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Reliability Supporting of Relay Protection for 110kV Transmission Line with High-load and Short-distance in a Ring Network

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***Abstract*—As part of its mandate to meet the increasing electricity demands of Ulaanbaatar while ensuring uninterrupted, reliable, and high-quality energy supply, the National Power Transmission Grid (NPTG) takes on the responsibility of expanding, revamping, and maintaining power transmission infrastructure, including lines, substations, and equipment. In order to enhance overall reliability, this expansion necessitates seamless integration of old and new systems. Implementing advanced technical solutions becomes imperative in order to meet these challenges. The city center, newly developed residential areas, and major consumers have been strategically located in close proximity to new transmission and distribution substations. As a result of 110 kV high-load circuit networks connecting these substations, a critical issue relates to the selectivity of short-distance lines. A relay protection solution has been explored for 110 kV high-load short-distance lines in this research, and its impact on the dynamic stability of the power system has been evaluated.**

Keywords—short circuits, stability, fault, directional comparison blocking protection, tripping

I. INTRODUCTION

Ulaanbaatar's electricity consumption increased by 40.8% or 350-400 MW compared to 2010. The number of households has increased by 80-100 thousand households [4]. Currently, one 220 kV has been built in the city of Ulaanbaatar, two substations have been greatly expanded, 18 new 110 kV substations have been installed, and the installed capacity of the transmission network has increased by 1000 MW/ transfer to one circuit/ [6], [10, 11]. Depending on their location, these substations must work with their special scheme, and it is necessary to introduce appropriate relay protection and automation (RPA)solutions for them. Five main substations connected to the 110 kV "Baga Toirog" network of Ulaanbaatar city (IHB-4, Dornod-2, Ulaanbaatar, Tuul, IHB-3) are connected by 60 km of high-voltage line (HVL) and the installed load is 350 MW. The 110 kV short-distance lines 103, 104, 105, 106, 107, 108, 109, 110, 111, and 112, which connect these substations, had to receive high load. High-load and short-distance line transmission conditions make it difficult to ensure selectivity and reliable operation of the main protection. Therefore, it is intended to solve this complicated situation and study the optimal solution to ensure the reliable operation of relay protection.

II. CURRENT LOADING STATUS OF ULANNBAATAR'S SUBSTATIONS

A. Loading status

The installed capacity of the Ulaanbaatar branch of the NPTG is 2475 MVA, 8 districts of the city center, conducts electricity transmission operations in 16 sub-districts of the province of the central region, provides operation, maintenance, and reliable operation of 1543,898 km of 220 and 110 kV high-voltage transmission lines (by transfer to one circuit), 34 substations [6], [10], [11]. Ulaanbaatar's population is growing, and construction and production are increasing, which has an impact on many things, such as lack of electricity generators, reliable operation, technical resources, technology, and personnel demand; a comparison of the total load of Ulaanbaatar can be seen from 2010-2021 (Figure 1). To provide increased electricity consumption, it was necessary to add substations and a high-voltage line [3], [4], [9].

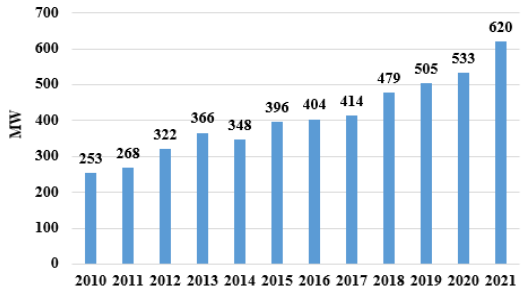

Fig. 1. Load graph of Ulaanbaatar city (2010-2021)

1450 MW or 75-80% of the total load of Mongolia's Power System (MPS) is accounted for by the Central Region Integrated System (CRIS). On the other hand, 600-650 MW or 40-45% of the total load of CRIS is occupied by the load of the city of Ulaanbaatar [2]. Due to the increasing load on Ulaanbaatar city, the Shonkhor substation with an installed capacity of 110/10 kV 2x40 MVA was put into operation in the 110 kV "Baga Toirog" network (Figure 2).

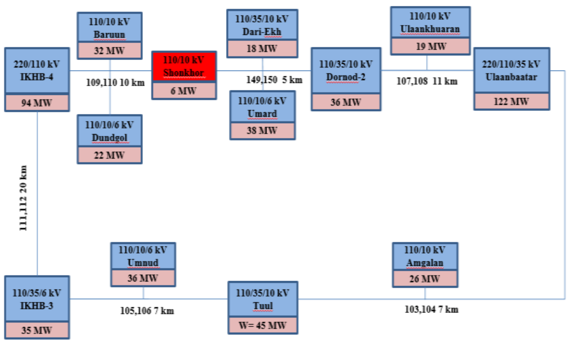

Fig. 2. Loads state of substations connected to the 110 kV "Baga Toirog" network [4]

50-60% of the total load of 620 MW of 34 substations in Ulaanbaatar is taken by the substations connected to the 110 kV "Baga Toirog" network [4]. In other words, the majority of the total load in Ulaanbaatar is the load in the central part of the city. Regarding the voltage level of the transmission network, it can be seen that the 110 kV side receives more load, and the autotransformers of the 220/110 kV IKHB-4 and 220/110/35 kV Ulaanbaatar substations play a special role in power distribution (Figure 3).

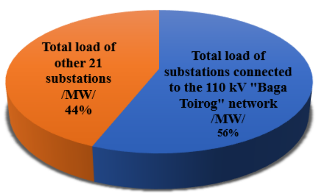

Fig. 3. The load volume of the substations connected to the 110kV "Baga Toirog" network of Ulaanbaatar

The advantages of connecting the 110/10 kV Shonkhor substation to the 110 kV "Baga Toirog" network are as follows:

- From the HVL-109 and HVL-110 connected between the 220/110 kV IKHB-4 substation and the 110/35/10 kV Dornod-2 substation, the 110 kV Dundgol, Umard, Baruun, Dar-Ekh 4 substations with high load were connected. For the maintenance and repair of HVL-109 and HVL-110, it is necessary to transfer the load of the above 4 110 kV substations to one of the lines. But in most cases, the load does not fit on one line, so some restrictions are required. However, the 110/10 kV Shonkhor substation HVL-109 and HVL-110 lines were split and connected, and load switching was solved.
- When 110 kV HVL-109, 110, 149, and 150 are switched, the reliability of the "Baga Toirog" network is preserved, the number of switchings related to mode switching is reduced, and the operational time is reduced.
- The selectivity of the above 2 lines has increased, and the number of consumers experiencing power outages has decreased.

The length of the HVL-109, 110 that connects the 110 kV ‘Baga Toirog’ network has decreased, the short circuit current has increased, and some difficulties have arisen to ensure the reliable operation of automatic relay protection [2]. In other words, the main protection is directional high-speed logic protection (DHSLP), and the allowable value is the 3rd zone of distance protection (DP-III) and the 4th zone of earth current protection (ECP-IV) pushing each other's approval signal. 110 kV lines and substations with a length of 5 km and an average load of 90-100 MW, and the calculation of automatic relay protection's layout on the data of substations, which work in exchange, do not provide selectivity.

B. Short circuit calculation of the network

The short circuit currents of the 6 and 10 kV sides of the 110 kV substations connected from the above line exceeded the 110 kV zones of DP-III and DP-II (Table 1). It has a very small difference from the short-circuit current on the 110 kV line, the 6, 10 kV busbar and the 3-phase short-circuit current values close to it (Table 2). Therefore, it has become difficult to calculate the automatic relay protection layout of 110 kV HVL. The results of the calculation of the substations connected to the 110 kV 'Baga Toirog' network, calculated in the Digsilent PowerFactor program, are shown (Tables 2).

TABLE I. CALCULATION OF THE LOAD AND RESISTANCE OF THE LINES THAT FROM THE 110KV “BAGA TOIROG” [1]

	Substation	**Line’ s mark**	**Line’ s name**	**Line’ s length /km/**	**Transmitted power /MW/**	**Line’ s resistance /ohm/**
Peak load after commissioning of the 110/10 kV Shonkhor substation /18 hours/						
1	220/110kV IKHB-4	ACMCC-295/40	109	10	91	0.98
			110	10	93	
2	110/10kV Shonkhor	ACMCC-295/40	109	10	66	0.98
			110	10	65	
3	110/10kV Shonkhor	ACMCC-295/40	149	5	64	0.49
			150	5	63	
4	220/110/35kV Ulaanbaatar	ACMCC-295/40	107	11	8	1.078
			108	11	9	
5	220/110/35kV Ulaanbaatar	AC-240/39	103	7	5	0.85
			104	7	8	

7	110/35/6kV IKHB-3	AC-240/39	105	7	76	0.85
			106	7	77	
8	110/35/6kV IKHB-4	AC-240/39	111	20	55	2.4
			112	20	55	

When a 3-phase short circuit occurs on the 6, 10 kV busbar of the substations connected to the 110 kV "Baga Toirog" network, the short circuit current that runs on the high side or the 110 kV side is calculated (Table 2). The last column of Table II indicates the “Fault current of the 110 kV bus of substation IKHB-4”, with which the important bus of power plant No. 4 is connected.

TABLE II. RESULTS OF THE SHORT-CIRCIUT CALCULATION

	Substation' s name	***110 kV busbar fault current when a 3-phase short circuit occurs on the low-side busbar of a substation***	**Short-circuit currents flowing through 110 kV HVLs during a 3-phase short-circuit on the low-side busbar of a substation**								**Fault current of 110 kV' s busbar of IKHB-4 substation [kA]**
			IKHB-4 substation [kA]		***Shonkhor substation [kA]***		***Baruun substation [kA]***		***Dornod-2 substation [kA]***		
			HVL-109	**HVL-110**	**HVL-109**	**HVL-110**	**HVL-109**	**HVL-110**	**HVL-149**	**HVL-150**	
1	Baruun	**0.997**	**0,543**	**0,567**	0,294	0,294					**0,643**
2	Shonkhor	**0.993**					0,483	0,483			**0,632**
3	Umard	**0.944**			**0,720**	0,275					**0,632**
4	Dari-Ekh	**0.630**							0,241	0,124	**0,602**

According to the calculations above, when a 3-phase short circuit occurs at any point of the substations connected to the 110 kV "Baga Toirog" network in Ulaanbaatar, the current is close to the maximum current flowing on the 110 kV system bus of the 220/110 kV IKHB-4 substation. A running indicator indicates that the length of these lines is very short. This is a major factor in the loss of stability of system operation.

III. RELAY PROTECTION OF THE 110KV “BAGA TOIROG” NETWORK

When the 110/10kV Shonkhor substation is connected to the "Baga Toirog" network, a solution was made to keep the 110 kV high voltage lines and the directional comparison blocking protection (DCBP) and to add differential current protection (Table 3). Depending on the number of substations that are fed from that 110 kV line, differential protections are selected along the 3 and 4 terminals for each line.

They are characterized by the use of independent fiber optic networks with each other, along with a synchronized time system. Furthermore, the concept of double main protection and double backup protection was created on one transmission line. The principle of operation of main and backup protections, the devices to be used, the channelization of data transmission, and the connection of secondary circuits are independent working solutions. In doing so, all the working conditions of traditional main and backup protection have been met.

With the introduction of this solution, the reliability of relay protection has been improved two times, independence has arisen, and microprocessor protections can monitor each other. These ideas can be implemented in all types of modern microprocessor devices and are the main basis for studying the importance of how they affect the stability of today's energy systems.

TABLE III. RELAY PROTECTION OF 110 KV “BAGA TOIROG” NETWORK LINES

	Line' s name	**Protection**	**Mark**	**Protection working status**	**New double protection**
1	HVL-109,110	Main Protection	SEL-411L	Line current differential protection	**Protection of 3 and 4 terminals protection**
		Main Protection	SEL-311C	Directional high-speed logic protection	
2	HHL-149,150	Main Protection	SEL-411L	Line current differential protection	**4 terminals protection**
		Main Protection	SEL-311C	Directional high-speed logic protection	
3	HVL-107,108	Main Protection	SEL-311L	Line current differential protection	**3 terminals protection**
		Main Protection	SEL-311C	Directional high-speed logic protection	
4	HVL-103,104	Main Protection	SEL-311L	Line current differential protection	**87L relay problem-solving**
		Main Protection	SEL-311C	Directional compare blocking protection	
5	HVL-105,106	Main Protection	SEL-311L	Line current differential protection	**Relay problem solving for Umnud substation 87L relay problem solving**
		Main Protection	SEL-311C	Directional compare blocking protection	
6	HVL-111,112	Main Protection	SEL-311L	Line current differential protection	**2 terminals protection**
		Main Protection	SEL-311C	Directional compare blocking protection	

A. Directional comparison blocking protection

The main protection relay senses the reverse and zero sequence currents and voltages (I2, I0, U2, U0) generated during the abnormal mode on the line, and by giving a "push" signal to the high-frequency post, the outputs of the relays (blocking signal-receiver) are activated, and a blocking signal is given to the operation circuit of the main protection. When the short circuit (SC) formed on the line reaches the protective device in the direction of the current, the relays of the two sides of the line give a "stop" signal to the two sides of the relays, and the relays take their blocking signals at the output and operate the circuit breaker to cut off line 2. is broken on the side, and the damaged line is separated from the circle system (Fig. 4). High-frequency posts exchange information with each other based on high-frequency waves using one of the phase wires of the HVL to transmit high-frequency modulated signals. This solution with high-frequency blocking protection has been used since 2009 when it was transferred from a mechanical relay protection device to a microprocessor relay protection device in combination with the PZVU-E post. This protection is fully available when replaced by a reserve busbar.

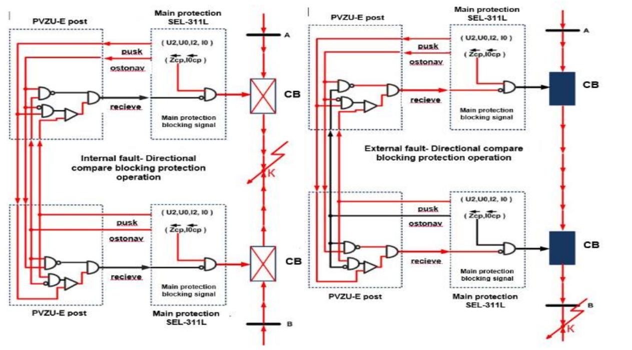

Fig. 4. The Principle functioning of Directional Comparison Blocking Protection

B. *Line current differential protection*

According to Equation (1), differential protection only compares the direction and angle of the current and works by its difference. SEL-311L or SEL-411L exchanges time-synchronized Ia, Ib, and Ic samples between two, three, or four-line terminals. Each relay calculates 3I2 and 3I0 for all line terminals. Current differential elements 87LA, 87LB, 87LC, 87L2, and 87LG in each relay compare Ia, Ib, Ic, 3I2, and 3I0 (IG) from each line terminal. All relays perform identical line current differential calculations in a peer-to-peer architecture to avoid transfer trip delays. [8].

$$I_{DIFF} = |\overline{I_1} + \overline{I_2} + \cdots \overline{I_N}| \quad (1)$$

$$\bar{\boldsymbol{k}} = \frac{\overline{\boldsymbol{I_R}}}{\overline{\boldsymbol{I_L}}}$$

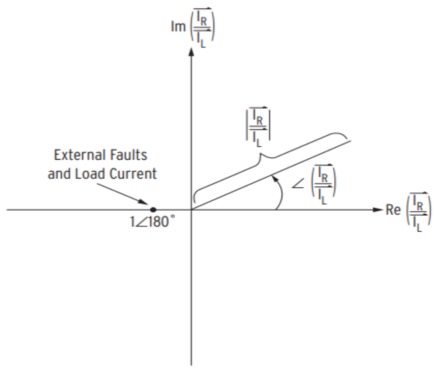

Fig. 5. The Alpha Plane Represents Complex Ratio of Remote-to-Local Currents

Figure 5 illustrates how the phase and negative-sequence differential elements operate for a two-terminal line. Three-terminal cases are described later, but all two-terminal discussions apply to three-terminal cases. Figure 5 shows the alpha plane, which represents the complex phasor or ratio of remote (IR) to local (IL) currents. There is a separate alpha plane for every current (phase, negative-sequence, zero-sequence, etc.).

Arbitrarily assign the current flowing into the protected line to have zero angle and the current flowing out of the protected line to have 180 degrees. Five amps of load current flowing from the local to the remote relay produces an A-phase current of 5∠0° at the local relay and 5∠180° at the remote relay. The ratio of remote to local current is

$$\frac{\vec{I}_{AR}}{\vec{I}_{AL}} = \frac{5\angle 180^o}{5\angle 0^o} = 1\angle 180^o \quad (2)$$

$$\frac{\vec{I}_{BR}}{\vec{I}_{BL}} = \frac{5\angle 60^o}{5\angle -120^o} = 1\angle 180^o \quad (3)$$

$$\frac{\vec{I}_{CR}}{\vec{I}_{CL}} = \frac{5\angle -60^o}{5\angle 120^o} = 1\angle 180^o \quad (4)$$

The shape of the restraint region is described by two settings, as shown in Figure 6. Setting 87LANG determines the angular extent of the restraint region. Setting 87LR determines the outer radius of the restraint region. The inner radius is the reciprocal of 87LR. All three types of elements (phase, negative sequence, and zero-sequence) further qualify trips with a differential pickup setting [8]. (Figure 6).

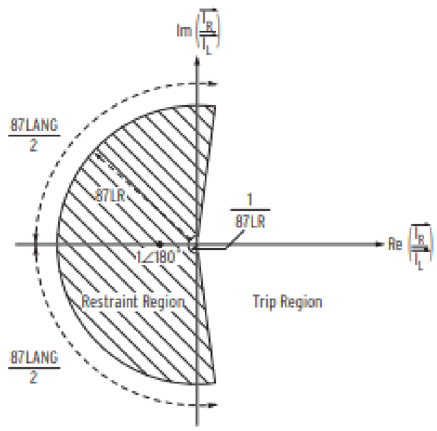

Fig. 6. SEL-311L Restraint Region Surrounds External Faults

The constraint region of line current differential protection for the SEL-311L MPR is shown in the alpha plane (Fig. 7). This range is calculated by angles A, B, and C, as shown in the figure [8].

- - 20 shift caused by the source angle and the source impedance angle
- - 21.6 shift caused by 2 ms channel asymmetry.
- - 40 shifts caused by CT saturation.

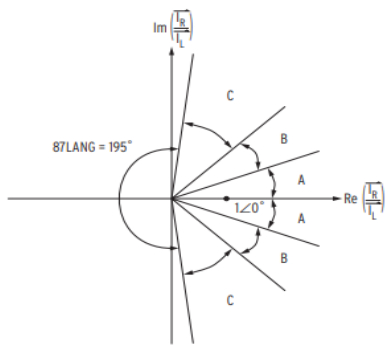

Fig. 7. SEL-311L relay protection trip region

The CHANNEL-X phase, negative sequence, and residual grounding element detection logic scheme are shown [8] (Figure 8).

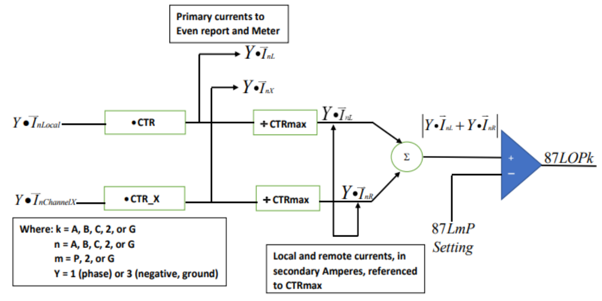

Fig. 8. Logic diagram of element 87L

IV. TWO MAIN PROTECTIONS – IMPLEMENTATION'S STATUS AND STABLITY CHECK

The *two main protection circuits* are independent of each other. There are include:

- Data transmission channels, high-frequency channels, fiber optic channels, and individual cores are used.
- It is fed from a separate winding on the secondary side of the measuring transformer or a voltage and current transformer.
- Current and voltage circuit cables, repair relays, and auxiliary equipment are separate.
- The main and backup protection devices use separate relay protection devices.
- Conducting or breaking circuits, connecting circuit cables, and breaking coils are separate.
- Secondary circuit cables are independent of each other.

However, according to the third and fourth ends, the sensing range of the differential protection is explained below.

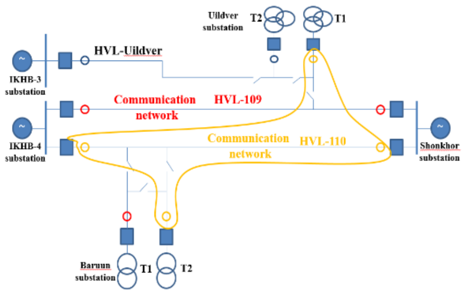

Fig. 9. Substations with 4 terminals protection SEL-411L relays from single line

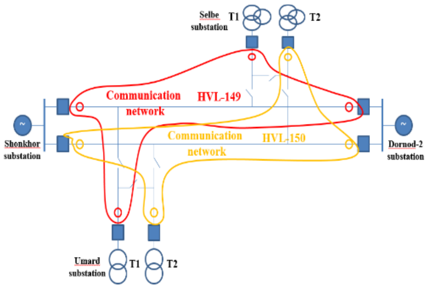

Fig. 10. Substations with 4 terminals protection SEL-411L relays from parallel lines

3 and 4 terminals protection are work done to add:

- 24 core fiber optic cable networks were installed at the Baruun, Dundgol, Umard, and Selbe substations.
- Relay protection with 87L function is installed in these stations.
- In addition, all the microprocessor relay protections of the above stations were equipped with a synchronous-time system and connected.
- An independent fiber optic RING network, independent of the Internet and other external networks, was created only for relay protection and automatic data transmission.

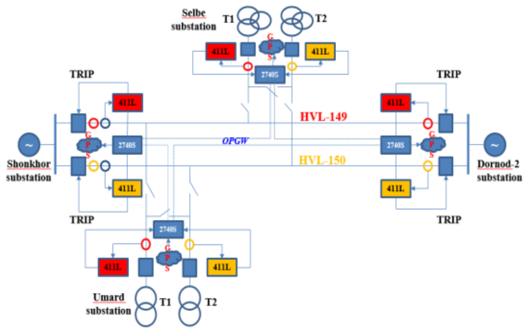

Fig. 11. Network of substations with four SEL-411L terminal protection relays

SEL-311L built-in 3-terminal protection network:

- Between the HVL-109 or IKHB-4, Baruun, and Shonkhor substations, 3 terminal protections were inserted using two core fiber optic cable channels.
- Between the HVL-110 or IKHB-4 substations, Dundgol, Baruun, and Shonkhor, a fiber optic cable channel was inserted using a STAR connection using 2 cores.
- Since the use of fiber optic cables in the "Baga Toirog" substations belongs to the *National Dispatching Center (NDC)*, we do not have enough fiber optic cores, so we used various options within the technical limits.

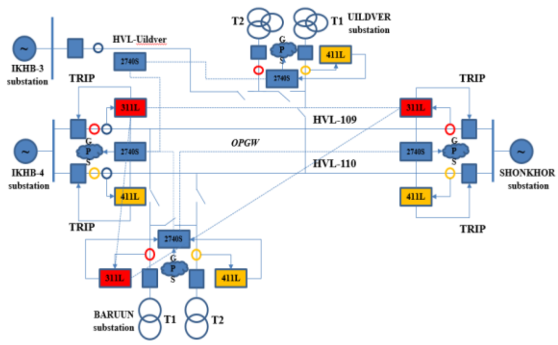

Fig. 12. Network of substations with 3 terminal protection SEL-311L relays

By introducing differential protection according to 3 and 4 terminals, the following risks have been reduced by improving the reliable operation of the HVL protection. It includes:

- When one main protection fails, the other main protection runs without delay.
- The coordination between the main and backup protection has become closer, the ability to complement each other has doubled, and control between the protection has been established.
- The probability that the protections will not work in the event of any damage to the main or backup protection circuits has been reduced by 2 times.
- It is no longer necessary to remove the other protection circuit for maintenance inspection of one protection circuit.
- From any station, it is possible to measure the relay protection devices at the opposite end, monitor load parameters, obtain emergency records, and, in some cases, adjust settings.
- In parallel current differential protection, the main protection continuously measures the current difference and continuously monitors the normal operation of the main protection.
- "Operational Acceleration" The probability of using a mode that affects the selectivity of protection by reducing the operational time of backup protection when the main protection is out of action has been reduced by 2 times. If the main protection fails, the protection automatically switches to the acceleration circuit.
- The flexibility of mode calculation has been increased by providing dynamic stability of the system.

Disadvantages:

Due to the increased integration of circuit solutions, logic programming, and devices used in the protection circuit, labor consumption has doubled. Maintenance and some adjustments require a more experienced professional.

Due to the need for precise measurements and the use of additional digital technologies, modern calibration tools are required. In branch substations of lines with 3 and 4 terminals main protection, main protection must be provided when 110 kV is switched and 2 transformers are connected simultaneously on 1 line. This is because Krichhoff's law is broken for the primary circuit.

V. Stability Checking of the Results

Below are the results of the calculation of how the stability of the system will be affected when the main protection is rejected in the 110 kV HVL-109,110 in cooperation with the engineers of the National dispatching center.

Based on this calculation, when the main protection of HVL-109,110 does not work or is rejected due to a short circuit, when the resistance to short circuit resistance reaches zone 2 of distance protection, the Turbogenerator-1,2 (TG) of Thermal Power Station-4 (TPS-4) is in asynchronous mode, as shown by the calculations of the Powerfactory program. To ensure the dynamic stability of the system, it is necessary to isolate the short circuit within 0.2 seconds of the short circuit in the HVL.

TABLE IV. Stability Calculation

Type of short-circuit	Connection mode	Fault location	Relay protection operation: *Protection worked*	*Zone*	*Working time /sec/*	Stability characteristics of the system
3 phase	HVL-109.110 connected	HVL-109 IKHB-4 side	Main protection/-/ Distance protection	I zone	0,1	stable
				II zone	0,5	The TPS-4 TG-1.2 generators are in asynchronous
		HVL-109 Domod-2 side		I zone	0,1	stable
				II zone	0,5	The TPS-4 TG-1.2 generators are in asynchronous
	HVL-109 connected, HVL-110 interrupted	HVL-109 IKHB-4 side		I zone	0,1	stable
				II zone	0,5	The TPS-4 TG-1.2 generators are asynchronous.
		HVL-109 Domod-2 side		I zone	0,1	stable
				II zone	0,5	The TPS-4 TG-1.2 generators are in asynchronous
	HVL-110 connected, HVL-109 interrupted	HVL-109 IKHB-4 side		I zone	0,1	stable
				II zone	0,5	The TPS-4 TG-1.2 generators are in asynchronous
		HVL-109 Domod-2 side		I zone	0,1	stable
				II zone	0,5	The TPS-4 TG-1.2 generators are in asynchronous

VI. 110 kV Line and Equipment Fault Research

Research on faults in the 110 kV network was carried out in the years 2015-2021, and a total of 118 faults occurred in 2021, 12 of which were not selective in the operation of relay protection and automation (RPA) [6, 7]. According to research, the reliability of relay protection and automation is 98.33%. This indicator is high for the reliable operation of the RPA, but it is understood that behind each number of faults, there is a risk of loss of system stability.

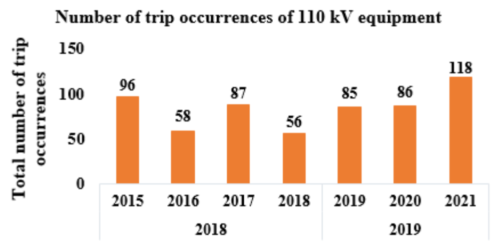

Fig. 13. Number of trips of 110 kV equipment (2015-2021) [5].

TABLE V. 110 kV Line and Equipment Fault Research

Trip	Equipment: *Substation*	Equipment: *HVL*	Number		Protection
selective			106		
Non-selective	Khushigt	HVL-139	2	Non-selective	Khushigt
	Khushigt	HVL -140	2		Khushigt
	Amgalan	T-2	1		Amgalan
	Shonkhor	CB	1		Shonkhor
	IKHB-3	Dundgol	2		IKHB-3
	IKHB-4	HVL -112	1		IKHB-4
	IKHB-4	Busbar breaker-2	1		IKHB-4
	IKHB-4	AT-1	1		IKHB-4
	Tuul	HVL -106	1		Tuul

From the above line and equipment fault research, considering the HVL-109, 110, 149, and 150 that make up the 110 kV "Baga Toirog" scheme:

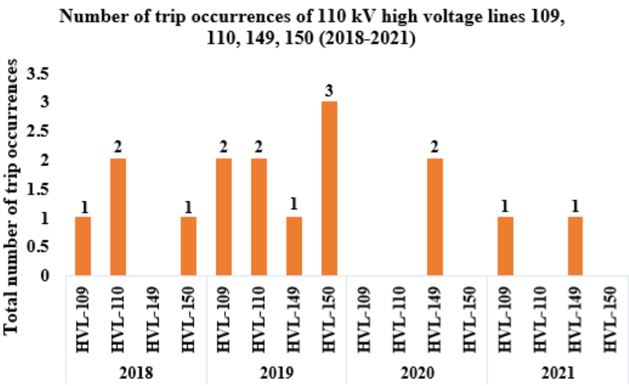

Fig. 14. Number of trip occurrences of 110 kV high voltage lines 109, 110, 149, 150 (2018-2021)

From the above faults, a conclusion was reached by comparing the records of 2 short-circuit faults that occurred at close distances before and after the introduction of differential protection on HVL-109,110 of 110 kV.

A. *In 2018, before connection of the 110/10 kV Shonkhor substation, recording of the main protection or directional high-speed logic protection (DHSLP) of the HVL-109 of 110 kV during the outage:*

On 30 May 2015, HVL-109 had a phase C short circuit to the ground, and Ic=1492A, 3I0=1929A, Uc=31.95, 3U0=8.9 kV. It can be seen from (Fig. 15) that the main protection of the HVL-109 works correctly and correctly according to the RPA, and within 0.118 seconds from the start of the short circuit, the circuit breakers in the Dornod-2 and IKHB-4 substations are tripped and the short circuit is eliminated.

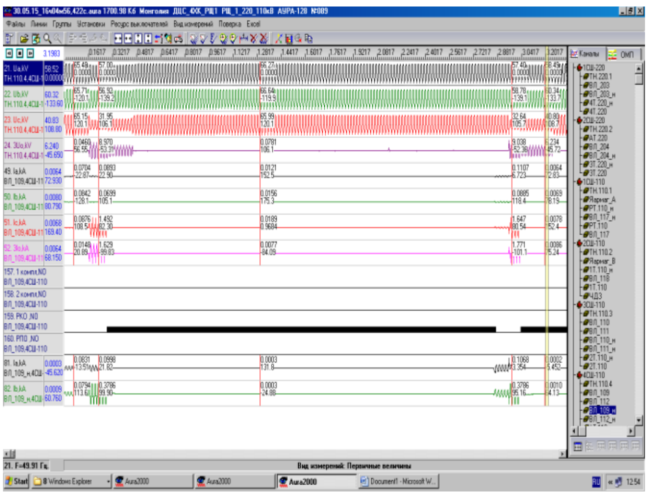

Fig. 15. AURA-89 record during phase C of the HVL-109 at the IKHB-4 substation

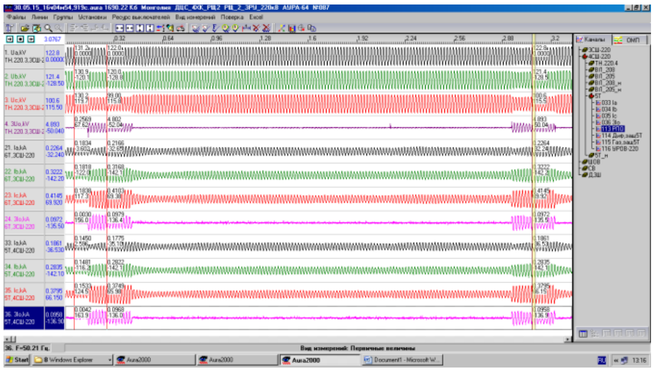

Fig. 16. Record of how the HVL-109 short circuit affects the 220 kV System busbar /SB/, 5T, and 6T of the IHB-4 substation

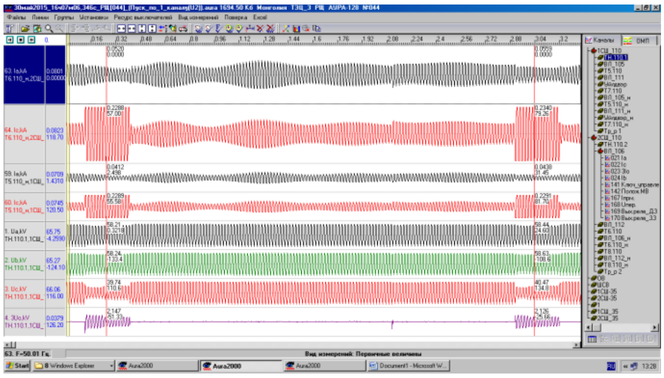

Fig. 17. Record of how the voltages of the 110 kV of the HVL-109 short-circuit IKHB-3 substation affect 5T and 6T

B. *Record of the short circuit during the installation of differential protections on HVL 109 and 110 after the connection of the 110/10 kV Shonkhor substation:*

On 25 September 2021, the main protection worked on HVL-109 due to a phase C short circuit to the ground. During the current short circuit, Ibz = 2083A flows from the IKHB-4 substation, and the main protection of the 4 terminals works correctly according to the RPA specifications, and within 0.06 seconds after the start of the short circuit, the circuit breakers of the HVL-109 broke in the IKHB-4 and Shonkhor substations. It can be seen from (Fig.18) that it is being destroyed.

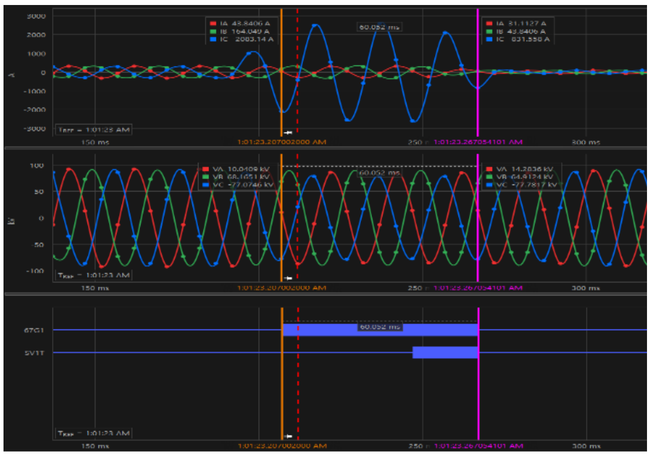

Fig. 18. Recording of an emergency fault of the HVL-109 of IKHB-4 substation

TABLE VI. RESULTS OF THE PROTECTION OF THE 2 DEFENCES

	Protection	**Substation**	**Line' s length**	**Line' s name**	**Fault current [A]**	**Operation time [sek]**
1	Directional high-speed logic protection	IKH-4 substation side	10 km	HVL-109	$I_C^{(1.1)} = 1492$	0,118
2	Line current differential protection	IKH-4 substation side	5 km	HVL-109	$I_C^{(1.1)} = 2083$	0,06

If compare the parameters during the above fault, the main protection or the directional high-speed logic protection worked accurately in 0.118 seconds during the short circuit of phase C of the HVL-109 to the ground, but at the time of the short circuit, the generators of the IKHB-4 and IKHB-3 substations (as shown in Figure. 15-17), the oscillations continued for about 3 seconds after the short circuit was eliminated by the RPA operation. This is only in the case of a 1-phase-to-earth short-circuit, and if there is a phase-to-phase short-circuit, the swing is stronger.

We see that the stability of the integrated network is ready to be compromised if the main protection operation time and the time until the circuit breaker trip are delayed. On the other hand, when the next short-circuit current of differential current protection is higher, the short-circuit clearing time is 0.07 seconds, which is 2 times less than the directional high-speed logic protection time. The system did not experience any oscillation during this fault. Therefore, the inclusion of current differential protection as the main protection is important to ensure the stability of the system.

VII. CONCLUSIONS

The 110 and 220 kV power equipment used throughout the transmission network, the reliability of the main and backup protection of the system, and the dynamic stability of the system are strongly interrelated. Because consumption around Ulaanbaatar city accounts for 75-80% of the total energy consumption of the Central Region of Power Energy Sector (CRPES). The shortage of power generators to meet this demand is about 300-450 MW. We supply this difference by importing from Russia and maintaining the balance of the system. In case of a dynamic transition in the power system, very fast relay protection devices are activated, and then system automation is activated. It takes time to stabilize the system. This time is measured in cycles or 0.02 seconds. During this time, the system parameters - current, voltage, and frequency - depend on the resistance of the circuit. From this study, it can be concluded that the backup protection of the high-load, too short-distance transit HVL is no longer functional. This is because the system around Ulaanbaatar city has reached a level that does not provide stability for the operation period of all levels except for the first level of preparatory protection. Furthermore, it is no longer possible to coordinate backup protection and traditional main protection calculations with other circuit protections and substation protections to ensure selectivity. Therefore, the selection and addition of current differential protection (87L) according to the main protection of the circuit diagram has a significant effect on the stability of the system.

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