Kyrgyz: Optimize Integration of Variable Renewable Energy (VRE)

Contract Modification: Technical Assessment for rehabilitation and construction of overhead lines and substations in the Kyrgyz Republic

Task A: Technical assessment for upgrading of 220 kV Kristall substation and associated Kristall-Yulduz 220 kV line.

Prepared for:

The World Bank Group

Final Draft

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List of Acronyms

°C:	Celsius Degree
$/USD:	Us Dollar
AIS:	Air Insulated Switchgear
CAPS:	Central Asia Power System
CIS:	Commonwealth of Independent States
CT:	Current Transformer
DGA	Dissolved Gas Analysis
EIA	Environmental Impact Assessment
EMS:	Energy Management System
EPP:	Electrical Power Plants
ESDD:	Equivalent Salt Deposit Density
FOTS:	Fiber Optic Transmission System
GIS:	Gas Insulated Switchgear
GOST:	Governmental Standards (ГОСТ in Russian)
GW:	1 Billion Watts
GWh:	1 Billion Watt-Hours
HF:	High Frequency
HPP:	Hydro Power Plant
HV:	High Voltage
ICT:	Information And Communication Technology
IEC:	International Electrotechnical Commission
IEEE:	Institute Of Electrical and Electronic Engineers
IPS/UPS:	Integrated Power System / Unified Power System
IQCM:	Internal Quality Check Mechanism
IT:	Information Technologies
km:	Kilometres
KPI:	Key Performance Indicator
kV:	1 Thousand Volts
kVA:	1 Thousand Volt-Amperes
kWh:	1 Thousand Watt-Hours
LILO:	Line-In-Line-Out
MoE:	Ministry Of Energy
MVA:	1 Million Volt-Amperes
MVAr:	1 Million Volt-Ampere-Reactive
MW:	1 Million Watts
MWh:	1 Million Watt-Hours
NDP:	Network Development Plan
NESK:	National Electric System Of Kyrgyzstan
NSDD:	Non-Soluble Deposit Density
NTC:	Net Transfer Capacity
OHL:	Overhead Line
OLTC:	On Load Tap Changer
OPEX:	Operational Expenditures
OPGW:	Optical Ground Wire
PLC:	Power Line Carier

QC:	Quality Control
QM:	Quality Manager
RES:	Renewable Energy Systems
RoW:	Right-Of-Way
SCADA:	Supervisory Control and Data Acquisition
SLD:	Single Line Diagram
SoW:	Scope Of Work
SPP:	Solar Power Plant
SPS:	Site Pollution Severity
SS:	Substation
TR:	Transformer
TSO:	Transmission System Operator
TWh:	1 Trillion Watt-Hours
UPS:	Uninterruptible Power Suply
VRE:	Variable Renewable Energy
VT:	Voltage Transformer
WB:	World Bank
WPP:	Wind Power Plant

Version draft final update notes:

Updates	Issue version/date
Comments and feedback are amended in to report as follows: ➢ Minor addition to executive summary ➢ Update in part: 4.2 Line conductor. ➢ Update in part: 4.7 Cost Breakdown. ➢ Update in part: 6: Summary and Results (Upgrading of 220 kV Kristall-Yolduz line) ➢ Update in part: 6.2 Rehabilitation of Kristall substation: ➢ Update in part: 6.3: Modernization of control & communication system of the 220 kV Torobaeva-Lochin line	Version Draft Final: 15 May 2024

1. Executive Summary

In the following study report, a technical assessment with desktop study and a site visit for the selected investment projects of Kyrgyz network are performed to prioritize the selected project regarding their impact and importance of the projects on transfer capacity between two countries (Kyrgyz - Uzbekistan).
This part of the assignment (defined as Task A) focuses on the following three projects.

- Rehabilitation of Kristall-Yulduz line
- Rehabilitation of Kristall substation
- Modernization of control & communication system of the 220 kV Torobaeva-Lochin line

These project items are reviewed and assessed for current and future grid operation including the generation expansion in the country and the other grid investment of NESK (Kyrgyz TSO). Power transfer capacity, reliability concerns, physical condition and implementation approach are the main input to reach a priority among these projects.

1. Regarding high level of loading value and being in a poor physical condition focuses the critical importance of Kristall-Yulduz line and it is recommended to be reconstructed with first priority. Estimated cost of building a new line from **Kristall to Yulduz** is about **12.2Million** USD excluding expropriation. The line is proposed to be renewed with 2AC 300 bundled conductor. Reconductoring and utilizing the existing towers are not recommended due to tower poor conditions and increasing withstand requirements for the towers as explained in the following parts of the report.

2. Serving at a critical joint of interconnections between Kyrgyz and Uzbekistan, **Kristall substation** has the second highest priority to be reconstructed at its own area. Reconstruction is recommended not only electromechanical parts but also for entire substation due to structural deficiency of substation. Due to land limitation, the reconstruction could be performed in partial scope with bypassing some lines to each other. Estimated cost is about **13 Million USD** with the assumption that replaced breakers and CTs are to be re-used after new substation is constructed.

- The Torbeava-Lochin line is operational more than 40 years with electromechanical and analogue systems. Network studies for current and future conditions show that importance of this line is not high due to low level of power transfer. Moreover, the control&protection building is not in a good condition and partial replacement of panels are not recommended. Thus, “**Modernization of control & communication system of the 220 kV Torobaeva-Lochin line**” could be postponed as last option to be implemented. It is recommended that entire control&protection infrastructure to be rehabilitated instead partial rehabilitation. The cost of modernization of double circuit Lochin line control-protection is estimated to 276k USD. If approved to rehabilitate the entire control-protection systems, total cost is estimated to be **~2.15 Million USD** (1.84 Million USD for building and 307k USD for control protection scheme.

2. Context and Objectives of the Project

The primary objective of this project is to provide technical assessments for a substation and lines that are currently in use alongside selected future projects determined by National Electric System of Kyrgyzstan (NESK). It also aims to support Ministry of Energy (MoE) and NESK in their capacity building by organizing a scheduled technical tour to selected countries' electricity power system-related institutes/governmental organizations, with a focus on their experiences with variable renewable energy (VRE). This project, which is a modification of the earlier "*Kyrgyzstan: Optimize Integration of Variable Renewable Energy (VRE)*" project, is divided into three tasks:

(a) **Technical assessment for upgrading of 220 kV Kristall substation and associated Kristall-Yulduz 220 kV line:** Developed over 35 years, the Kristall-Yulduz 220 kV overhead line and the Kristall 220 kV substation are important links between electricity power systems of Kyrgyzstan and Uzbekistan. Due to its long operational life and high loading level, probability of failure is getting increased. Although the substation went through a partial repair, incompatible technology and equipment continue to cause problems, making remote data collecting and control problematic. A comprehensive assessment that focuses on control, protection, and communication systems will reveal limitations and offer suggestions for modernizing the substation and the line. Plans are also being made to update the 220 kV Lochin-Torobaeva interconnection overhead line (OHL)'s control and communication system under this task.

(b) **Technical assessments for selected activities of the proposed investment program:** Transmission line and substation projects were identified by the previous VRE integration and planning studies. These consist of reconstructions and new constructions. Connection of new small hydro power plants (SHPPs), wind power plants (WPPs) and solar power plants (SPPs), new 500, 220 and 110 kV transmission lines, the construction of a new 500 kV substation, and the upgrade of existing substations are just a few of the projects for which the assignment entails thorough studies under that task. Technical requirements, recommended upgrades, cost breakdowns, and projected implementation schedules will all be determined via assessments. Updated cost estimates and investment suggestions will be informed by the findings, with financing availability determining the order of priority.

(c) **Support to a study tour by selected Government Officials from MoE/NESK:** The consultant is going to assist the MoE and the NESK plan and carry out a study tour to two or three countries that have successfully integrated large-scale VRE. This assistance will include recommendations for countries, brief preparation, agenda development, coordination with host agencies, discussion topic suggestions, and delegation accompaniment.

The report presents detailed studies conducted both on-desk and on-site for Task (a) of the project, focusing on the assessment of the 220 kV Kristall substation (SS), 220 kV interconnection overhead lines between Kristall-Yulduz and Torobaeva-Lochin.

3. 220kV/110kV Kristall substation

The Kristall substation is located in the Jalal-Abad region, about 300 meters distance to the Naryn river. It connects Shamaldysayskaya HPP and Tashkumyrskaya HPP to the main electricity grid with 1 km and 18.3 km double circuits respectively. Being that the Andijan and Namangan areas of Uzbekistan are only 20 km away, it serves as a connection terminal for the cross-border lines between Kyrgyzstan and Uzbekistan. In past years, at maximum day some interconnection overhead lines recorded as heavy loaded. It has been in service for more than ~35 years. Since then, some components are replaced under modernization processes like some relay protection devices while some components such as protection panels are outdated and need a renewal. A general view of the substation view area and electrification diagram are shown as follows.

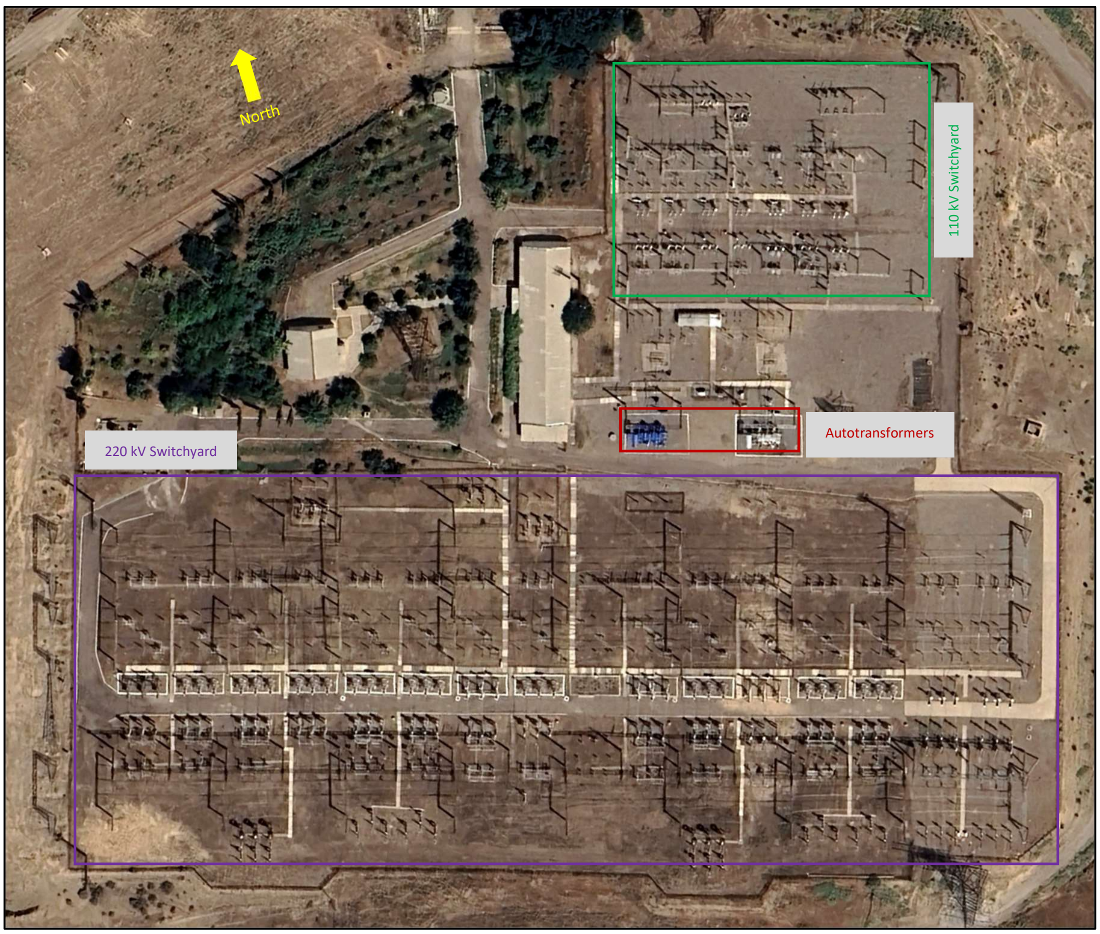

Figure 1: Satellite view of Kristall substation.

Figure 2: Regional network of Kristall Substation

3.1. General information and structural conditions

Kristall substation site access road is a type of ~1,600m branch from the main road. Access road is a dirt road with some slope and sharp turn. If the substation is reconstructed with higher capacity autotransformer, some improvements on the access road may be necessary to allow a low bed heavy truck drive with heavy auto transformers.

Figure 3: Kristall Substation access road.

The substation has no water mains connection, a storage tank is used with 2 hours capacity. The operators informed that they asked for water connection but there are no water mains nearby. Some of the electromechanics components are replaced with new one. However, main switchgear is designed with concrete poles. Modern switchgears are preferred to be installed over steel lattice poles. Some of the concrete poles have misalignment on their vertical axis which shows the seismic vulnerability of the main supports. The building has some cracks and additional strengthening was implemented in the past. There are also some insulator cracks at the tension conductor of portals. The ground gravels are not enough, vegetation exists on the ground which may risk the reliability of the switchgear in case of fire or dust deposit. Substation entire ground has no planar integrity. Different aground altitude exist in the substation. Concrete poles, building and tension insulators are shown as follows.

Figure 4: Part of Control & protection building with some defects.

Figure 5: Insulator cracks in tension conductors at Kristall substation.

Figure 6: Vegetation beneath switchgear and misalignment of poles.

Figure 7: Vegetation beneath switchgear, non-planar ground in the entire switchgear.

3.2. Switchgear topology

Kristall substation designed and constructed with air insulated type and with double busbar and transfer busbar scheme. Kristall substation with air insulated switchgear (AIS) has a double busbar with bypass scheme both for 220kV and 110kV. Double bus with transfer feeder scheme provides one redundancy in case of any faulty feeder exists. This type of topology provides two single bus operation with bus coupler switching. Single line diagram of Kristall substation is shown as follows.

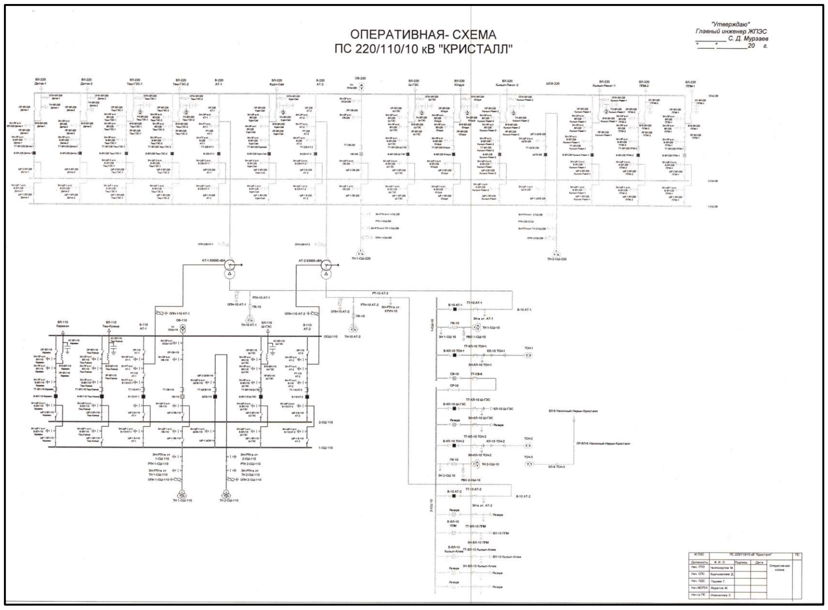

Figure 8: SLD of Kristall substation.

3.3. Autotransformers

There are 2x63MVA 220/110kV autotransformers in the substation manufactured in 1992. Autotransformers have off-load tap changers but are not used frequently due to the aging of mechanical structure of tap changer. Modern tap changers are operated with on-load tap changing which provides flexible voltage regulation for the down layer network. With the reconstruction of substation, higher capacity (~125MVA) autotransformers with on load tap changers could be implemented. One important deficiency about the autotransformers is the non-existence of firewalls or any active fire prevention systems. There are only manual used fire tubes located at the switchgear. The reconstruction project shall include a proven fire protection/prevention systems and firewalls. Autotransformers of Kristall substation are shown as follows.

Figure 9: Kristall substation Autotransformers.

3.4. Instrumentation (Current Transformers CTs and Voltage Transformers VTs)

Instrumentation in a substation is primarily performed via current and voltage transformers. Capacitive voltage transformers also provide coupling for the power line carrier tuning circuit. The current transformers of all line feeders are renewed with new type current transformers. But the CTs of auto transformers and the all VTs (except for Datka feeder) are old type. During reconstruction of the substation, replaced equipment shall be dismantled, stored carefully and they could be used at the new substation. Old CTs and VTs shall be replaced with the construction of substation.

Figure 10: CTs of Datka feeder

Figure 11: Replaced new CTs

Figure 12: Old CTs of autotransformer.

3.5. Switches, (Breakers and disconnectors)

Circuit breakers in the substations are replaced with new SF6 types except for #of two autotransformer feeders. These two old breakers are of oil filled type with closing resistors. They have some oil leakage indications on the breaker body with poor condition. Contrary to breakers, disconnectors are old, and the mechanisms are not working properly. Metallic parts are corroded, and the drive mechanisms are not in good conditions. Replaced circuit breakers have good conditions and they should be used after the reconstruction. However, disconnectors need to be renewed during the reconstruction of substation.

Figure 13: Circuit breakers in Kristall in good condition and relatively new.

Figure 14: Old circuit breaker at autotransformer feeder, oil filled type and oil leaks exist.

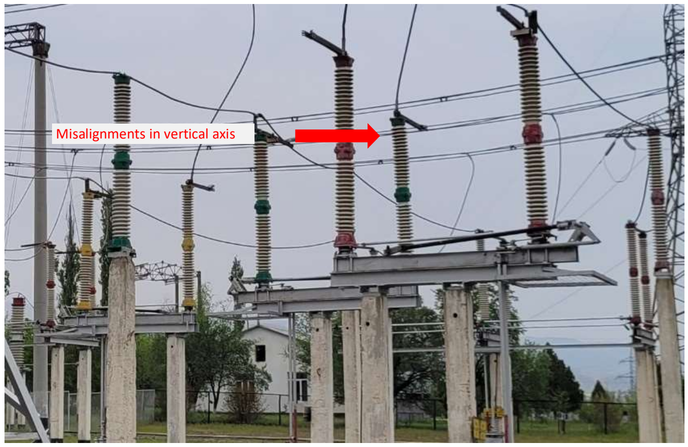

Figure 15: Disconnectors in Kristall SS in a poor condition.

3.6. Station auxiliary power

Kristall substation have three different station auxiliary power source. Two of them are supplied via autotransformer tertiary winding and one additional MV line from local network. In the aspect of redundancy and availability, three source are well enough for regular operation. However, during emergency conditions like regional blackout, neither autotransformers nor the local MV feeder cannot supply the station unless the black start recovery station exists in the region. In other words, Kristall substation has no black start capability. Being an important interconnection substation among Kyrgyz and Uzbekistan, Kristall is strongly recommended to be designed with black start. In the global practice, such type of important substations generally has two independent supply and one diesel generator available for station auxiliary supply. Similar design is recommended for the reconstruction of Kristall SS with two auxiliary supplies from new autotransformer and a diesel back-up generator for black start recovery.

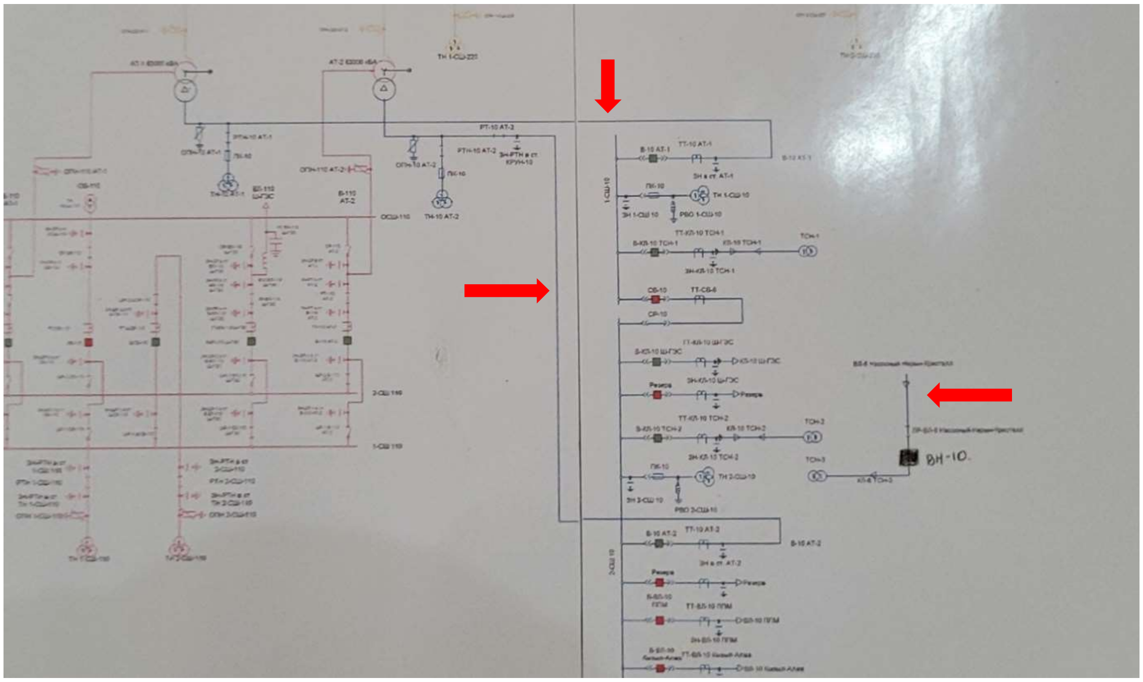

Figure 16: Station auxiliary power supply scheme of Kristall with two connections to autotransformer tertiary and one MV feeder from local MV network.

3.7. DC battery system

DC battery systems in a substation is vital power source for control and protection systems. All the relays, telecommunication hardware and control systems are supplied form DC supply of the substation. Batteries provide regulated and smooth voltage supply avoiding grid supply fluctuation. In case of any grid fault occurred nearby, station auxiliary supply may have transient voltage dip and this may cause DC equipment working improperly. However, batteries in a substation are not affected from transient voltage events and provides stable voltage supply to the DC systems. General design practice for grid substation recommends two independent battery sources for DC supply. In Kristall substation, there exists only one battery bank in operation. Batteries itself are good condition but the battery room is old, no anu smoke detector or ventilation is not proper. It is recommended that new design of Kristall should include two independent battery banks with full redundancy.

Figure 17: Battery bank of Kristall SS

Figure 18: Kristall SS batteries, with V L 2-550 model with liquid electrolyte (lead acid, dilute sulfuric acid).

Figure 19: Battery charger system with redundant equipment.

3.8. Protection and control Scheme of Kristall substation

Kristall substation has been serving in the grid more than 35 years. Meanwhile, some equipment like breakers and CTs are replaced with new one. However, the main structure of control and protection system is old with outdated technology. The two feeders of Datka line 1-2 has been installed in 2010 with recent technology of digital control and protection panels/relays. Control panels for Datka 1-2 and Kurpsai are new digital type. The remaining feeders are controlled over old version panels with analogue systems. Only Datka line 1 have fibre optic teleprotection scheme in Kristall, remaining lines are using power line carrier for teleprotection.

Lines are protected with main and backup protection. Differential protection serves as main which requires telecommunication. Distance protection operates as backup and does not require communication. Since the Kyrgyz grid line protection scheme relies on differential protection, a reliable communication is essential among substations with fibre optic channel. Unfortunately, Yulduz line has no fibre optic channel and teleprotection is met via PLC (power line carrier). Another issue for control protection is the building that the relays are located. There is no free space to add any relay. In case of partial replacement, existing electromechanics panels should be dismantled and same area could be equipped with new type of relays. This option requires the related feeder to be taken out of service for 1-2 months. Specific to Yulduz line, NESK Dispatch confirmed that Yulduz line could be taken out of service for some definite time if relay panels are to be replaced. Due to the constructional condition of the entire building, it is not recommended to implement a partial replacement.

Figure 20: Old version analogue type control panel of Kristall.

Figure 21: digital type control panels of Datka 1-2 line and Krupsai line in Kristall.

The Yulduz line protection system on the Kristall SS employs old-fashioned electromechanical relays, those visible in the Figure 22.

Figure 22: Current Protection System Equipment of 220 kV Yulduz Line on Kristall SS

Besides the protection systems with old electromechanical relays of most of the lines connected to the Kristall SS, there are digital relays installed by NR Electric (China) for the new Datka lines on the protection and control room of the SS depicted on Figure 23.

The reliability of using these relays is questionable due to the inherent limitations and disadvantages of conventional electromechanical relay systems when compared to modern digital counterparts. Some of these drawbacks include:

- The reliability and stability of early electromechanical relays with moving parts is uncertain, as they are highly dependent on environmental conditions. Analog signals may experience distortion due to factors such as temperature fluctuations, metal fatigue from repeated use, and wear and tear caused by aging equipment. These relays are also prone to increased vulnerability to dirt, moisture, vibrations, shocks and, oxidizing by an arcing event between the contacts.
- Impractical to be integrated to modern automation systems due to compliance issues with modern communication protocols and interfaces and their relatively slower response time compared to modern high speed automation systems.
- Electromechanical relays incur significantly greater outage expenses when compared to numerical relays.

- Electromechanical relays are limited in functionality compared to their modern digital counterparts, lacking features such as logging, logic, data exchange and analysis capabilities.

Figure 23: Digital Relay Line Protection Cabinets of Datka Lines on the Kristall SS

3.9. Installation Process and Method for New Protection System

If the choice is made to install fibre optic cable on the existing line or a newly constructed line between Kristall and Yulduz SSs, the PLC system will continue to be operational as a backup protection system, preventing common mode failures, while the OPGW is serving for the primary teleprotection system.

If the decision is made to upgrade the electromechanical relays with new digital ones, currently the control unit of the building doesn't have any spare space to accommodate additional racks. Therefore, the replacement process must be carried out gradually or in a short period of time, with the new relay panels placed in the same location as the old ones. Both the main and backup protections may need to be temporarily out of service simultaneously. Based on NESK's past experiences with similar procedures for the protection system of new Datka lines, it typically takes two months or less to install a new relay. During this period, the existing line will be offline. Considering the dispatch and operation schedule of the line as per previous experiences of NESK personnel, it is possible to find a suitable time interval to conduct this procedure without causing any disruptions to the system due to the absence of the Kristall-Yulduz line. Complete outage of the line may not be necessary if NESK can manage the renewal process of both protection systems consecutively. In such a scenario, the main and backup protection systems can be renewed sequentially, ensuring that at least one protection system remains operational throughout the process to safeguard the Kristall-Yulduz line.

3.10. Estimated Cost of a New Protection System

Table 1 presents projected cost distributions subcategories/items, including estimated amounts for certain items. It's important to emphasize that both the quantities and costs of these items are subject to potential changes due to factors such as market conditions and developments in technology specific to the project.

Table 1: Cost Breakdown of Estimated Cost of New Protection System for 220 kV L-Kr-Yu

Category	Sub-Category	Item	Amount	Unit	unit cost USD (material and installation, excluding VAT)	total cost
Protection & Automation	Protection & Control Devices	Relay Panel for the Line (both terminal substation)	2	set	30,000	60,000
		Control Panel for the Line, Kristall substation only	1	set	30,000	30,000
		communication panels (both terminal substation)	2	-	20,000	40,000
	Commissioning	-	10	man-day	800	8,000
Total cost, USD						138,000

Table 2: Estimated cost about renovation of Kristall substation

Item	Unit price, x1000, $	Amount	Total x1000, $
220kV/110kV Autotransformers 125MVA	2,000	2	4,000
220kV switchgear (excluding CBs and CTs), 16 bays	3,200	1	3,200
110kV switchgear (excluding CBs and CTs), 7 bays	840	1	840
Control & protection systems for 23 bays	1,840	1	1,840
Control protection building for 26 bays	800	1	800
Fire protection system	400	1	400
Access road rehabilitation	150	1	150
Water mains installation	60	1	60
Mobilization and land rehabilitation	300	1	300
Other electrical and civil works	1,500	1	1,500
Total			**$13,090**

4. 220 kV Kristall-Yulduz OHL

The 220 kV interconnection line between Kristall SS of Kyrgyzstan and Yulduz SS of Uzbekistan is operating since 1986. The line route between the two substations is 64.5 kilometres (km) long overall of which will be called as "L-Kr-Yu" throughout the report.

Figure 24: Route of L-Kristall-Yulduz between Kristall and Yulduz SSs

Table 3: Nameplate of the L-Kristall-Yulduz OHL

Name of line, from substation to substation	L-Kr-Yu (Л-Кр-Ю), from Kristall to Yulduz
Tower types, pole, tubular lattice, guyed	- Guyed steel lattice masts - Concrete poles - Self-supporting steel lattice towers
Owner/Operator of the line	Both Kyrgyz Republic (17.9 km) and Republic of Uzbekistan (46.6 km)
Commissioning date	1986
Voltage level	220 kV
# of circuit, #of bundle, conductor type (ACSR-AAAC, AAC)	1 circuit AC-400 (ACSR)
Line route (.kmz) and distance(m/km)	See the Figure 24, 64.5 km
Type Insulator material	- Glass - Porcelain
#of grounding poles and conductor	1 ground line (partly)

Historically, Kyrgyzstan has been a net exporter of power. Even though the country's profile has changed recently; particularly during the summer, it still exports excess power generated by hydro sources to Uzbekistan at a defined net transfer capacity (NTC) of 1500 MW.

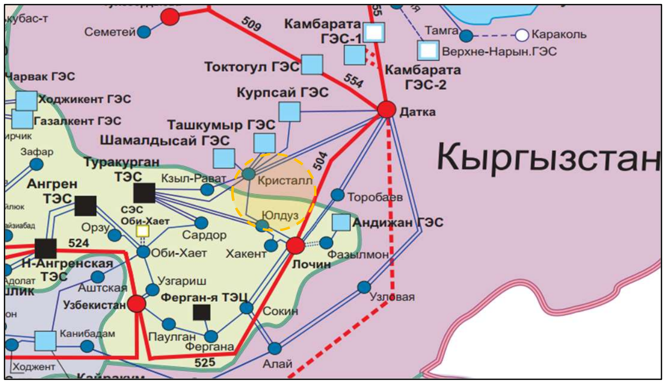

Figure 25: The L-Kristall-Yulduz Line on the CAPS Map

The Kristall substation, situated in the Jalal-Abad region, is approximately 300 meters from the Naryn river, with a railway road passing between them reaching up to near Yulduz SS. It acts as a crucial connection point for cross-border power lines between Kyrgyzstan and Uzbekistan. During the peak hydroelectric production in summer, the substation facilitates energy exports to Uzbekistan. L-Kristall-Yulduz was recorded to experience %85 loading on the maximum day in 2021, i.e., 1st of June. On the same day, some of the other 220 kV OHLs connected to Kristall SS also experienced heavy loads. Especially, during the evening peak periods, the SHPPs on the Naryn river meets the demand and due to the increasing export to Uzbekistan, the line operates heavy loaded.

In addition to having a long service life of the substation equipment, the line's frequent heavy loading increases the probability of failure. As it approaches the end of its operating life in accordance with the IEC-60826[1] standard, this line is required to be renewed for the coming years.

4.1. Line Route and Topographic Assessment

17.9 km L-Kr-Yu, shown in Figure 26, routes entirely along to a rough, semi-arid hill from the start of the Kristall SS to the junction on the 14th km. The remaining portion of the line continues until it crosses the Naryn River and enters Uzbek territory, where the elevation profile gradually lowers and begins to level out, running parallel to areas used for human settlement and agriculture.

Figure 26: Route of 220 kV L-Kr-Yu OHL

[1] IEC Design Criteria of Overhead Transmission Lines, 2017

The single line diagram (SLD) of lines on the same geographic area appears in Figure 27. The L-Kr-Yu and two other interconnection lines that link Kyrgyzstan and Uzbekistan follow the same route for seven kilometres. From the seventh to the fifteenth kilometre, the L-Kr-Yu and one of the other lines continue along parallel paths. The line then begins to follow its own route at the 15th km from the Kristall SS.

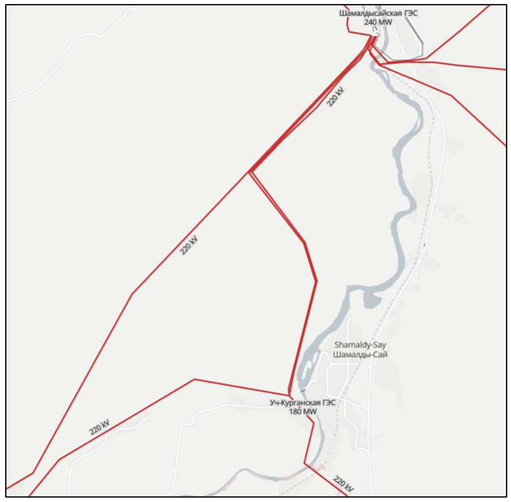

Figure 27: Lines on the Route of L-Kr-Yu on OpenInsfrastructureMap[2]

The SLD in Figure 28 below gives some detailed information about the L-Kr-Yu. The first two towers leaving the Kristall SS carry both the 220 kV Kristall-Kizilravat line and L-Kristall-Yulduz. The routes of these two lines separate between the second and third towers, as shared in the photos in Figure 29.

[2] https://openinframap.org/#10.83/41.2458/72.1502

Figure 28: Detailed SLD of L-Kr-Yu

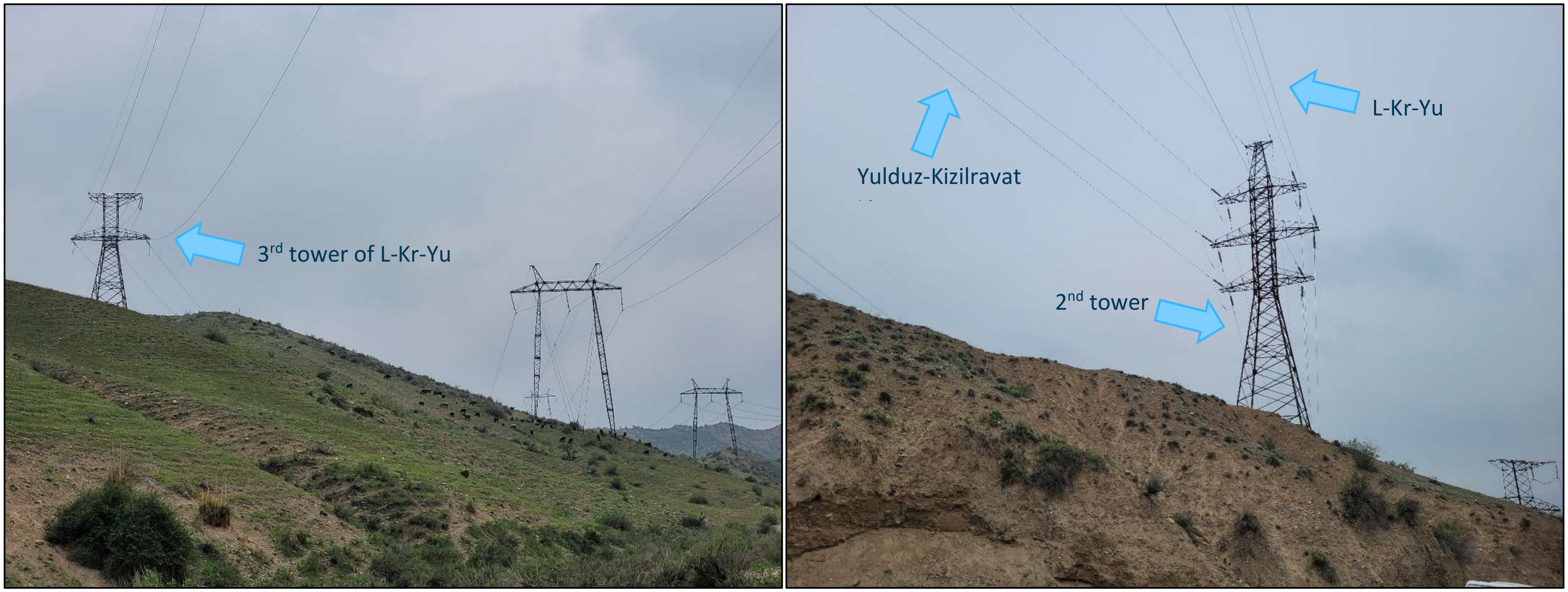

Figure 29: 3rd and 2nd transmission towers of the 220 kV L-Kr-Yu

The international standard IEC-60826 classifies the OHL crossed areas based on temperature and altitude for calculating wind loads on the line components and equipment. Similarly, altitudes up to 1000 m are usually classified as standard environment conditions for the calculation of electrical design parameters of transmission lines, such as current carrying capacity, isolation criteria, etc. This section of the line is under the <1000 m category according to the stated standard, with the greatest altitude on the route measured at 914 m as in Figure 30.

Figure 30: Elevation Profile of line L-Kr-Yu

According to international standards, there are general guidelines to follow while choosing the line route. The following topics are some of the key aspects to consider:

Climate and Air Quality Conditions: Making accurate identification of the climatic conditions of the terrain is crucial for better design decisions, particularly while assessing the impact of ice and wind climatic loads on the line route. Otherwise, the overhead line may experience unwelcome incidents including galloping, blackouts, even transmission towers may collapse under some extreme weather conditions etc.

The vertical air movement is shaped by the local and regional geography, resulting in icing and clouds. On their windward side, coastal mountains cause clouds and precipitation by forcing moist air upward. At high altitudes, when valleys lift moist air and intensify winds, severe icing happens. The L-Kr-Yu line experiences non-snowy weather because it is in a hilly area rather than high-altitude mountains, putting it under the category of "mediterranean-influenced hot-summer humid continental climate" according to Köppen-Geiger Climate Classification. Observed average mean, min and max surface air temperature are reported as 5.79°C, -0.04°C and 11.63°C respectively in the Jalal-Abad region.

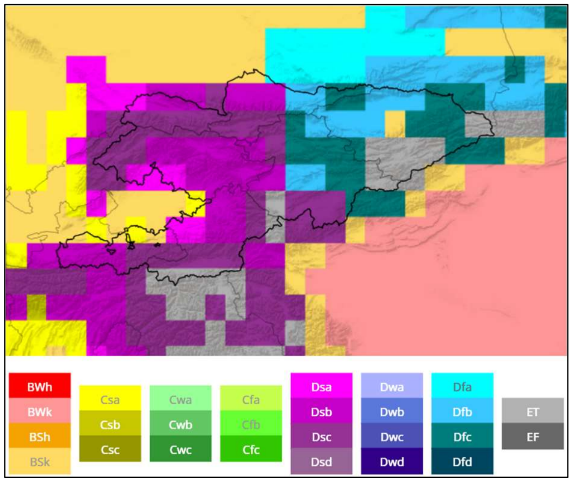

Figure 31: Köppen-Geiger Climate Classification Kyrgyzstan 1991-2020[3]

Geotechnical Conditions: The route of L-Kr-Yu can be divided into two main topographical sections. Each one of these two distinct sections have their own characteristics and specifications:

1. The segment from Kristall substation to where the land levels out and the line approaches the Naryn river again. This portion appears relatively stable over time and provides a solid foundation for the towers.

Figure 32: Satellite View of Area where 1st Segment of L-Kr-Yu is Located between 1985 and 2024

2. The second segment, extending to the river crossing, passes through areas with human settlements and agricultural activities.

[3] Climate Change Knowledge Portal (CCKP)

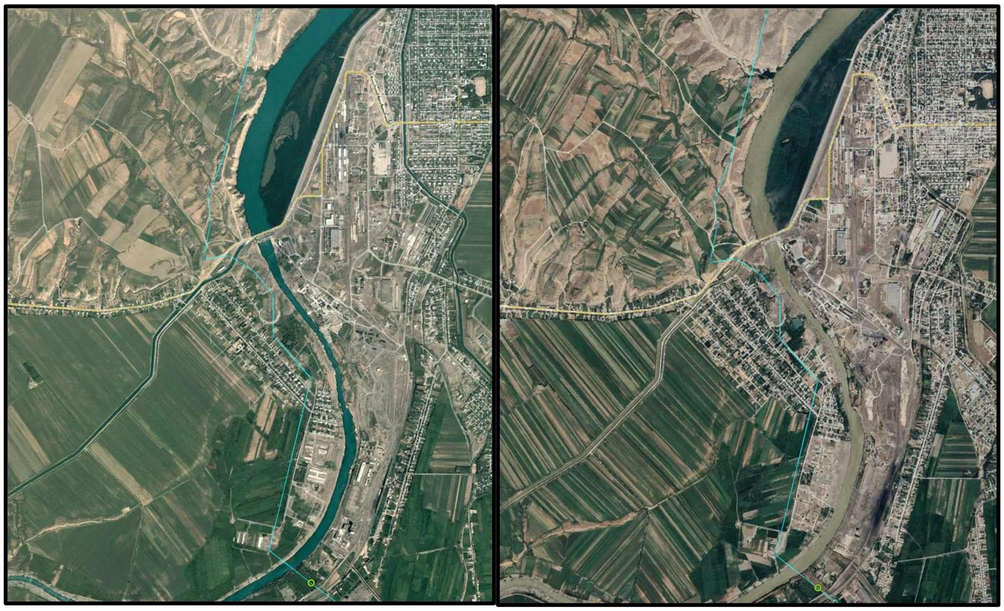

Figure 33: Satellite View of Area where 2nd Segment of L-Kr-Yu is Located between 2002 and 2024

The type of tower and foundation designs are greatly influenced by the geotechnical features of the vicinity. For instance, river crossings and other locations with a high risk of avalanches are considered special circumstances for strength coordination, as per the IEC-60826 standard. Thus, further precautions must be taken with the tower at the L-Kr-Yu's first border crossing site across a river.

Right-of-Way (ROW):

In the vicinity of the second segment of L-Kr-Yu, there has been minimal development of new neighbourhoods over the past two decades, mostly away from the line's route. However, should a new route or parallel tower route be required, the right of way designation for the line must be adjusted accordingly. The existing housing in the area consists of low-rise buildings, simplifying the process of meeting clearance requirements. Conversely, any encroachments on this clearance pose a safety risk to both the transmission lines and nearby residents. It's vital to promptly address such violations, ensuring that necessary clearance and safety measures are maintained to uphold the safe operation of the transmission lines and minimize risks to the community. Except for the second segment of L-Kr-Yu, the land along the route appears to be government-owned, minimizing RoW concerns. Additionally, no protection zones or archaeological areas that could pose RoW issues have been identified on the route of the line.

Bird Migration Routes:

When birds build nests atop large transmission towers or unintentionally come into contact with overhead transmission lines, they can unintentionally create short-circuit accidents on those lines. Another issue is pollution flashover, which is a surface flashover phenomenon brought on by moisture and dirt along the insulator surface. There are reportedly many stork nests along the path of the line. Insulators can be polluted by bird droppings, which can cause an arc. It is highly advised to install bird guards/repellent thorns/spikes for the new line (upgraded line) to discourage birds from perching, particularly since it is unfeasible to alter the tower's route and bird pollution already affects insulator strings.

Since there are already bird nesting spreads in a wide area and common bird activity especially on a specific part of the route, instead of seeking for a new route, using the existing route seems reasonable.

Reconstruction Planning According to Line Route:

The newly constructed line may either run very close to the current line or replace it entirely, utilizing the same trajectory. Various approaches can be followed when reconstructing the line. The foremost recommendation is for NESK and NEGU to collaborate throughout the process, ensuring effective management and shared understanding. Here are some key highlights and potential approaches to consider:

- If agreeable and feasible, one potential course of action is to reconstruct the entire line from Kristall to Yulduz. In such a case both parties should agree on the type of the line and construction schedule.
- The reconstruction timeline for the line requires careful consideration. It's essential to identify any critical time constraints or seasons during which the line must be operational, as well as any periods when labour may be limited due to national holidays or extreme weather conditions. These variables should be meticulously evaluated in the planning process, integrated into risk assessments and alternative contingency plans.
- The tendering process for the line can be approached either in stages or as a complete package, depending on the finalized design choice. The key factor in making this decision is primarily whether the existing route will be retained, necessitating the dismantling and reconstruction of towers along this route, or if an alternative route will be selected for the new line.
    - In the scenario where the old route remains unchanged and the current network assets are to be dismantled, it may be more appropriate to manage the tendering process in phases. Considerations regarding seasonal constraints on both line usage and construction activities may influence the planners overseeing the process.
    - In the second scenario, a completely new parallel network route will be established, while the existing network assets will be retained as a backup route. In this situation, an initial feasibility assessment of maintaining the old route should be conducted, weighing maintenance requirements against the potential emergency use of the backup line. It's important to ensure that the operational expenditures (OPEX) for the line do not outweigh the anticipated benefits, unless it's deemed critical for balancing, trade, or other technical constraints. Given the line's independence from the prior route, it does not appear to be any obvious disadvantage to tendering the complete line as one piece in this scenario.
    - Between these two options, a third approach involves designing the new route in a manner that utilizes the previous route for certain segments while rerouting others. The 1st segment of the L-Kr-Yu, consisting of government-owned lands, offers greater ease in determining a new parallel route. However, in areas with terrains like agricultural fields or human settlements, such as in the 2nd segment of the L-Kr-Yu, the existing route might prove to be the most optimal or even the only feasible solution. In such instances, different parts of the line may require different solutions. In such a case, the parallel old lines could then serve as backups for emergency situations arising from seasonal dispatch variations.

4.2. Line Conductor

The phase conductors of the existing line are AC-400 which corresponds to ACSR (Aluminum Conductor Steel Reinforced) type in governmental standards (GOST) of Commonwealth of Independent States

(CIS) with the specifications provided in the Figure 34. Typically, current carrying capacity of the conductor is 825 amperes according to data given by NESK.

GOST/ГОСТ-839-80 Grade AC

Code	Areas	No. of Wires		Wire Diameter		Diameter		DC Resistance	Rated Strength	Mass per Unit Length		
				Al	Steel	Core	Conductor			Al	Steel	Total
	Al/St	Al	Steel	mm	mm	mm	mm	Ω / km	N	kg/km	kg/km	kg/km
400/51,9	400/51,9	54	7	3,07	3,07	9,21	27,64	0,072	123037	-	-	1509,7
(400/18)	381/18,8	42	7	3,4	1,85	5,6	26	0,076	85600	1052	147	1199
(400/22)	394/22	76	7	2.57	2	6	26.6	0.073	95115	1089	172	1261
(400/51)	394/51,1	54	7	3,05	3,05	9,2	27,5	0,073	120481	1090	400	1490
(400/64)	390/63,5	26	7	4,37	3,4	10,2	27,7	0,074	129183	1074	498	1572
(400/93)	406/93,2	30	19	4,15	2,5	12,5	29,1	0,071	173715	1119	732	1851
450/31,1	450/31,1	45	7	3,57	2,38	7,14	28,55	0,065	107467	-	-	1484,6
450/58,3	450/58,3	54	7	3,26	3,26	9,77	29,32	0,064	138417	-	-	1698,4

Figure 34: Technical Data of the AC-400 Conductor[4]

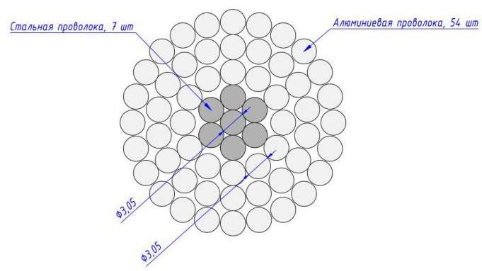

Figure 35: Cross-section of a Standard AC-400/51 Conductor

According to the IEC-60826, the typical operating period of a transmission line varies between 30 years to 80 years. It is generally accepted that transmission lines have a useful (economical) life of 35-40 years on average. L-Kr-Yu, which dates back to 1986, has been linking two countries for 38 years, hence it is potentially regarded to be in its retirement phase and to be in require of reconstruction.

Lightning protection of overhead lines is generally provided by ground wires hung on the highest level of the tower. There is a ground wire, whose type is coded C-70 in GOST standards, between certain towers on the route of the line. It is basically a 70 mm^2galanized steel rope used on high voltage power lines which can withstand 48 kA short circuit current, see the Figure 36. However, there is no OPGW (optical ground wire) on this Kristall-Yulduz line

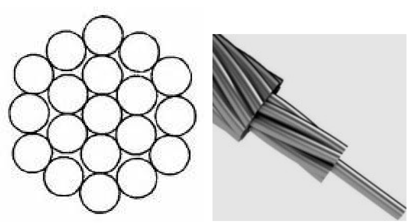

Figure 36: Cross-section of a standard C-70 ground wire.

Optical ground wires (OPGW) are a widely adopted and confirmed technology. These lines are multipurpose, offering both a path for grounding electrical surges and enabling communication,

[4] EMTA-Product-Catalogue.pdf (emtakablo.com)

automation, protection, and data collection through the incorporation of optical fibre cables. It is highly recommended to use that technology as a new grounding wire. It can be obtained in varying numbers of fibre optic cables and aluminium layer thicknesses with different short circuit withstanding.

Based on previous studies, depending on the season, the line's load is predicted to increase by 20–45% over the next 20 years. L-Kristall-Yulduz regularly experiences relatively heavy loading during peak hours. It is therefore recommended to upgrade the line with larger cross section or bundled conductors.

1. In Uzbekistan's transmission network, there are 220 kV lines equipped with AC-500 conductors. Although the Kyrgyz network hasn't utilized this conductor size for 220 kV overhead lines yet, collaboration with Uzbek authorities could enable upgrading the entire L-Kristall-Yulduz line to AC-500.
2. Alternatively, employing two bundled conductors is another viable option. The cross-section of bundled conductors could be selected as 2AC-300, providing a total current carrying capacity of 1380 amperes, surpassing the 945 amperes capacity of AC-500. Many overhead lines, like Datka-Torobaeva, already utilize this two-bundled configuration of AC-300. For this second option, again, it is recommended to coordinate with Uzbek authorities to ensure the entire line is upgraded to the same conductor type.

Either of these upgrades would improve the line's ability to handle higher transfer limits between countries in addition to preventing overloading in the upcoming years. Prioritizing the use of two bundled conductors over upgrading to a larger cross-section is preferred regarding *higher ampacity/unit size, better skin effect, improved thermal performance, less surface electrical field gradient and less audible noise/interference performance*. Typical current comparison of single conductor to equivalent size bundled conductor is given in CIGRE TB[5] as follows.

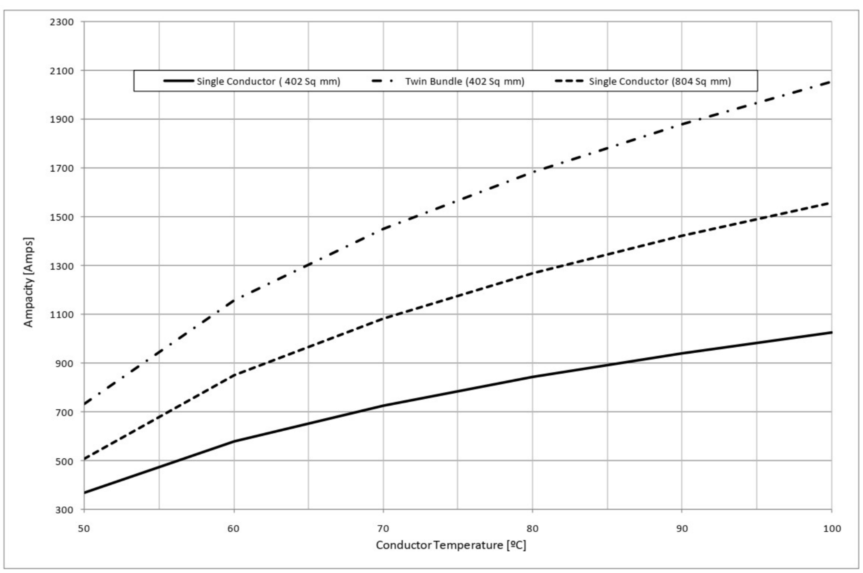

Figure 37: current ampacity comparison of single and bundled conductor.

[5] TB 763 - Conductors for the uprating of existing overhead lines

4.3. Tower Types

It has been confirmed that there are multiple kinds of transmission towers/structures along the line's root. As mentioned, there are 63 towers within the Tash-Komyr section, falling under the jurisdiction of the Kyrgyzstan Republic. These towers extend from Kristall substation to the river crossing point, where the responsibility for the L-Kristall-Yulduz line shifts to Uzbek authorities. Mainly, along the path, three types of towers have been recognized as in the Figure 38:

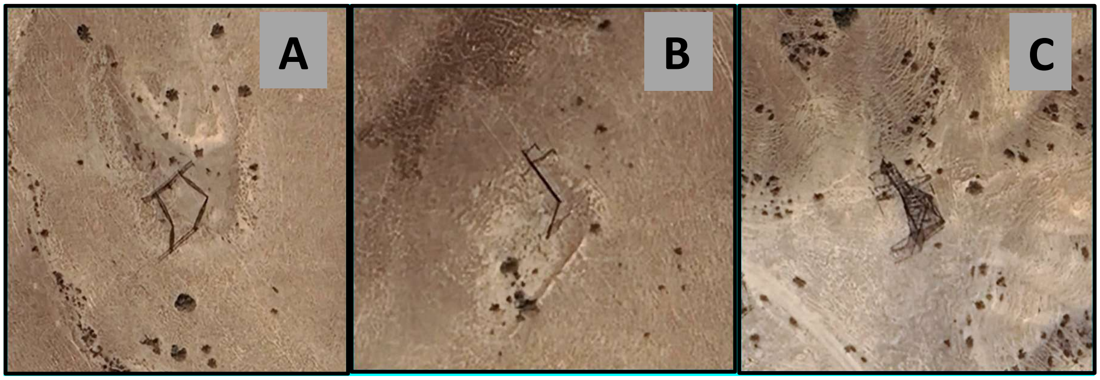

Figure 38: Satellite View of Tower Types on the Route of the Line

A: Guyed steel lattice masts are a practical and cost-effective solution for overhead power transmission in areas with limited space or budget constraints. Their simplified design, consisting of two vertical poles connected by a horizontal crossarm, allows for easy installation and versatile configuration options. These towers offer reliable support for transmission lines while minimizing land requirements and construction costs, making them a popular choice for various transmission projects. On the L-Kr-Yu route, this tower structure is currently configured for single-circuit use, although it can also be adapted for dual-circuit configuration if needed.

B: Concrete poles are not always the first choice in transmission systems, as steel is typically used for towers because to its successful price/performance ratio. Nonetheless, they have several benefits, such as lower maintenance costs after installation, and a narrower central mast. It also offers the option for both single-circuit and double-circuit configurations.

C: Self-supporting steel lattice transmission towers are upheld by four legs with separate foundations. They offer advantages such as enabling turns and angles and being suitable for areas with uneven terrain. Along the line's route, these towers are primarily employed as tension towers, particularly in areas where the route angle changes as in the Figure 39.

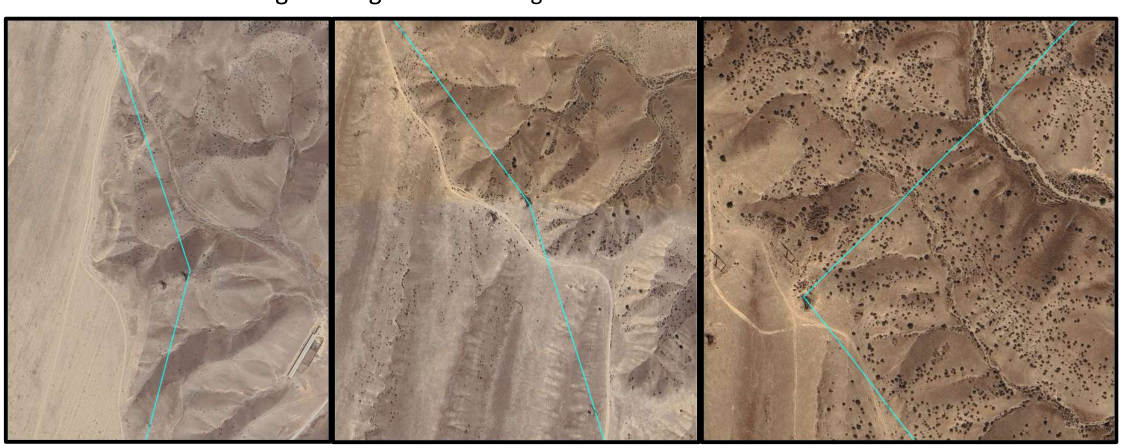

Figure 39: Instances of Locations Along the Route Where the C Type Tower is Utilized

The distribution of pole types (A, B, C types defined in this subchapter) is nearly equal along the Kyrgyz section of the entire line. The part from Kristall substation to the point where the land turns into flat and line gets close to the Naryn river again is not seemed as exposed to long term topological changes and suitable for sound footing of foundation of the towers. Thus, guyed steel masts and concrete poles can still be advantageous in that section of the route. Meanwhile, self-supporting steel lattice transmission towers are typically used for the rest of the route, which continues to appear suitable for the second segment. As per common practice, anchor steel lattice towers serve as the dead-end tower, a configuration also adopted for the L-Kristall-Yulduz line as in the Figure 40.

Figure 40: Kristall Junction Point of L-Kr-Yu

Bird nesting is prevalent in the area between towers numbered 19-62, increasing the likelihood of streamer outages caused by pollution from bird droppings on the insulator strings, particularly from storks. Bird guards are highly recommended to be utilized especially in that area of the line route. This equipment has been tested and proven effective in reducing flashovers caused by bird droppings across various geographical locations over several years. As outlined in the IEEE Guide for Reducing Bird-Related Outages[6], streamer outages caused by large birds are a longstanding and common issue for transmission towers, which can be effectively prevented by installing bird guards. Figure 41 shows an example on the Datka line near Kristall substation where bird guard is installed on the align of insulators.

[6] https://ieeexplore.ieee.org/document/5724322

Figure 41: Bird Guard Application Example from A 110-Kv Tower in Finland[7].

NESK has reported that they have installed some bird guard on the Kristall-Yulduz line and obtained a good operational experience for line performance.

4.4. Insulator Types

Air quality can impact insulator design choices, particularly due to nearby sources of pollution like cement factories. IEEE-1863-2019 references site pollution severity (SPS), outlined in IEC/TS 60815-1, which categorizes pollution levels from very light to very heavy. Insulator strings for transmission lines must withstand continuous operating voltage, switching, and lightning overvoltage, considering the SPS and environmental conditions. The number and type of insulators are determined based on factors like equivalent salt deposit density (ESDD)/non-soluble deposit density (NSDD) and local pollution levels. Agents that may give rise to considerable air pollution are not detected in the surrounding area of the L-Kr-Yu route.

It seems like almost all the insulators on the route are I-type. On the anchor towers close to the section of the second segment of the line's path that crosses a river, porcelain tension insulators have been placed between anchor towers numbered 58-62.

[7] P. Taklaja, P. Hyvönen, J. V. Klüss, J. Niitsoo and I. Palu, "Preventing Bird Streamer Outages Using Alternative Tower Configurations," in IEEE Transactions on Power Delivery, vol. 29, no. 5, pp. 2402-2409, Oct. 2014, doi: 10.1109/TPWRD.2014.2303084.

During the site inspection, it was observed that there are some sections of glass insulators missing along the L-Kr-Yu route.

4.5. Accessories

- **Corona ring:** Installing corona rings on conductors prevents corona discharge, a phenomenon that is known to cause material degradation, interfere with radio frequencies, and waste of energy. This safety precaution is especially important in high-voltage systems where there is a greater possibility of corona discharge. Corona rings also lessen the negative effects of electrical stress on nearby components, improving operational efficiency and requiring less maintenance, which contributes to system reliability. On the L-Kr-Yu overhead line, no corona rings were observed during the site-visit.

- **Arc horn**s are an essential preventative measure against the damaging effects of electrical arcing. They are placed strategically on overhead line conductors. They support the extended lifespan and dependable operation of overhead line infrastructure by redirecting and dispersing the immense heat and pressure of arcing incidents.
  No arc horn usage was detected on the Kristall-Yulduz line.

  Vibration damper: Strategically placed along overhead line conductors, vibration dampers are necessary for reducing the effects of mechanical vibrations. Conductor fatigue, excessive wear, and even structural failure might result from these oscillations. These devices lower the chance of conductor damage and downtime due to vibration-induced difficulties, which is essential for assuring reliable and safe operation. They have also been utilized on the L-Kr-Yu line.

- **Overhead wire markers**: Strategically placed alongside conductors, overhead wire markers improve visibility for low-flying aircraft and flights, hence promoting aviation safety. These marks help to identify the wire's path, lowering the possibility of collisions. The elevation level along the L-Kr-Yu route is less than 1000 m, which is significantly lower than the normal flying altitude and the route is not close to any airport, therefore, an overhead wire marker is not required.

- **Bird diverters/guards**: By producing visual signs that discourage birds from approaching hazardous areas, bird diverters—which are mounted on power lines—avoid bird collisions. By reducing the possibility of outages and equipment damage, they protect humans and birds. Given the significant bird population in the L-Kr-Yu area, it's prudent to consider deploying bird diverters or bird guards. During the site visit it is stated that some parts of the line are equipped with bird guards and operational performance is enhanced. It was observed bird guards on the Kristall-Datka lines, depicted in Figure 42.

Figure 42: A Tower of Kristall-Datka Line with Bird Guards Near the Kristall SS

- **Spacer:** Spacer components are integral elements utilized within transmission lines to regulate and maintain the spacing between conductors. Their primary function is to ensure adequate separation between conductors, thus enhancing electrical insulation and safety by mitigating the risk of unwanted faults or short circuits. Since the L-Kr-Yu line consists of a single bundle conductor, there is currently no need for the use of this equipment. However, if a decision is made to upgrade the line to a 2AC-300 type twin bundle, the use of this equipment will become necessary.

4.6. Communication Technique

Presently, leased HF channels underlying throughout the cascade of hydro stations are utilized for data communication. However, their effectiveness is compromised by their low reliability, unregulated maintenance schedules and other factors like;

- The communication of the line is directly reliant on the local telecommunication service provider, as they can perform maintenance activities without needing any permissions, thus affecting the line's operation.
- The current speed of data transmission via leased high-frequency channels is reported to be insufficient to meet the requirements for SCADA/EMS.

Teleprotection of the L-Kr-Yu line is provided by PLC (power line carrier). This system is old, and no redundant link exists. Since the lines have differential protection based on electromechanical relays, a reliable link based on optical ground wire is necessary as main link and PLC could be used as backup link. Building a OPGW on to existing line may have some difficulties due to tower static design limit Another option could be the construction of a new line with OPGW included.

4.7. Cost Breakdown

The breakdown of costs for the main and subcategories of the project is outlined in Table 4. The table shows both option with AC 500 and 2AC 300 (twin bundle conductor) cost estimate. The cost data is normalized to 100% for 2AC 300 conductor (preferred) option. Preferred option with 2AC 300 conductor has a cost estimate 12.2M USD. Other option (not preferred) with AC 500 conductor has cost estimate of 103M USD with 14% less compared to preferred 2AC 300. Although being a bit more expensive, 2AC300 have a unit cost of 8,880 $/Ampere while AC 500 have 10,893 $/Ampere. In other words, the entire cost of both assets is different by 14% higher for 2AC 300. However, 2AC 300 conductor can carry a unit current ampere 18% less cost than the AC 500 conductor. Moreover, equivalent resistance of both option have different values, ~65mΩ/km for AC 500 and 53m Ω/km for 2AC 300 conductor of which benefits ~19% less losses compared to AC 500 for the same line loading.

Expenditures for materials and construction & civil works are expected to begin during the pre-construction phase. Following the final task in the last month of the project, which involves energization and commissioning, the project will be concluded.

Table 4 presents projected cost distributions for various subcategories/items, including estimated percent amounts. It is important to emphasize that both the quantities and costs of these items are subject to potential changes due to factors such as market conditions, developments in logistics, and finalization of route decisions specific to the project.

Table 4: Cost Breakdown of The Total Project Cost of 220 kV L-Kr-Yu

Category	Sub-Category	Item	Sub-Category / Item %			
			AC 500 conductor, %	Category %, AC 500	**Twin Bundle (2AC 300) conductor, %**	Category %, 2AC 300
Project	-	Tender Process	1	9	1	10
		Engineering	3		4	
		Environmental Impact Assessment	3		3	
		RoW Permissions (Excluding Expropriation)	2		2	
Material	Conductor	Main conductor	12	49	15	57
		OPGW	2		2	
	Tower	Tower body	27		29	
	Accessories	Insulators	8		11	
		Corona Ring				
		Vibration Damper				
		Bird Guard				
		Spacer				
Construction & Civil Works	Logistics	Labour	5	27	6	32
		Machine Rentals	5		5	
	Tower	Foundation	6		7	
	Line	Conductor Stringing	11		14	
Commissioning	-	Site Tests & Energization	1	1	1	1
Total %			**86**	**86**	**100**	**100**
Total Expected Cost (USD) of the Entire Project 64.5km (190k$/km for 2AC 300, 163.4k$ for AC 500)			**10.294.200**		**12.255.000**	

4.8. Fault Performance

There are two emergency shutdown records of the 220 kV Kristall-Yulduz line in 2023 as stated in the following table.

Table 5: Fault Records of the L-Kristall-Yulduz in 2023

#	Date	Time	Shutdown
7	17/01/2023	23:49	На ПС Кристалл аварийно отключилась В-ВЛ-220 Юлдуз от ДФЗ, ЗНЗ 1ст, АПВ не успешное, УПФ "В" ИМФ 40 км. 18.01.23г в 00-08 РПВ не успешное. На ВЛ-220 Кристалл-Юлдуз на оп. №122 (территории Узбекистана) обнаружен обрыв провода верхней фазы. ВЛ-220 Кристалл-Юлдуз выведен в ремонт. (At the Kristall substation, 220 Yulduz OHL was emergency disconnected from the DFZ, ZNZ 1st, automatic reclosure was not successful, UPF "V" IMF 40 km. 01/18/23 at 00-08 RPV not successful. On 220 Crystal-Yulduz OHL at op. No. 122 (territory of Uzbekistan), a break in the upper phase wire was detected. 220 Kristall-Yulduz OHL is out for repairs.)
22	10/04/2023	19:45	Аварийно отключилась ВЛ-220 кВ Кристалл-Юлдуз. На пс Кристалл от ДФЗ, ЗНЗ-1ст, АПВ неуспешное, УПФ "В", ИМФ- 53,3 км (узб.уч). На пс Юлдуз от ДФЗ, ЗНЗ, АПВ неуспешное, УПФ "В". В 19-55 на пс Кристалл РПВ неуспешное, отключение от ТУ рез. защит, ЗНЗ-3ст, ИМФ-53,5 км (узб. уч.). В районе дождь. расчетное МП (КДЦ) - 73 км от пс Кристалл (узб.уч.) 11.04.23 в 05-20 Произведен осмотр ВЛ-220 Кристалл-Юлдуз Узб. ВВС, на опоре № 161 (8 км от пс Юлдуз), обнаружен обрыв провода верхней фазы, провод лежит на земле. ВЛ-220 кВ Кристалл-Юлдуз выведена в ремонт по узб. заявке. (The 220 kV Kristall-Yulduz OHL switched off. On the Kristall station from DFZ, ZNZ-1st, APV unsuccessful, UPF "V", IMF - 53.3 km (Uzb. territory). On Yulduz SS from DFZ, ZNZ, APV unsuccessful, UPF "B". At 19-55 at the Crystal RPV station unsuccessful, disconnection from the TU res. protection, ZNZ-3st, IMF-53.5 km (Uzb. territory). It's raining in the area. estimated MP (CDC) - 73 km from the Kristall substation (Uzb. territory) 04/11/23 at 05-20 Inspection of 220 Kristall-Yulduz OHL Uzb. wind Force, on support No. 161 (8 km from the Yulduz station), a break in the upper phase wire was discovered, the wire lies on the ground. 220 kV OHL Kristall-Yulduz was put out for repairs according to Uzbek. application.)

While two faults per year may appear insignificant at first glance, it indeed represents a considerable frequency of faults considering the fault index of transmission lines. This fault index is one of the key performance indicators (KPI) for Transmission System Operators (TSOs), and efforts are typically directed towards reducing it over time. Data for the frequency of faults in buses and lines can be obtained through the fault index. For buses, it shows the annual number of faults, while for lines, it shows the annual number of faults per one hundred kilometres. It is considered that faults are distributed evenly. Weather and geographic factors are the main determinants of the fault index, especially for overhead lines. Furthermore, the fault index may also be impacted by the existence of additional connected lines[8]. The fault index of L-Kristall-Yulduz is calculated as 3.1. This frequency is

[8] INAN, E. & Alboyaci, Bora & Bak, C.L.. (2010). A Case Study Of Turkish Transmission System For Voltage Dips.

notably high for an interconnection transmission overhead line operating at high voltage levels. Typical values for fault index could be less or around 1 occurrence/year*100km as per global practice.[9][10]

Outstanding portion of the transmission line faults occurs due to climatic events and natural disasters such as thunderstorm, lightening, heavy wind, heavy rain, heavy snow, heavy icing, heavy fog, earthquake, fire. Of the 12 emergency shutdowns in 2023 concerning OHLs linked to Kristall SS, 5 were attributed to severe weather conditions, indicating that a remarkable proportion of fault occurrences are weather-related, mainly strong winds or thunderstorms.

4.9. Market and Logistic Condition for New Line Construction

In the cost breakdown, which is shown in Table 4, the materials required to construct a new transmission line are divided into three subcategories: conductor, tower structure, and accessories. The challenges, timeframe, and expenses associated with shipping these materials are influenced by various factors including:

- The possibility of sourcing materials from a domestic manufacturer.
- The accessibility of the delivery location through conventional transportation methods such as land, sea, air, or rail.

These factors play a significant role in determining the complexity, duration, and overall expenditure involved in transporting the required materials for the project. Additionally, fluctuations in weather conditions and logistical considerations can further impact on the shipping process.

The tower body and anchor support materials planned for use in all transmission towers along the route are expected to be made from hot-dip galvanized steel, like the current practice. These members are typically transported to the construction site in individual pieces and tower erection is made near the final location of the towers as in Figure 43.

Figure 43: Some Stages of a Tower Erection Process

It is imperative to assess the availability of the hot dip galvanizing industry within Kyrgyzstan. Should there be a requirement to procure these materials from international markets in neighbouring

9 https://www.entsoe.eu/Documents/SOC%20documents/Nordic/2023/2022_Nordic_and_Baltic_Grid_Disturbance_Statistics_FOR_PUBLISHING.pdf

10 https://www.teias.gov.tr/faaliyet-raporlari

countries, selecting the most efficient delivery method becomes important. Although there have been recent efforts with neighbouring countries to build an intercountry railway network, current railway network of Kyrgyzstan simply composed of a Northern line linking Lugovaya to Bakykchy, connecting Kyrgyzstan with Russia via Kazakhstan, and a Southern line consisting of four sections connecting Kyrgyzstan with Uzbekistan and Russia at four different points.

Although there have been recent efforts with neighbouring countries to build an intercountry railway network, current railway network of Kyrgyzstan simply is composed of;

- a Northern line linking Lugovaya to Bakykchy, connecting Kyrgyzstan with Russia via Kazakhstan, and
- Southern lines consisting of four sections connecting Kyrgyzstan with Uzbekistan (and Russia) at four different points, see Figure 44.

As already mentioned, the railway's southern lines pass also near to the Yulduz and Kristall SSs.

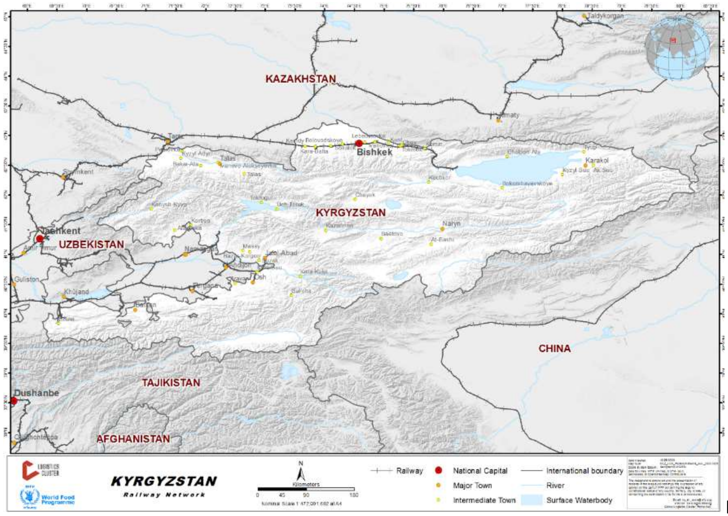

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Figure 44: A Map of Kyrgyzstan Railway Network[11]

Utilizing overland transportation presents an alternative method for transporting all materials to the vicinity of the site. Transmission towers will be delivered in pieces, accessories are already disassembled, and the lines will be shipped coiled around a pulley. This allows for the shipment of components in smaller quantities, accommodating the weight limits of both land transportation and railway/freight options. Additionally, scheduling shipments can take into account both the construction phase of the line and the capacity constraints of transportation methods.

[11] https://dlca.logcluster.org/24-kyrgyzstan-railway-assessment

5. Control and communication system of the 220 kV Torobaeva–Lochin line.

The 220 kV Torobaeva-Lochin line has been operating more than 40 years and playing a critical role for interconnecting Kyrgyz - Uzbekistan power grid. Double circuit line has a cross section of AC 240 mm2 for each circuit with ~220MW capacity/circuit. In the network analysis performed at the previous stage of the project, line loading is less than 50% even with the N-1 condition. Most of the power injected to Torbaeva busbar is consumed at Fozilmon substation of which has a winter load more than 200MW. This fact avoids the overloading of the Torobaeva-Lochin line. The regional network around Torobaeva is shown as follows.

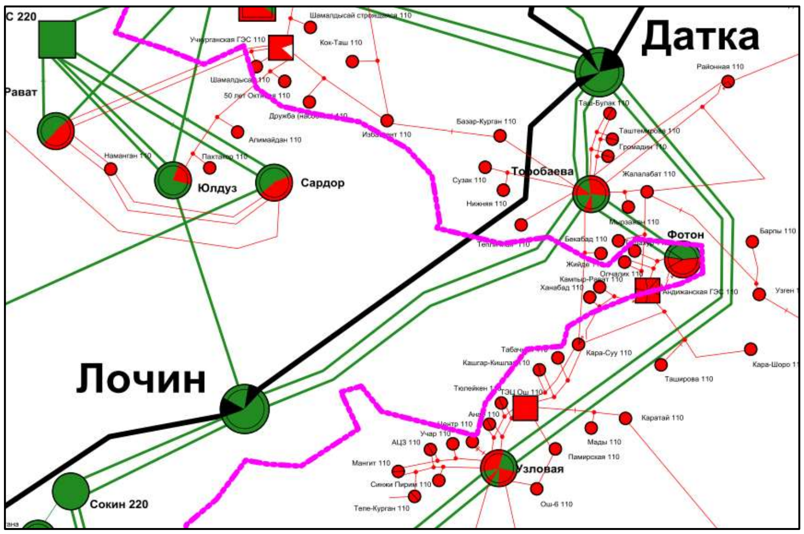

Figure 45: Regional network around Torobaeva

Similar to Kristall substation, Torobaeva substation has also mainly old type of electromechanics relays and control panels. Datka lines have new type relay and control panels with Datka 1 only having fibre optic link. Datka 2 has only PLC communication.

Lochin line about ~120km has only ~25% of the line has ground wire for the portion with higher probability of lightning stroke. There is no spare are in control or protection room to instal an additional panel. No fibre link exists on Lochin line. The relay and control panels are shown as follows.

Figure 46: Electromechanics and digital (Datka 1-2) relays in Lochin substation.

Figure 47: Lochin line (left-right) differential & distance protection.

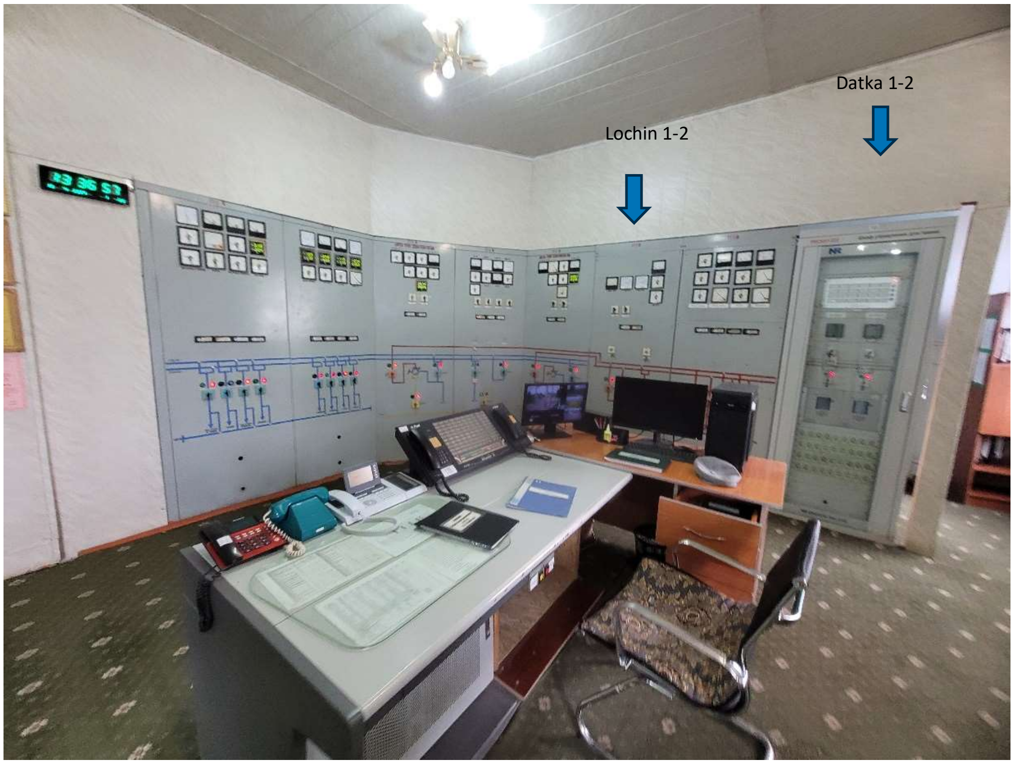

Figure 48: Control panels of Torobaeva substations, (Datka feeder control is new)

5.1. Installation Process and Method for New Protection and control System

Similar to Kristall substation, Lochin line protection schemes could be replaced with new modern digital systems only if the existing panels area is used due to space limitation in the building. This requires the outage of each line one by one about ~1-2 months. As the line flow is not too high even with N-1 case, line outage could be scheduled in a proper season.

For the control panels of the lines, space limitation is also valid and existing panels should be used for replacement of control systems. Two lines share the same panel and replacement work requires the outage of both lines for a period of 1-2 month. It may be still practical to switch off both line for replacement schedule because the line has not too high loading both winter and summer peak times.

5.2. Estimated Cost of a New Protection and Control System

The following table shows the cost estimation of replacement works for Lochin line control and protection system in Torobaeva substation.

Category	Sub-Category	Item	Amount	Unit	unit cost USD (material and installation, excluding VAT)	total cost
Protection & Automation	Protection & Control Devices	Relay Panel for the Line (both terminal substation)	4	set	30,000	120,000
		Control Panel for the Line, Torobaeva substation only	2	set	30,000	60,000
		communication panels (both terminal substation)	4	-	20,000	80,000
	Commissioning	-	20	man-day	800	16,000
Total cost, USD						276,000

6. Summary and results.

This report including desktop study and the site visit gives a technical assessment, implementation approach and priority of the projects including:

- Upgrading of 220 kV Kristall substation
- Upgrading of 220 kV Kristall-Yolduz line
- Modernization of control & communication system of the 220 kV Torobaeva-Lochin line

The above projects are reviewed in the aspect of cross border trade among Kyrgyz and Uzbekistan. Network analysis have been performed and the line loadings are calculated till 2040 with different generation-consumption dispatch scenarios. Calculations are performed with normal and contingency states. Following the network analysis, a site visit organized to Kristall and Lochin substation to observe the general conditions of the mentioned grid asset, check the land availability for reconstruction and discuss with NESK people about the congestion over these assets. Finally, a meeting with WB is arranged after site visit and brief summary is presented to WB officials about the conditions of proposed assets. It is also agreed that the assessment study to focuses on prioritizing, stages of phases and cost assessment.

Regarding the above findings and reviews mentioned above, # three project items are summarized in terms of impact on cross border trade, risk/reliability, applicability and urgency as follows. Estimated cost is also mentioned for the project implementation.

Upgrading of 220 kV Kristall-Yolduz line:

Kristall-Yolduz line has been in operation more than 35 years and serving to cross border trade among Kyrgyz and Uzbekistan. Line has a maximum power capacity about ~300MW. In the network analysis, it has been observed that the line is heavily loaded towards planning horizon. Moreover, there are some winter operational times that already exceed 250MW of power flow on this line. Thus, **impact** of Kristall-Yulduz line on import-export capacity of Kyrgyz is too high. Line itself has a higher fault index (~3/100km*year) which may risk the **reliability** of power transfer between two networks. Being an aged line also adds more risk to line reliability.

Regarding long operational life (>~40 years) of the proposed renewed line, Kristall-Yulduz line is recommended to be replaced with higher capacity with twin bundle conductor; **AC 2x300 ACSR**. This line may carry more than ~1200A yielding about 450MW capacity. Considering the operational life of existing line (towers and conductors), it is not practical to string a new conductor on to old towers and hence, entire line is recommended to be renewed. Existing towers have design parameters which are based on old type (at the time of design) of data. The ambient conditions effecting tower strength like wind forces and corrosive conditions are old and probably will change for the following 40 years. This concept is related to impact of climate change on outdoor structures. In addition to tower design parameters, replacement of conductor with larger size will add more static and dynamic forces on to the tower body which is beyond the original design limit. As mentioned in the previous parts, current line has no continuous ground wire path and new scheme requires an OPGW path for reliable communication. Adding OPGW to the existing towers also puts additional stress to the tower structures. If the average thunderstorm day in the region is increased for the last 40 years and expected to increase for the next 40 years (which is the usual case with climatic change), insulation coordination of line is also a concern to increase dimensions of tower crossarms.

One option could be to replace the existing conductor with the high temperature low sag conductors (HTLS) which may have same weight with the existing conductor. However, these types of conductors have advantages with operation of higher temperature and larger current capacity. Contrary to normal conductor temperature (~80 ^{0}C), HTLS conductors may operate at ~200 degree and can carry larger currents. At higher temperatures, conductor resistance is getting large, and losses may be larger for the same current capacity. Main concern for the tower is the structural withstand capacity. To keep the existing static forces on the tower and in case same weighted HTLS conductor is stringed to existing tower, it may carry larger power compared required for future load growth but with larger losses due to higher operating temperature. Since the Kristall-Yulduz line utilization is expected to be high, 65km line losses could high. In practice the cost and thermal losses of HTLS conductors are typically higher than conventional conductors[12]. The main advantage is that HTLS conductors can enhance security reserves and transmission capacity without impacting the negotiated right-of-way, ideally with minor modifications of towers (mostly clamps of the conductors and their mountings or light tower's reinforcement) and sometimes fewer towers. In our tower case, even minor modification with OPGW addition could be not feasible due to strength of the towers. Regarding the case for the towers, it is recommended to build a new line with 2AC 300 conductor instead of reconductoring or utilizing the existing towers.

[12] https://www.entsoe.eu/Technopedia/techsheets/high-temperature-low-sag-conductors-htls

New line should have entire ground wire with optical fibre (OPGW). Line construction could be partly parallel to existing line and partly instead of old towers if land acquisition is not available. In case of using any existing tower area, the line flow is to be interrupted during site works. Thus, the line construction should be scheduled in steps by obeying to the border trade conditions.

The physical damage of line conductor (fallen conductor events) shows the higher degree of **urgency** for the line replacement. It indicates that the line conductors and fittings/accessories are worn off and it is not possible to prevent and detect such risky event. Since the conductor and entire line has identical structure, it is highly probable that fault events with physical damage could occur in the following years.

Total estimated cost of new line with 2AC 300 construction is about **12.2Million USD** (190k$/km) excluding land expropriation and added value tax. Cost items are given as follows:

Category	Sub-Category	Item	Sub-Category / Item %	Category %
Project	-	Tender Process	1	10
		Engineering	4	
		Environmental Impact Assessment	3	
		RoW Permissions (Excluding Expropriation)	2	
Material	Conductor	2*AC-300/39	15	57
		OPGW	2	
	Tower	Tower body	29	
	Accessories	Insulators	11	
		Corona Ring		
		Vibration Damper		
		Bird Guard		
		Spacer		
Construction & Civil Works	Logistics	Labour	6	32
		Machine Rentals	5	
	Tower	Foundation	7	
	Line	Conductor Stringing	14	
Commissioning	-	Site Tests & Energization	1	1
Total %			100	100
Total Expected Cost (USD) of the Entire Project 64.5km (190k$/km)				**12,255,000**

Upgrading of 220 kV Kristall substation:

Kristall substation is commissioned in ~1987 and keeping a critical role on Kyrgyz-Uzbekistan connection at the south-west part of the country. There are three interconnection lines at 220kV terminated in Kristall incoming form Turakurgan TPP, Kizilravat and Yulduz substations of Uzbekistan. Moreover, direct connection of Kurpsay and Tashkumir power plants and direct link to 500/220kV Datka substation give rise to **importance** Kristall substation on Kyrgyz-Uzbekistan connection. Having too many connections mentioned above, Kristall substation has the highest level of impact on the import-export capacity of both networks. However, considered from the **reliability**/redundancy of substation about the line feeder and protection, all the internal systems have back-up like busbar (double busbar), breaker (bypass breaker exist) power capacity (two autotransformers with moderate loading), protection relays and auxiliary power. In other words, although substation has the highest impact on border line operation, the probability of failure for entire substation is less and resulting risk raised from substation is less than the one that raised due to Yulduz line does have.

Breakers and current transformers are replaced with new one and they should be re-used at the new substation. Other parts/components should be replaced with new one during construction. Substation is recommended to be designed with steel lattice type gantries instead of concrete poles. Since a complete free land near Kristall is not available, reconstruction should be done in stages. It is necessary to temporarily cancel some lines and to use that lines' feeder area to perform the reconstruction. Cancelling may be realized as shunt connection of any two incoming line with two outgoing line, which will provide 4 bays free to construct the initial stage of switchgear. Once the partial construction is completed, remaining lines to be shunt connected to each other and part of switchgear to be renewed.

Since the substation has redundant capacity for all main parts, it is not classified as **urgent** among the project mentioned in this study. But it is worth mentioning that structural condition of substation is not in a good condition. In 1992, an earthquake in the region has damaged the substation and some constructional strengthening was implemented. In case of a seismic activity with higher magnitude, the buildings or support concretes may partially or totally collapse. Considering the earthquake event period with long years, the Kristall substation is recommended to be reconstructed after the new Yulduz line build.

Total estimated cost of a typical substation with similar features (bus bar scheme, number of feeders, transformer capacity) like Kristall is about ~**13Million $.** Cost breakdown for Kristall substation is tabulated as follows.

Item	**Unit price, x1000, $**	**Amount**	**Total x1000, $**
220kV/110kV Autotransformers 125MVA	2,000	2	4,000
220kV switchgear (excluding CBs and CTs), 16 bays	3,200	1	3,200
110kV switchgear (excluding CBs and CTs), 7 bays	840	1	840
Control & protection systems for 23 bays	1,840	1	1,840
Control protection building for 26 bays	800	1	800
Fire protection system	400	1	400
Access road rehabilitation	150	1	150
Water mains installation	60	1	60
Mobilization and land rehabilitation	300	1	300
Other electrical and civil works	1,500	1	1,500
Total			**$13,090**

Modernization of control & communication system of the 220 kV Torobaeva-Lochin line

The line between Torbaeva-Lochin is in operation for more than 40 years. The line has an AC 240 conductor with ~220MW capacity for each circuit. There is not optical link for this line and the teleprotecton is provided via power lien carrier (PLC). Network analysis towards 2040 shows that this line is loaded below 50% for different dispatch and grid scenario, even with the N-1 contingency case. Similar to other lines, it has protection with main and backup systems. While the main protection with differential type relies on real time communication, distance protection operates locally and do not need teleprotection.

Regarding the low level of loading for existing and future scenarios, control&communication feature of this line has low impact on the transfer capacity between two networks. Since the line has operating cycle more than 40 years and protected with electromechanical relays, operation of line may rise reliability concern. Similar to Kristall substation, there is no spare area for additional control and protection panels in the building.

Regarding the low importance and impact of the line over transfer capacity between two countries, the consultant recommends postponing the rehabilitation of control&protection infrastructure to a schedule after the above two projects are completed. Moreover, partial rehabilitation is not recommended for control & protection, entire substation or the control & protection infrastructure could be renewed later.

In conclusion the priority of investment, phases of installation and estimated cost are summarised as follows:

6.1. Rehabilitation of Kristall-Yulduz line:

Renovation of this line has the **first priority** due to high level of loading and reliability concerns arise from conductor damage faults. New line is recommended to design with higher capacity type of twin bundled AC 300 conductor (AC 2x300). Parallel route of existing line could be feasible in terms of topographic conditions. However, part of the current line is passing near settlements and land acquisition may not be possible for new line. In such case, the route of existing line could be used by dismantling the old tower. Dismantling and construction of new line should be scheduled with dispatch centre of both utilities. It is worth mentioning that optical ground wire (OPGW) is essential regardless of lightning density on the route. OPGW line provide a reliable communication link owned by NESK and provides an additional ground fault path for unbalanced faults of which secures the step and touch voltage at the surrounding of the line. Estimated cost of entire line construction is ~ **12.2 Million USD**

6.2. Rehabilitation of Kristall substation:

Kristall substation is a part of interconnection between two utilities and serving more than 35 years. Although the breakers and current transformers are replaced with new ones, concrete structures, concrete poles, disconnectors, VTs, some oil filled breakers, control & protection schemes and auxiliary systems (water supply, fire protection, DC supply) are old and not in a good condition.

Main structure of concrete bodies has defects and misalignment on the switchgear. Concrete support poles have cracks and corrode. Design of substation's construction (civil and steel parts) assumed to be prepared regarding the conditions in the past. Once the replacement of primary electromechanical component like breaker, disconnector, CT/VT and other equipment is planned, up to date equipment are available in the market. Due to the grid is still growing (addition of new power plants and transmission asset) load currents and short circuit currents are also increasing steadily. One of the main design criteria considered for switchgear construction is the static forces by load current ambient conditions, and dynamic forces by short circuit events on the grid. As the load current or short circuit is increased, the electro mechanic forces exerted on support structures are also increased. Increased short circuit or lightning discharge currents generates step and touch voltage which may exceed the safety limit due to aged earthing mat beneath the substation. Replacing the electrical component like breaker, disconnector or CTs/VTs will assure the withstand capability of new equipment. However, the civil structures supporting main equipment will still stay there with insufficient withstand capability to ambient conditions and electromechanical forces. Not only the lumped component (breaker, disconnector, CTs/VTs) but also the distributed elements like bus bar conductor, tension and suspension strings, anchor structures and insulators are exposed to such mechanical forces. It is also known that Osh region has the highest rate of seismic risk in Kyrgyz[13]. Regarding the above conditions, operating the substation with rehabilitated electromechanics component which are superimposed on the aged and worn-out civil structures will not provide the entire reliability and safety of the substation operation.

Regarding the general condition of main concrete infrastructures (poles, building and support structures), partial replacement or renovation of main equipment is not recommended. The substation should be entirely reconstructed as a second priority among the assessed projects. Due to free land limitation, design and construction shall progress in stages by temporarily disconnection and shunt connection of adjacent lines. Temporary connections are to be planned as per line flows and physical orientation of lines around substation. Estimated cost of Kristall substation excluding the renewed equipment (breakers and CTs) is about ~ **13 Million** USD.

6.3. Modernization of control & communication system of the 220 kV Torobaeva-Lochin line:

Although this line has an age of more than 40 years and operated with electromechanical/analogue control & protection systems, the power flow on this double circuit line is very low even for the N-1 contingency case. This loading level makes the line itself less important and rehabilitation of control & protection has the last priority for renovation.

Regarding the concrete/building infrastructure of the substation, it is recommended to renew the entire control/protection infrastructure within a proper scheduling without any urgency. Similar to Kristall building, Torobaeva substation control &protection building is not in a good condition. It seems to have some cracks and separation on the joining part of side walls and the upper parts. There are some sealing deficiencies at ground level for relay panels. Regarding the steady change in climatic conditions, building withstand capability to outer conditions (wind, rain, dust deposit/pollution) could have decreased in 40 years and may not be enough for the next years. Relays are sensitive indoor equipment and should be installed and operated in clean and well protected room. It is not easy or practical inside an old building to track and prevent any liquid leakage, humidity increment, dust deposit or other possible violation of

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[13] Measuring Seismic Risk in Kyrgyz Republic Seismic Risk Reduction Strategy, WB

which may cause a failure of control protection system. Due to being on a seismic activity zone the Osh province has experienced 5 earthquakes for the last two century[14]. The ageing of the building in following years will make the seismic risk higher for the control & protection rooms. Another point could be mentioned here is the fire risk inside the building. There is no active fire prevention and the material used at the floor is not of fireproof type.

Since the need of this item (rehabilitation of control & protection scheme of Lochin line) have the last priority, it may be operated for some years, meanwhile the building will entirely complete its technical life and total renewal of building with all new control&protection scheme will be feasible. Otherwise, there will be double work one for the control & protection scheme and after a few years, building is to be reconstructed due to ageing. Additionally, rehabilitation of entire building with all relay/controls component will provide less unit price for control&protection system compared to individual relay replacement.

If the only control/protection of the double circuit line is decided to be refurbished, estimated cost to be **276k USD**. On the contrary, if the entire control and protection scheme is to be renewed, the estimated cost to be about ~**2.15 Million USD** (1.84 Million USD for building and 307k USD for control protection scheme)

[14] https://doi.org/10.1051/e3sconf/202447403010