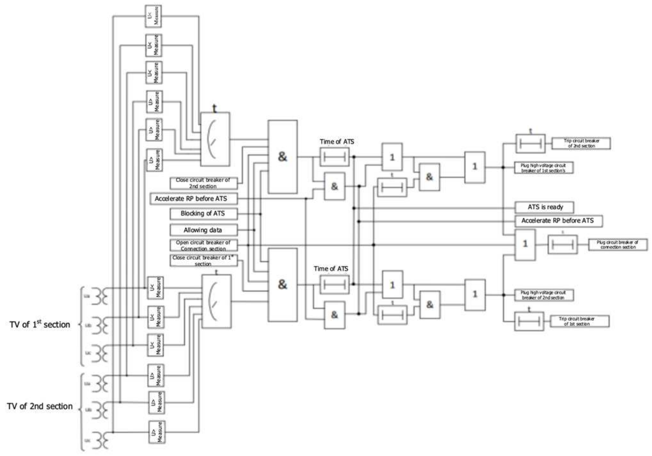


In the same way, based on the instruction manual used by the bus and other equipment, which appropriate method is used in Mongolia. The digital substation relay protection architecture has been developed for the Mongolian substation.

Within the implementation of the digital substation in Mongolia, a digital substation with 2 transformers of 110/35/10kV needed a total of 8 merging units. It includes 6 transformer merging units, 2 units for 10kV arc protection for the bus, and 2 units for differential protection for the bus. Overhead line protection isn't included here.

ATS, the main automation in the substation, is performed using ABB or SEL brand equipment. SEL-487E was used to create the ATS in that implementation. This was accomplished by developing a logic circuit using an Undervoltage protection function (ANSI code is 27) with some relay's function. An interactive scheme has been developed for the digital substation's 10kV section in Mongolia.

FIGURE II. LOGIC SCHEME OF ATS



Analog and digital signals are sent to the control room via smart devices. And we can see circuit breaker status information on the display of the substation's control room.

III. PENETRATION OF SCADA, WAMS INTO THE SYSTEM AND FEATURES

Conventional substation of Mongolia has SCADA and WAMS, but there are only electrical meter data is taken. That is based on IEC60870 and IEEE1344 standards, and we can use it very well. Refer to "Figure III" display of SCADA in the control room of the "National Electricity Transmission Network" company.

To create a new energy management system, WAMS has been used since 2019 to measure the vector values of the system's major steady-state and transition process parameters in the large nodes of the Mongolian energy system.

The structure of the WAMS system in Mongolia is connected to the latest intelligent and time synchronization bus via TCP/IP network devices using station PDCs. In addition, the internal network is protected by a firewall, which transmits information to the control center [5]. Initially, 10 substations were connected, now 41 required facilities are connected. The usage of hardware is ELPROS WAProcter. Display of Mongolian SCADA.

FIGURE III. SCADA DISPLAY OF "TELEVISION" SUBSTATION

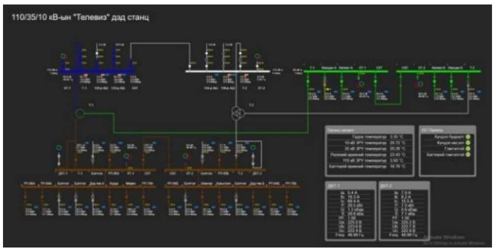
We use this system for the following measurements. It is mentioned below:

1) Control the phase angle difference in real-time
2) Detection of low-frequency fluctuations
3) Detection of voltage instability
4) Detection of over/underrated values
5) Real-time data exchange with other energy systems and SCADA system
6) Improve mode calculator (ongoing)
7) Improve system dynamic modeling (ongoing)
8) Used for post-disaster analysis.

The "Electrical Main Transmission System Company of Mongolia" plans to connect 23 220kV high voltage lines, 82 110kV lines, 15 power plants, and 4 transformers to a total of 124 points in 31 locations with WAMS [5].

There is only one substation with remote control in Mongolia, it is the "Television 110/35/10 kV" substation. We can see the state of the circuit breaker and can trip and plug from the central control room. It is not a digital substation. It was solved by connecting very long control cables from the necessary points of the substation to the devices in the control room.

FIGURE IV. SCADA DISPLAY OF TELEVISION SUBSTATION



SCADA system solution for that substation:

A. Software:

For the remote-control automation software, Zenon Energy Edition control automation software from COPA DATA, Austria was selected with unlimited TAG and unlimited license.

B. Hardware:

The remote-control automation system server is selected with high performance, server capacity, satellite synchronous time system, and industrial-purpose processor for further expansion.

C. Communication information:

To improve the reliability of the network, a fiber optic RING network was created by creating an infrastructure between the points "Television", "Nairamdal", "Songino" and outdoor switchgear using network-managed switches.

D. Network connection

The SATEC-PM130 device connected to the network via RS485 connection connects to the SEL-AXION device via the DNP3 protocol. SEL relay protection devices are connected to the network via an ETHERNET connection, SEL-AXION devices connect to the SEL-3354 computer via SEL protocol, and ZENON EE software collects and transmits data. As you can see from the above, the protocol exchange between different types of systems (WAMS and SCADA) is solved using a protocol converter. As to whether it's good enough to run a station. Because this system isn't good enough compared to the digital substation system.

We need the following to create a remote-controlled digital substation:

a) Fiber optic cables

Mongolian substations use a lot of power cables. Therefore, when making a digital substation, we must use a fiber optic cable. So, we can expand our database and collect more information.

b) Fiber optic measuring transformers

When converting to a digital substation, the voltage and current transformers must be converted first. This device isn't based on the electromagnetic principle, it will be more reliable and more accurate.

c) Merging units and relay protection, automation

A merging unit is needed to make the primary circuit information more organized. Information of the primary circuit is transferred by the digital signal from current and voltage transformers to relay protection and automation devices through the merging unit. We can change the secondary circuit by having a new process bus. Devices used in relay protection and automation systems that support IEC61850 should use its functionality. If the standard is not supported, it is necessary to replace it with another device.

E. Time synchronization

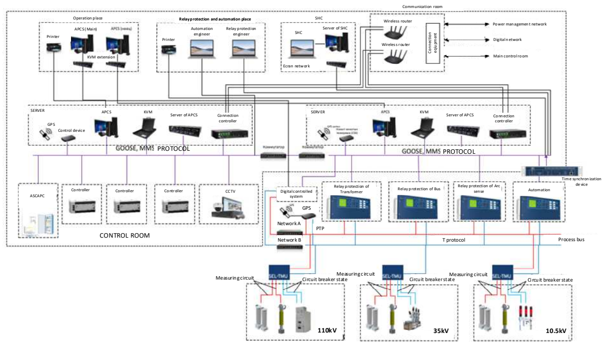
By using time synchronization for our energy system, we can get our data more realistic and true.

F. IEC61850 Protocols

We use Modbus, IEC60870, and SEL protocols. These protocols aren't good enough to use in digital substations. We need to use the IEC61850 standards for digital substations in our system. Since Mongolian substations usually have a voltage level of 110/35/10kV, it is suitable to use the IEC61850-9-2LE protocol in closed distribution facilities and IEC61850 MMS and GOOSE protocols between smart devices and equipment [3].

By using these protocols, we will be able to provide relay protection information, use of merging units, 110kV and above transformer measurements, 6-35kV transformer measurements, logic keys, and GOOSE blocking and self-diagnosis of open distribution switchgear. The use of protocols and the SCADA architecture of the digital substation in Mongolia were also designed.

FIGURE V. ARCHITECTURE OF DIGITAL SUBSTATION



First, Goose, SV, and MMS protocols must be properly used by the substation at each level. We need to use IEC-

61850 protocols. And defines the data information to be transmitted to the system via the MMS protocol [4].

TABLE 1. Data information

Data section	Report type	Buffering time	Purpose
APCS's state	No buffer	1000 bufTm	-Change the data -Explore the characteristics -For general purposes -Collect information -Settings edit -Report timestamps
Relay protection's state	Buffer	100 bufTm	-Change the data -Explore the characteristics -Enter with ID -Report timestamps
APCS's measurement	Buffer	500 bufTm	-Change the data -Explore the characteristics -For general purposes -Collect information -Settings edit -Report timestamps
Relay protection's measurement	No buffer	500 bufTm	-Change the data -Explore the characteristics -For general purposes -Collect information -Settings edit -Report timestamps

G. Devices for digital substation

Also, the digital substation must utilize the various devices required for its use. There are include the physical connection to IEDs, the OSI Model for computer communications, network topologies, etc. By using the necessary devices in the network, we can transmit information to the local network and the central control network, and we have a great opportunity to exchange information with each other. For example, Information and measurement of APCS and relay protection. More specifically, by implementing a digital substation, we will be able to remotely modify data, explore properties, modify, general purpose, collect data, edit configuration, report timestamps, and other purposes. The software of the digital substation is solved by "SEL" technology in Mongolia.

IV. IMPLEMENTATION ISSUES

An incomplete conventional substation shows us the great risk in Mongolia due to global warming and massive flooding. We know that all work in the electrical industry has a lot of risks. Due to the wide variety of existing control systems, there are many problems with inter-protocol data exchange. And this can't provide cyber security. Differences in protocols do not maintain good time synchronization. By using IEC61850 standard protocols, we will benefit more in terms of better speed and a wider range of data. We need to exchange experience with qualified engineers on international digital substations. Our point is mostly to convert existing substations into digital substations. Therefore, from which substation will electricity be supplied to the consumers of that substation? The problem will appear. But we can work it out. We can solve this when we exchange experience with experienced engineers to convert our conventional substation into a digital substation according to the country's characteristics.

V. CONCLUSION

Cybersecurity and systemic inadequacies exist in Mongolia's energy system. Therefore, digital substation solutions are highly needed to compensate for the lack of application of SCADA and WAMS systems. In this article, it is intended to develop a digital substation on the existing station in Mongolia. Because digital substations have many positive effects on the environment, health, and safety work. Fiber networks require less energy, they also generate less heat and require less cooling than copper cable networks. And less cooling means even fewer carbon emissions.

When building a digital substation in Mongolia, there is a problem of changing and testing the entire secondary circuit. During the development of the digital substation, the general architectures were established sequentially. To become a country with digital substations, Mongolia must solve the new experience of engineers and system changes. It is quite possible to create a digital substation in Mongolia.

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