The Hashemite Kingdom of Jordan
Ministry of Energy and Mineral Resources (MEMR)
National Electric Power Company (NEPCO)

Preparatory Survey on the Project for Strengthening Capacity of Power System Operation in the Hashemite Kingdom of Jordan

Preparatory Survey Report

June 2023

Japan International Cooperation Agency (JICA)

Asia Engineering Consultant Co., Ltd.
Tokyo Electric Power Services Co., Ltd.
Nippon Koei Co., Ltd.

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PREFACE

Japan International Cooperation Agency (JICA) decided to conduct the preparatory survey on the Project for Strengthening Capacity of Power System Operation in the Hashemite Kingdom of Jordan, and entrusted the survey to the joint venture consists of Asia Engineering Consultant Co., Ltd., Tokyo Electric Power Services Co., Ltd., and Nippon Koei Co., Ltd.

The survey team held a series of discussions with the officials concerned of the Government of Jordan, and conducted field investigations. As a result of further studies in Japan, the present report was finalized.

I hope that this report will contribute to the promotion of the project and to the enhancement of friendly relations between our two countries.

Finally, I wish to express my sincere appreciation to the officials concerned of the Government of Jordan for their close cooperation extended to the survey team.

June 2023

Hiroo Tanaka
Director General,
Infrastructure Management Department
Japan International Cooperation Agency

Summary

Summary

1. Overview of Jordan

The Hashemite Kingdom of Jordan (hereinafter referred to as "Jordan") is a country with an area of approximately 89,000 square kilometers, and the political system is a constitutional monarchy headed by a hereditary king. Jordan is one of the countries with the least water resources in the world, and even the capital Amman receives about 50 hours of water per week. It is also a non-oil producing country and lacks natural resources. As a result, the country relies on imports for energy, and in recent years has focused on developing renewable energy sources such as solar and wind power. The major import partners are China, Saudi Arabia, and the United States, and the top three import items in 2020 based on trade value are petroleum and bitumen oil (other than crude oil), petroleum and bitumen oil (crude oil), and passenger cars (other automobiles). On the other hand, major export partners are the United States, India, and Saudi Arabia, and the top three export items in 2020 were cotton clothing, potash fertilizer (limited to mineral fertilizers and chemical fertilizers), and other clothing.

Jordan's per capita GDP in 2021 will be USD 45,243.66, and real GDP will grow by 2.2% in 2021 after shrinking by 1.6% in 2020 due to the spread of COVID-19. However, the unemployment rate in the fourth quarter of 2021 remains high at 23%. The unemployment rate for young people (ages 15 to 24) and women are particularly high at 52% and 31%, respectively, and the impact on people in socially vulnerable positions is conspicuous. However, capital investment, which accounted for 3.5% of GDP in 2021, is expected to expand next year as well, and is expected to play a role in boosting the recovery of the labor market.

2. Project Background and Outline

In the Jordan's power sector, the introduction of renewable energy is being promoted as a national policy, due to the lack of natural resources such as oil. The share of renewable energy in the installed capacity has grown rapidly from almost zero in 2014 to 28% in 2021. However, the increase in renewable energy generation causes the reduction in the generation capacity of thermal power synchronous generators and the deduced share of the thermal generation must result in the decrease in the inertia force of the power system, which must weaken the synchronous stability and the power supply reliability. The average power outage duration per customer is increasing from 26 minutes (2017) to 209 minutes (2022), and in May 2021, a large-scale power outage occurred across Jordan.

While there is a demand for improved power supply reliability, the protection relay systems of key substations in Aqaba and Amman, which are essential for stable operation of the power system, have not been updated due to lack of funds. Old electro-mechanical relays and static relays continue to apply. If the protection relay (a device that minimizes the extent of power outages by detecting a fault that has occurred in the power system and quickly disconnecting the faulted section equipment) cannot operate properly, a

large fault current will continue to flow and the equipment will be damaged. In addition to damage to the power system, an unstable phenomenon occurs in the power system, causing a large-scale long-term power outage.

Under these circumstances, the Jordanian government has requested to replace the old protection relays with digital protection relays with excellent reliability and maintainability at the Aqaba substation, the Amman South substation, and the Amman East substation. A request was made to the Japanese government to implement a grant aid project, the Project for Strengthening Capacity of Power System Operation, with the aim of stabilizing the operation of the power system.

3. Outline of Preparatory Survey Results and Project Details

In response to a request from the Government of Jordan, JICA dispatched a preparatory survey team to Jordan from October 14, 2022 to November 2, 2022. In addition to reconfirming the content of the request and discussing the project component with NEPCO, a project site survey and collected related materials were conducted.

After returning to Japan, the Study Team summarized the necessity, content, relevance, and effectiveness of this project in a preliminary survey report (draft) based on field surveys and collected materials. In addition, JICA will dispatch a study team to explain the outline design to Jordan from March 10 to March 18, 2023, to explain and discuss the proposed cooperation project, and reach a basic agreement with the relevant parties in Jordan.

Targets for replacement of protection relays by the cooperation target projects determined as a result of the survey are shown in the table below.

Table 1 Overview of replacement protection relays

Substation	Classification of protection	Renewal method	Work spot
Amman South	400kVTransmission line	Replace relay units	Existing relay panel
	400kV/132kVTransformer	ditto	ditto
	400kVBusbar	ditto	ditto
	132kVTransmission line	ditto	ditto
	132kV/33kVTransformer	ditto	ditto
	132kVBusbar	ditto	ditto
Aqaba	400kVTransmission line	ditto	ditto
	400kV/132kVTransformer	ditto	ditto
	400kVBusbar	ditto	ditto
	132kVTransmission line	Replace relay panel	New relay room
	132kV/33kVTransfiormer	ditto	ditto
	132kVBusbar	ditto	ditto

Aqaba Cable End Switching Station	400kV Cable line (Egypt interconnector)	Replace relay units	Existing relay panel
Amman East	400kV Transmission line (Amman South line)	Replace relay units	Existing relay panel

The protection relay of the transmission line between Amman South and Amman East will be a digital current differential relay system that can improve the reclosing function, and the transmission line protection relay at Amman East substation must be replaced with the same type relay as that at Amman South.

For the method of protection relay replacement, NEPCO proposed a replacement method by protection relay unit basis, and to have NEPCO directly manage the replacement work. As a result of confirming examples of construction work, concerns about construction quality were dispelled, and it was basically agreed that NEPCO would perform the replacement work on a unit-by-unit basis. Since the installation location of the protection relays for the 132kV equipment in Aqaba will be changed, it was decided to replace each panel, and NEPCO will carry out the replacement work directly.

4. Project Implementation Period and Estimated cost

The implementation process will total 24 months starting from the conclusion of G/A, which is composed of 5 to 6 months for bidding and contracts, 10 months for equipment production, 2 months for transportation and customs clearance, and 6 months for on-site construction and adjustment testing. In addition to the Japanese grant portion, the project cost borne by NEPCO is estimated to be about 30 million yen.

5. Project Evaluation

(1) Validity

In the some 400kV/132kV substations, old types of protection relays such as static and electromechanical are still used, and there is a major concern that their protective performance may be degraded. In addition, the old types of protection relays need maintenance outages of protected equipment (transmission lines, transformers and busbars) to inspect and repair the relay. Due to the depletion of repair parts over time, the necessary downtime for the relay maintenance becomes longer and the risk of power outage results in larger during the inspection and repair works.

When a power outage occurs, especially if it lasts for a long time, it has a great impact on the lives of citizens and economic activities, such as the stoppage of pumps that pump up groundwater and supply agricultural water, as well as power outages in factories and buildings. This project will help to reduce such risks, and its relevance is high. In addition, it will directly contribute to reducing power outages and is expected to be effective.

(2) Effectiveness

1) Quantitative effect

Replacing protective relays with digital relays will improve the reliability of removing grid faults, reduce power outage time by reducing equipment downtime due to periodic inspections, and reduce NEPCO work man-hours.

It is expected that the annual average of 209 minutes of power outage per consumer in 2022 will be reduced to 1/3 in 5 years, which translates into an annual average reduction of 3.1 billion yen in terms of economic loss in Jordan. In addition, NEPCO's maintenance and inspection man-hours have been reduced by a total of 285Man-day. As inspections should be performed by one team 3 person of engineer, foreman, and technician, it is calculated from the labor cost that 14.9-million-yen reduction effect per year is expected.

2) Qualitative effect

In May 2021, a blackout, a power outage that spreads throughout Jordan, occurred, but the occurrence of such a large power outage can be suppressed. In addition, since Jordan's domestic water supply is pumped up from groundwater, there is a possibility that the water supply will also stop if there is a power outage, which may cause major social unrest. The reducing power outage will also lead to the elimination of social anxiety.

A blackout that occurred across Pakistan in January 2021 is an example of a large-scale power outage caused by an outdated protective relay (electro-mechanical type) that could not clear a fault. Because the main protective relay (electromechanical type) was inoperable for the ground fault at the 220kV substation, the fault extended and the whole system collapsed. NEPCO’s protection system also uses many old electromechanical relays, and there is a risk of a large-scale blackout similar to that of Pakistan in the event of a fault. Renewal of the protection relays will avoid such risks.

Contents

The Project for Strengthening Capacity of Power System
Operation in the Hashemite Kingdom of Jordan
Preparatory Survey Report

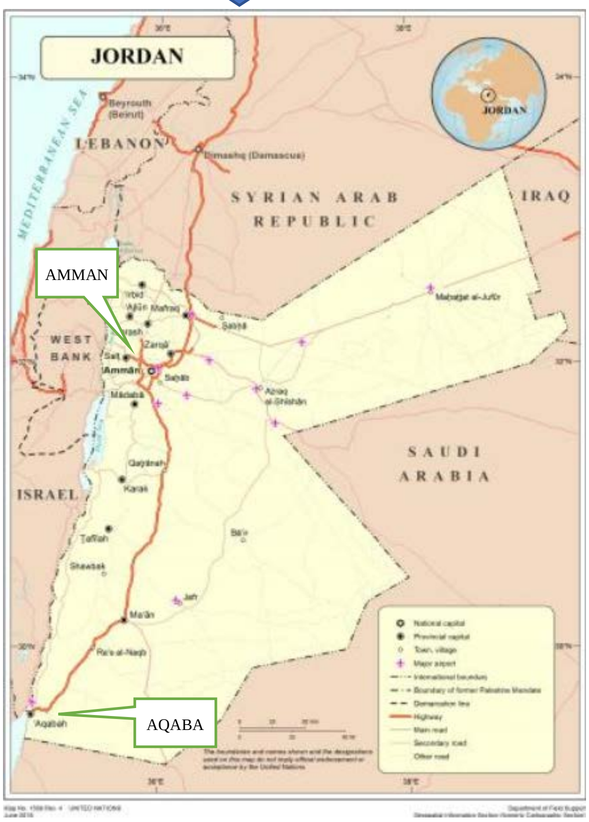
Contents

APPENDICES

Location Map / Perspective

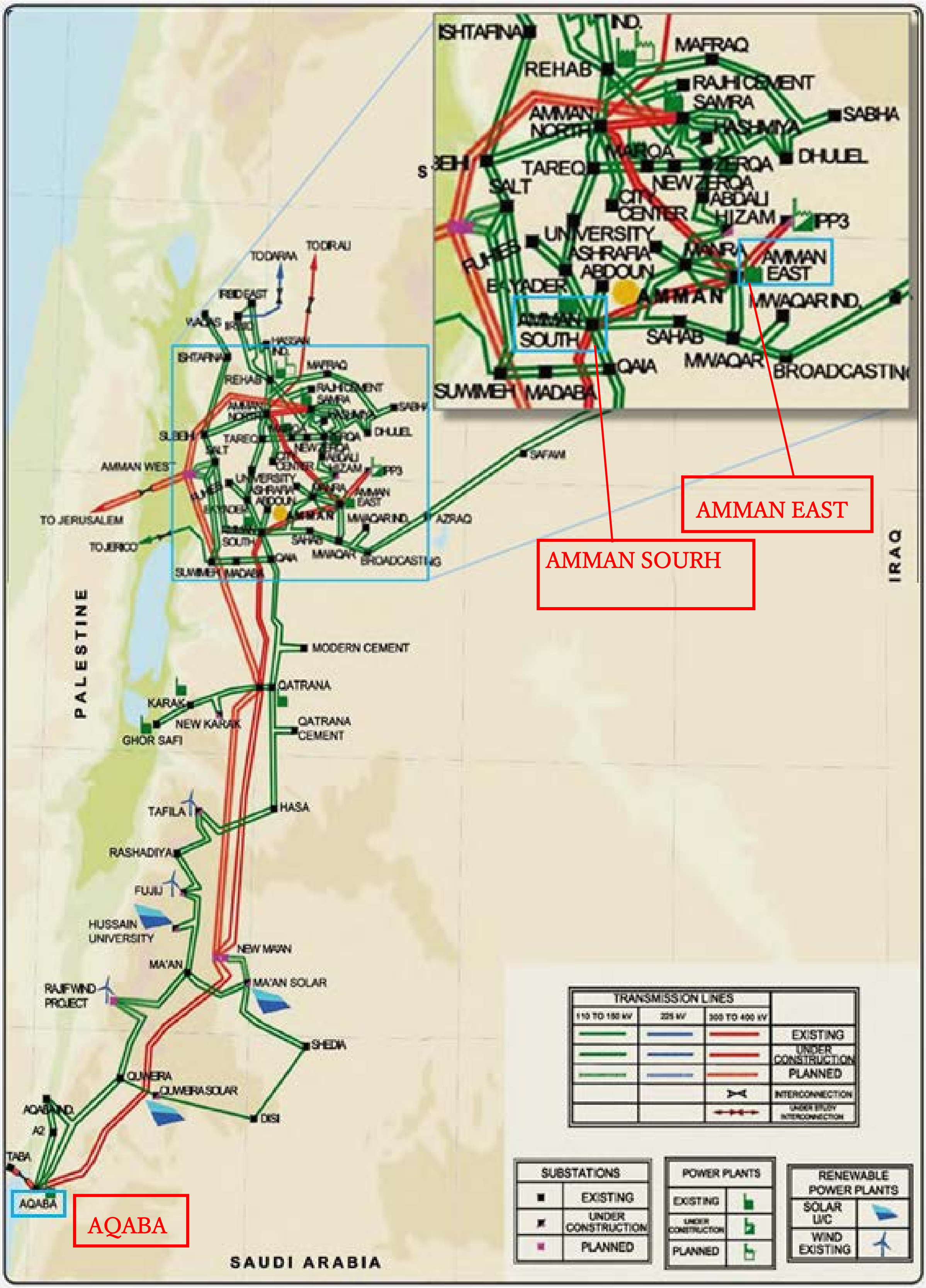
Location Map

The locations of the Amman South, Amman East and Aqaba substations in Jordan, which are the target of this project, are shown.



Source: Prepared by the Study Team based on UN Geospatial

Jordan (NEPCO) Power System



Perspective

(1) Image diagram of relay unit replacement (existing panel)

Current situation

After relay replacement

(2) Panel renewal (132kV Aqaba substation) image

Current status Image

After update

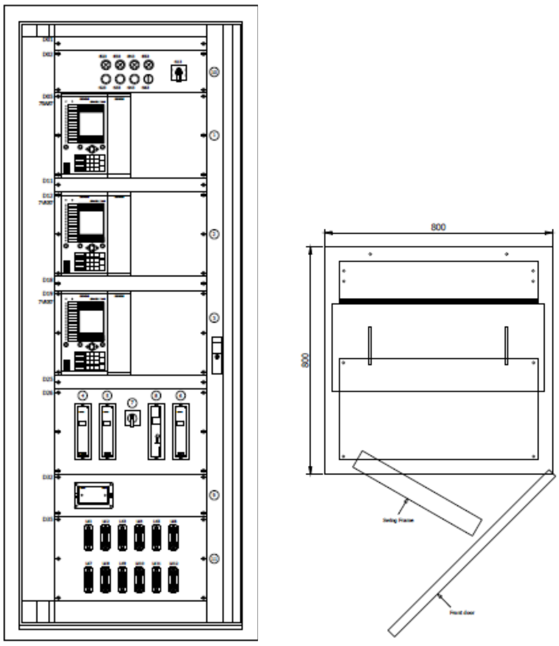


Figure 1. A panel outline figure (example)

List of Figures & Tables / Abbreviations

Figure list

Table list

Abbreviations list

AFDs	AGEnce Frangaise de Developpement
A/P	Authorized to Pay
AR	Auto-reclosing
B/A	Banking arrangements
BCU	Bay Control Unit
Bias. Diff	Biased Differential relay
CBs	circuit breaker
CBF	Circuit breaker failure protection
CBJ	Central Bank of Jordan
CT	Current Transformer
EBRD	European Bank for Reconstruction and Development
E/N	Exchange Notes
DEF	Directional Earth Fault Relay
DIFF (DIF)	Differential relay
DOC	Directional Overcurrent Relay
DZ	Distance relay
EF	Earth Fault Relay
ETC	Electric Training Center
FL	Fault Locators
G/A	Grant Agreement
GDP	Gross Domestic Product
GOJ	Government of Jordan
HV	High Voltage
JICA	Japan International Cooperation Agency
JODs	Jordan Dinar
JPY	Japanese Yen
kWh	Kilo watt hour

LV	Low Voltage
MD, M/D	Minutes of Discussion
MEMR	Ministry of Energy & Mineral Resources
MWh	Mega Watt Hour
NCC	National Control Center
NEPCO	National Electric Power Company
OC	Overcurrent Relay
OVR	Overvoltage Relay
P, S, N	Primary, Secondary, Neutral
PMRs	Project Monitoring Report
SAS	Substation Automation System
SEF	Sensitive Earth Fault relay
ShR	Shunt Reactor
SYNC (25)	Synchronizing relay
Trip CC SV	Trip Circuit Supervision
USAID	United States Agency for International Development
USD	United States Dollar
UV	Undervoltage relay
VTs	voltage transformer
DIF CC (87CC)	Differential for Current Circulating

Chapter 1

Background of the Project

Chapter 1. Background of the Project

1-1 Current Situation and Issues of the Power System Sector

1-1-1 Current Status and Issues

Since the Hashemite Kingdom of Jordan (hereinafter referred to as "Jordan") is poor in natural resources, and in ensuring energy security, the development of renewable energy is one of the most important issues. The Jordanian government enacted “Renewable Energy & Efficiency Law (2012)” and promoted the development of renewable energy. In consequence, renewable energy ratio in the capacity of power generation of Jordan has rapidly increased up to 28% in 2021 from almost 0% in 2014 (National Electric Power Company (NEPCO) annual report).

On the other hand, fluctuations in renewable energy output affect to keep the supply-demand balance and planned grid operation, and there are concerns about a decline in power supply reliability due to destabilization of the power grid system. The average power outage time per customer gradually increases, 26 minutes (2017), 30 minutes (2018), 72 minutes (2019), 136 minutes (2020), and 209 minutes (2022). (NEPCO Annual Report). In May 2021, a large-scale blackout occurred across Jordan.

For the stable operation of the power system, it is essential to improve both the soft and hard aspects. Old static and electromagnetic relays are still in use for transmission line protection relays, busbar protection relays, transformer protection relays, and so on for 400kV substation protection of NEPCO power system. Renewal of these old type relays for 400kV power system is an important for the stable operation. However, it has not been carried forward because of lack of funds, concerning about declining protection performance. Similarly, the 132 kV substations that supply power to key hubs such as the Aqaba Special Economic Zone and Amman capital city continue to use static and electromechanical outdated protection relays.

Protection relays play a very important role in detecting faults at high speed when faults occur in transmission lines, transformers, busbars, etc. of the power system, sending trip signals to circuit breakers, and quickly isolating fault sections. If the 400kV system's protection relays fail to operate properly, a large fault current will continue to flow, leading to equipment damage, as well as unstable phenomena in the power system, causing large-scale or long-term power outages. In addition, static and electromagnetic relays currently in use require periodic inspection and adjustment with outages of the related facilities (transmission lines, transformers, busbars), which poses the risk of power outages due to inspections. Furthermore, there are issues such as the vulnerability of the failure recovery system due to the depletion of repair parts due to aging and the decrease in the number of specialized engineers who can handle maintenance, and the lack of data necessary to identify the cause of grid faults due to the lack of data storage functions.

1-1-2 Development Plan

Jordan's national development policy, "Jordan National Vision and Strategy 2025[1]" classifies various social and economic sectors into four factors, government, business, society, and citizens, and analyzes the issues that each should address. Here, energy security is listed as one of government issues, and the share of renewable energy in the energy mix should be increased to 11% by 2025.[2]

The sector strategy "Jordan Energy Strategy 2020-2030[3]" also recommends the diversification of power sources, including renewable energy. The share of renewable energy in the installed capacity of power generation expanded from almost zero in 2014 to 28% in 2021, but the strategy envisions a further increase in the share to 31%.[4] "The Executive Action Plan of Jordan Energy Strategy 2020-2030", which is the action plan of the strategy, shows a concrete plan for that purpose.

In the Jordan's power sector, the introduction of renewable energy is being promoted as a national policy, due to the lack of natural resources such as oil. The share of renewable energy in the installed capacity has grown rapidly from almost zero in 2014 to 28% in 2021. However, the increase in renewable energy generation causes the reduction in the generation capacity of thermal power synchronous generators and the deduced share of the thermal generation must result in the decrease in the inertia force of the power system, which must weaken the synchronous stability and the power supply reliability. It becomes essential to pay more attention to the stable operation of the grid. This project, which replaces outdated analog protection relays with digital protection relays, will improve the reliability of Jordan's power system in the event of a system fault. The digital protection relays can remove fault points quickly and reliably, and consequently contributes to stable power system operation. Therefore, this project is consistent with Jordan's development strategy of promoting the introduction of renewable energy.

1-1-3 Socio-economic Situation

Jordan has an area of approximately 89,000 square kilometers.[5]The political system is a constitutional monarchy with the hereditary king as the head of state.[6] Although neighboring countries include oil-producing countries, Jordan itself is a non-oil-producing country and lacks natural resources, which makes Jordan dependent on imports for energy. The major import partners are China, Saudi Arabia, and the United States, and the top three import items in 2020 based on trade value are petroleum and bitumen oil (other than crude oil), petroleum and bitumen oil (crude oil), and passenger cars (other automobiles). On the other hand, the main export partners are the United States, India, Saudi Arabia, etc. The top three export items in 2020 were cotton clothing, potash fertilizer (limited to mineral fertilizers and chemical fertilizers), and other

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1 https://andp.unescwa.org/plans/1153
2 Jordan National Vision and Strategy 2025 p.85
3 https://www.memr.gov.jo/EBV4.0/Root_Storage/EN/EB_Info_Page/StrategyEN2020.pdf
4 Summary of Jordan Energy Strategy 2020-2030 p.21 Figure3
5 https://www.mofa.go.jp/mofaj/area/jordan/data.html#section1
6 Ditto

clothing.[7].

Jordan's per capita GDP in 2021 was USD 45,243.66, and real GDP growth was 2.2% in 2021 after shrinking by 1.6% in 2020 due to the spread of COVID-19.[8] However, the unemployment rate in the fourth quarter of 2021 remained high at 23%. In particular, unemployment rates for young people (15-24 years old) and women were high at 52% and 31%, respectively[9], the impact on socially vulnerable groups was significant. However, the capital investment that accounted for 3.5% of GDP in 2021[10] was expected to expand next year as well, and was expected to play a role in boosting the recovery of the labor market. Electric energy is an important infrastructure that supports capital investment and socioeconomics, and stable operation of electric power systems and improvement of supply reliability are desired.

1-2 Background and Outline of Grant Aid Cooperation

For the stable operation of Jordan's power system, improvements in both soft and hard aspects are essential. In terms of software cooperation, JICA has been implementing the "Renewable Energy System Integration and Stable Supply Promotion Project" with NEPCO since FY2019 in order to contribute to both the promotion of renewable energy and the stable operation of the power system. While it is strengthening the operational capabilities, NEPCO's power system is equipped with static and electromechanical relays for transmission line protection relays, busbar protection relays, transformer protection relays, etc. at 400kV substations. Not only operational capacity building, it is important to replace relays for stable system operation, but the renewal of the old relays has not proceeded because of lack of funding.

If the protection relays cannot operate properly, a system fault will spread, and in the worst case, it may lead to a blackout. Once a blackout occurs, it will take time to recover from it, and during that time social unrest and economic loss will be great.

Under these circumstances, the Government of Jordan requested the Government of Japan to implement a project to replace the protection relay equipment at the Aqaba Substation and other core substations with digital protection relay equipment which has superior reliability and maintainability. Based on this request, JICA carried out this preparatory survey in order to confirm the necessity and validity of implementing this project as grant aid, to formulate the plans necessary for the implementation of the project, to estimate the approximate project costs, and to propose the contents of the partner country's share of the necessary work to achieve the project goals.

[7] https://jo.usembassy.gov/wp-content/uploads/sites/34/09-2022-Jordan-in-Numbers.pdf
p.1 Jordan's trade summary
[8] https://www.worldbank.org/en/country/jordan/publication/jordan-economic-monitor-spring-2022Jordan Economic Monitor Spring 2022 p.ix
[9]Ditto p.2
[10]Ditto p.7

1-3 Japan's Cooperation Trends

Japan has provided the following assistance in the past in relation to Jordan's power sector.

Table 1-1 Japan's assistance related to the power sector in Jordan

Classification of project	Implemented FY	Name of project	Summary
Technical cooperation	1985-1990	Technical Cooperation Project for the Electric Power Training Centre in the Hashemite Kingdom of Jordan	Establishing an electric power training centre to train engineers engaged in the electric power business in the fields of generation, transmission or distribution
	2004-2005	Rehabilitation of NEPCO Training Centre in the Hashemite Kingdom of Jordan	Strengthening the structure of the electric power training centre to meet advanced training needs for cutting-edge technologies
	2014-2016	The Project for the Study on Electricity Sector Master Plan in the Hashemite Kingdom of Jordan	Settlement of a 2015– 2034 master plan for the electric power sector and support for establishing a management system for its periodic update
	2019-2023	The Project for Integration of Variable Renewable Energy into Power Network System and Enhancing Supply Reliability in the Hashemite Kingdom of Jordan	Strengthen organizational capacity necessary to stabilize the grid system and improve supply reliability
Training Program	2020-2022	Management Efficiency and Analyzing the Impact of Tariff Structure to the Power Utilities	Through planning and strengthening implementation capacity for improving electricity business management, NEPCO it contributes to improving the quality of service delivery and the sustainability of operations of NEPCO.
	2020-2022	Energy efficiency, savings and demand side management	Capacity development related to the planning and implementation of energy conservation policies.
Loan Aid (Development Policy Loan)	2022	Power Sector Reform and Resilience Enhancement Program Loan	This project provides financial support to the Jordanian government, which is working on reforms aimed at strengthening the power sector.

1-4 Cooperation Trends of Other Donors

In Jordan, various donors such as USAID, AFD, and EBRD are providing assistance to the power sector.[11] Among them, the project "NEPCO Restructuring Loan" implemented by EBRD[12] included in "Replacement Of Sub-Station Automation System (SAS) In Existing Substation With Replacement Of All Old Relays[13]" has in common the replacement of outdated protection relays at existing substations, and is highly similar to this project.

Table 1-2 EBRD Jordan Aid Project

Project Title	NEPCO Restructuring loan (Replacement of Sub-Station Automation System (SAS) In Existing Substation with Replacement of All Old Relays)
Executing agency	European Bank for Reconstruction and Development (EBRD)
Aid form	sovereign loan
Amount of money Unit: thousand USD	265,000[14]
Fiscal year	Up to 18 years from 2018[15](Continued from 2020 to the present)
Project target institution	NEPCO
Overview	・ NEPCO Restructuring Loan is used for the following two purposes[16]. ① Financing capital investments to improve renewable power integration, such as smart grid systems and new substations ② Extend tenors of existing debt and refinance to terms more suited to business ・ Of the loans①up to USD 65million,②up to 200 million. ・ As part of the project "Replacement Of Sub-Station Automation System (SAS) In Existing Substation With Replacement Of All Old Relays①", the SAS systems (Substation Automation System) at Ammann North and Katrana substations will be updated and all obsolete protection relays will be replaced.

[11] For example, as an example of assistance to the power sector,Energy Sector Capacity Building by USAIDThere are projects such ashttps://pdf.usaid.gov/pdf_docs/PA00T3JR.pdf
[12] https://www.ebrd.com/work-with-us/projects/psd/nepco-restructuring-loan.html
[13] https://ecepp.ebrd.com/delta/viewNotice.html?displayNoticeId=19085470
[14] https://www.ebrd.com/work-with-us/projects/psd/nepco-restructuring-loan.html
[15]Non-Technical Summaryhttps://www.ebrd.com/work-with-us/projects/psd/nepco-restructuring-loan.htmlp.1
[16]Non-Technical Summaryhttps://www.ebrd.com/work-with-us/projects/psd/nepco-restructuring-loan.htmlp.1

1-5 Project Site and Surrounding Conditions

1-5-1 Development Status of Related Infrastructure

The construction of this project will be carried out in the existing relay rooms of Amman South Substation, Amman East Substation and Aqaba Substation. The relay rooms of these substations are equipped with electricity, water supply, and air conditioning, and the work environment is good. Also, all the substations have easy access roads connected to the main roads, so there is no problem in transporting equipment.

A current differential relay is applied to Amman South - Amman East line protection, and the communication channels between relays at both terminals can be realized via the directly connected optical fibers, because the distance is 31 km or less and there is no performance problem. Considering NEPCO's optical fiber installation record, there is no problem with optical communication installation work.

1-5-2 Natural Environmental Conditions

According to the Köppen climate classification, Jordan has three climates. The western Mediterranean region has a Mediterranean climate, the inland region has a steppe climate, and the region near the border with Saudi Arabia and Iraq has a desert climate.[17] The desert climate occupies the largest area, and 75% of the country is classified as a desert climate with an annual rainfall of 200 mm or less.

Figures 1-1 and 1-2 show the average temperature and precipitation in Amman and Aqaba. In Amman, where the target site is located, the highest average daily temperature is 32.4 degrees in August, and the lowest average daily minimum temperature is about 3.6 degrees in January.[18] Aqaba, where another target site is located, has the highest average maximum temperature in July at 39.4°C and the lowest average minimum temperature in January at 8.9°C.[19] Aqaba is warmer than Amman throughout the year.

Jordan generally has little rainfall throughout the year, and Amman and Aqaba are no exception. However, in Amman, from December to February, 50 mm to 60 mm of total precipitation is observed.[20] On the other hand, in Aqaba, even in December, the rainiest month of the year, total rainfall remains at around 8 mm per month.[21] In Jordan, about 60% of water withdrawal comes from fresh groundwater,[22] electric power is used for pumping up groundwater and conducting long-distance water transmission.[23] In fact, as shown in Figure 1-3, consumption by pumping (pumping groundwater) accounted for 16% of electricity consumption by sector in 2018.[24] Power outage prevention is directly linked to the country's stable water supply.

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[17] https://www.mofa.go.jp/mofaj/gaiko/oda/sanka/kyouiku/kaihatsu/chikyu/world_info/asia/jordan/index.html
[18] https://worldweather.wmo.int/en/city.html?cityId=215
[19] https://worldweather.wmo.int/en/city.html?cityId=591
[20] See note 18
[21] See note 19
[22] https://unesdoc.unesco.org/ark:/48223/pf0000380721 p.138 Figure 8.7
[23] https://www.jica.go.jp/activities/issues/water/ku57pq00002cybbn-att/guideline_water.pdf p.9 Note 66
[24] https://www.memr.gov.jo/EBV4.0/Root_Storage/EN/EB_Info_Page/StrategyEN2020.pdf p.31

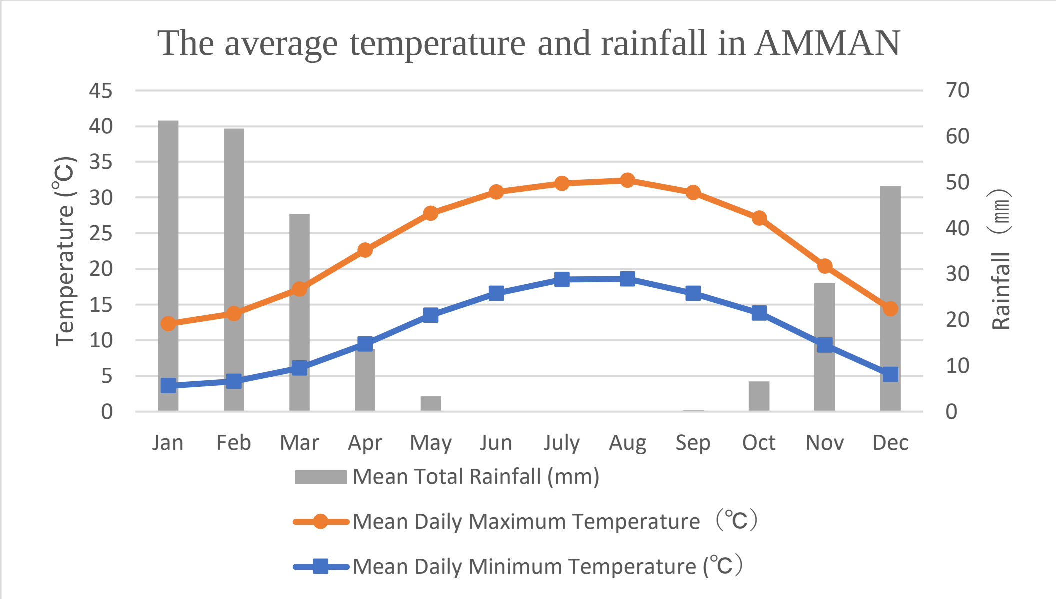


Figure 1-1 Average temperature and precipitation in Amman

(Source: Prepared by the Study Team based on World Weather Information Service)

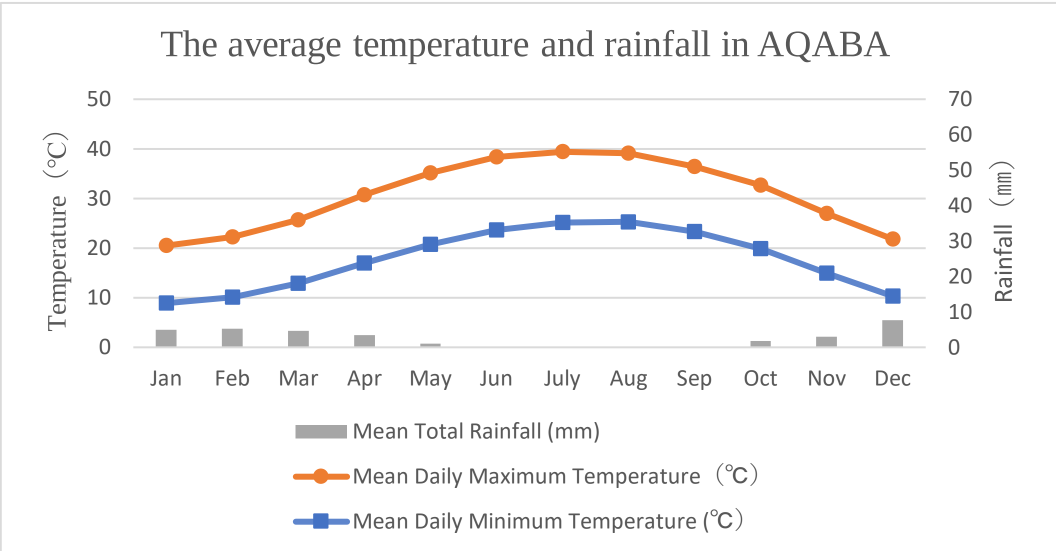


Figure 1-2 Average temperature and precipitation in Aqaba

(Source: Prepared by the Study Team based on World Weather Information Service)

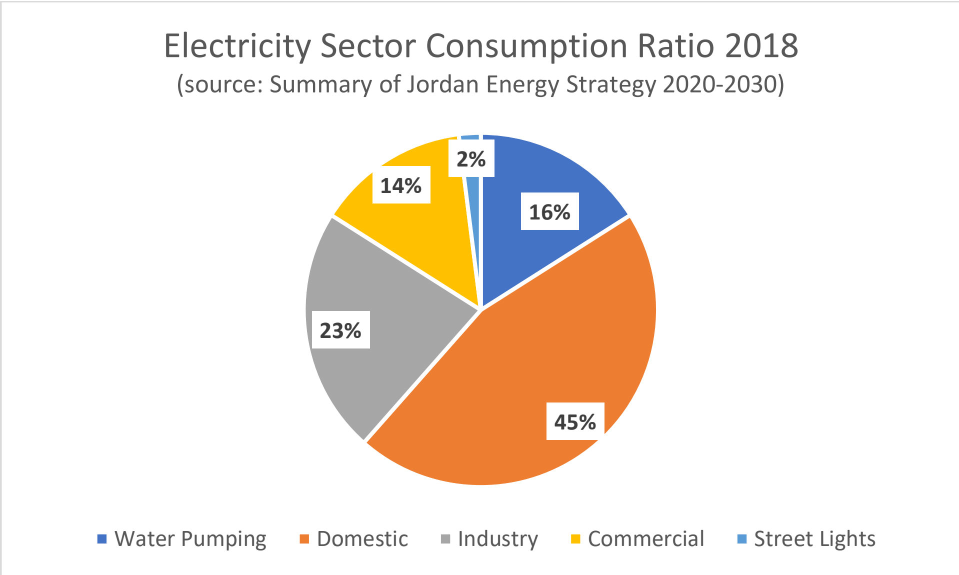


Figure 1-3 1Electricity Consumption Ratio by Sector

(Source: Prepared by the study team based on the Jordan Energy Strategy 2020-2030)

1-6 Environmental and Social Considerations

The equipment to be procured under this project will be deployed inside the substation, and no impact on the environment or society is expected. Therefore, it is classified as Category C in the JICA Guidelines for Environmental and Social Considerations.[25] This means that the project will not have any undesirable impacts on the environment or society.

1-7 Considerations in Implementing the Projects in Recipient Countries

In carrying out this project, the protection relay replacement work will need the protected equipment outages, such as the transmission line, transformer, or busbar. For this reason, it is necessary to coordinate the replacement work plan with the maintenance outage plan managed by the National Control Center (NCC) as early as possible. In particular, the 132 kV busbar is a double main busbar system, and it is necessary to alternately stop one side of the busbar to replace the busbar protection relay. However, it is necessary to study the work method in detail in advance so that the outage period can be shortened as much as possible. The study of the work method is not limited to the busbar protection relay, but the replacement of other protection relays will also be examined in detail in advance.

In addition, when replacing the protection relay of the transmission line, it is necessary to open the circuit breaker at the remote end even though the protection relay at the remote end is not replaced. During the replacement work period, a detailed study will be carried out in advance taking account of the outages in other substations to secure the total supply reliability in the network.

[25]See DOD MD p.4 11. Environmental and Social Considerations

Chapter 2

Contents of the Project

Chapter 2. Contents of the Project

2-1 Project Outline

The purpose of this project is to replace aging protective relays with the latest digital relays, mainly at the 400kV Amman South Substation and 400kV Aqaba Substation, which play an important role in the stable operation of the NEPCO power system. It aims to improve the stable operation capability of the power system and reduce the power outage duration and frequency.

- The aging 400kV transmission lines, 400kV transformers, and 400kV busbar protection relays in 400kV Amman South Substation and 400kV Aqaba Substation will be given top priority for replacement.
- For the protection relay of the 400kV Amman South-Amman East transmission line, it will be applied a current differential relay system that adopted a multi-phase reclosing system with a large stability improvement effect. Since the relays of both Amman South and Amman East must also have the same specifications, it is considered as both of them to be replaced.

In addition, considering the importance and degree of deterioration of the equipment to be protected, the 132kV protection relays are also to be replaced as follows.

- The 132kV equipment at the Aqaba Substation is an important facility responsible for supplying power to the Aqaba region, which is a special economic zone. Therefore, the 132 kV transmission line, 132 kV transformer, and 132 kV busbar protection relays are subject to replacement.
- Since the Amman South Substation is an important substation supplying the metropolitan area, the aging 132kV transmission line, 132kV transformer, and 132kV busbar protection relays will be replaced.

The method of replacement except for Aqaba 132kV relays is protection relay unit basis (retrofitting work), which NEPCO has experience with. This will reduce power outage time associated with replacement work and ensure replacement work reliability, as well as learning maintenance and operation techniques for NEPCO's new protection relay through testing and operation at the time of replacement. Aqaba 132kV relays are installed on the panel basis in a new relay room because NEPCO have a plan to move them to the new building.

By replacing the old analog relays with the latest digital relays, this project will contribute to reduce NEPCO's manpower required for maintenance inspections, because the new relay does not need the routine maintenance and inspection works of protection relays (14.9 million yen per year). This project aims to reduce the average annual power outage time (reduce annual average economic loss of 3.1 billion yen), thereby contributing to the social and economic development of Jordan.

2-2 Outline Design of the Japanese Assistance

2-2-1 Design Policy

As a basic design policy, in order to improve the supply reliability of NEPCO's 400kV trunk system, the old transmission line protection relays, transformer protection relays, and busbar protection relays at the Amman South substation and Aqaba substation will be replaced with digital relays. The basic specification of the transmission line protection relay is a digital current differential relay system, which can be expected to improve the reclosing method. When providing a protection relay of the same type, it is necessary to update the transmission line protection relay of the opposing substation. Therefore, replacement of transmission line protection relays at Amman East Substation was also targeted.

Based on the above, the design was carried out according to the following basic selection policy.

- The aging 400kV Amman South Substation and 400kV Aqaba Substation's 400kV transmission lines, 400kV transformers, and 400kV bus protection relays will be given top priority for replacement.
- Regarding the protection relay of the 400kV transmission line, if the current differential system is introduced, the protection relay of the opposing substation must also have the same specifications, so this equipment is subject to replacement. The introduction of the current differential method enables the application of the multi-phase reclosing method, which is expected to contribute to the improvement of transient stability. The current differential relay system will be applied only to the Amman South-Amman East line protection relays, partly because the relays have only recently been upgraded to the digital relays at Qatrana and New Ma'an substations. NEPCO will consider expanding the application to other transmission line protection in the future.

In addition to the 400kV protection relays originally planned, considering the importance of the equipment to be protected and the degree of deterioration of the protection relays that protect the equipment, it was decided to investigate 132kV protection relays and add them to the design targets. The basic selection policy is as follows.

- The 132kV equipment at the Aqaba Substation is an important facility responsible for supplying power to the Aqaba region, which is a special economic zone. 132 kV transmission lines, 132 kV transformers, and 132 kV busbar protection relays are subject to replacement.
- Since the Amman South Substation is an important substation supplying the metropolitan area, the aging 132kV transmission line, 132kV transformer, and 132kV busbar protection relays will be replaced.

2-2-2 Basic Plan (Construction Plan / Equipment Plan)

2-2-2-1 Overall plan

Initially, it was assumed that the protection relays would be replaced protection relay panels, but NEPCO proposed to adopt a replacement method protection relay unit basis and that NEPCO proposed directly manage the replacement work. NEPCO had a lot of experience with this replacement on a unit-by-unit basis method. It was agreed to do so, and formulated a basic plan based on this policy. Since it is necessary to change the installation location (relay room) of the protection relays of the 132 kV equipment in Aqaba, it was decided that the replacement work would be done by panel basis, and that the replacement work would be carried out directly by NEPCO.

The outline of the substation to be replaced and the protection relay to be replaced is according to the design policy of 2-2-1and Table 2-1 as follows.

Table 2-1 Outline of equipment to be replaced

Substation	Protection relay type	Exchange method	Work place
Amman south	400kV Transmission line	Unit replacement	Existing relay panel
	400kV/132kV Transformer	Unit replacement	Existing relay panel
	400kV Busbar	Unit replacement	Existing relay panel
	132kV Transmission line	Unit replacement	Existing relay panel
	132kV/33kV Transformer	Unit replacement	Existing relay panel
	132kV Busbar	Unit replacement	Existing relay panel
Aqaba	400kV Transmission line	Unit replacement	Existing relay panel
	400kV/132kV Transformer	Unit replacement	Existing relay panel
	400kV Busbar	Unit replacement	Existing relay panel
	132kV Transmission line	Panel replacement	New relay room
	132kV/33kV Transformer	Panel replacement	New relay room
	132kV Busbar	Panel replacement	New relay room
Amman East	400kV Transmission line (Amman South Line)	Unit replacement	Existing relay panel

2-2-2-2 Equipment plan

The equipment to be provided this time is shown in Table 2-2 for the 400kV protection relay, and the 400kV Egyptian interconnection cable protection relay at the Aqaba cable terminal will be replaced as relay unit. NEPCO will carry out installation work.

Table 2-2 Quantity of 400kV protection relays to be renewed

Protection type	Kind of Relays	remarks	unit quantity				total
			amman south	amman east	Aqaba	aqaba cable end	
Transmission line protection	current differential relay	Integrated type such as distance relay, overcurrent relay, voltage relay,	4	4		1	9
	distance relay	Integrated overcurrent relay, voltage relay, overload protection,	4		6		10
	Hig-impedance differential relay	Stub protection	8		6		14
	Autorecloser				3		
Out-of-step protection	Distance type out-of-step relay	Egypt interconnector			1		1
Shunt reactor (ShR) protection	overcurrent relay				5		5
	High-impedance differential relay				6		6
Breaker failure protection & control (DIAMETER)	Overcurrent relay (CBF)		18		22		40
	Synchronization confirmation relay		9		8		17
Transformer protection (400kV/132kV transformers, generator transformers)	Biased differential relay		4		7		11
	High-impedance differential relay		4		4		8
	overcurrent relay		2		0		2
Busbar protection	High-impedance differential relay		8		8		16
Relay setting tool (laptop PC)			1	1	1	1	4

Table 2-3 summaries the 132kV protection relays for the Aqaba substation and the Amman South substation, with the 132kV protection relay for the Aqaba substation being provided as a panel and the 132kV protection relay for the Amman South substation being provided as a unit. The replacement of these protection relays will also be directly managed by NEPCO.

Table 2-3 Quantity of 132kV protection relays to be renewed

Protection type	Relay method	Remarks	Unit quantity		Total unit Q'ty	Panel Q'ty
			Amman South	Aqaba		Aqaba
Transmission line protection	Distance relay	Integrated overcurrent relay, voltage relay, overload protection,	7	4	11	4
	Overcurrent relay	OC/EF/SEF	9	4	13	
	Control	BCU		4	4	
Transformer protection (400kV/132kV transformer secondary, 132kV/33kV transformer)	Biased differential		3	4	7	6
	High-impedance differential relay	Restricted EF	3		3	
	Current/voltage relay	OC/EF/SEF/UV/25	9	10	19	
	Control	BCU		6	6	
Busbar protection	High-impedance differential relay	High Imp	4	4	8	4
Buscoupler Bussection	Current/voltage relay	OC/EF/SEF/UV/25	2	2	4	2
	Control	BCU		2	2	
Relay setting tool (laptop)			1	1	2	

The installation work of the protection relay will be carried out directly by NEPCO, in which commissioning tests will need to be carried out after the replacement of the protection relay, and it is envisaged that the installation work will be carried out simultaneously at several substations. Therefore, the testing equipment will be insufficient and the testing equipment listed in Table 2-4 will be the provisioning equipment.

Table 2-4 Test equipment

Equipment name	Quantity
Relay test equipment CMC356	2
Same as above primary injection tester CPC100	1

The specifications are based on NEPCO's standard specifications, and 400kV protection will have two main protection (duplicated) system. On the other hand, 132kV has single configuration, but for transmission line protection and transformer protection, the operational reliability will be improved by separating the relay units for main protection and back-up protection. Furthermore, taking into account the co-ordination with the system of the opposing new substation by another donor, the following system will be applied.

Table 2-5 Protection scheme (Amman South Substation 400kV)

Equipment name	Main/backup	Protection scheme	Remarks
Transmission line protection Amman East Line	1st Main	Current differential	Distance and overcurrent relay built-in
	2nd Main	Current differential	Distance and overcurrent relay built-in
Transmission line protection Qatrana Line	1st Main	Directional comparison	Overcurrent relay built-in
	2nd Main	Directional comparison	Overcurrent relay built-in
Transformer protection	1st Main	Biased differential	Overcurrent relay built-in
	2nd Main	Biased differential	Overcurrent relay built-in
Busbar protection	1st Main	High-impedance differential	
	2nd Main	High-impedance differential	
Breaker failure protection (CBF)	1st Main	Overcurrent protection	
	2nd Main	Overcurrent protection	

Table 2-6 Protection scheme (Amman East Substation 400kV)

Equipment name	Main/backup	Protection scheme	Remarks
Transmission line protection Amman South Line	1st Main	Current differential	Distance and overcurrent relay built-in
	2nd Main	Current differential	Distance and overcurrent relay built-in

Table 2-7 Protection scheme (Aqaba substation 400kV)

Equipment name	Main/backup	Protection scheme	Remarks
Transmission line protection	1st Main	Directional comparison	Overcurrent relay, overload protection built-in
	2nd Main	Directional comparison	Overcurrent relay, overload protection built-in
	Stub	High-impedance differential	
Reactor protection	1st Main	High-impedance differential	
	2nd Main	High-impedance differential	
Transformer protection 400/132kV	1st Main	Biased differential	Overcurrent relay built-in
	2nd Main	Biased differential	Overcurrent relay built-in
Busbar protection	1st Main	High-impedance differential	
	2nd Main	High-impedance differential	
Breaker failure protection (CBF)	1st Main	Overcurrent protection	
	2nd Main	Overcurrent protection	

Generator transformer protection	Primary protection	Biased differential protection	
	Backup protection	Overcurrent protection	

Table 2-8 Protection scheme (Aqaba cable end 400kV)

Equipment name	Main/backup	Protection scheme	Remarks
Cable line protection Egyptian interconnector	1st Main	Current differential	

Table 2-9 Protection scheme (Aqaba 132kV)

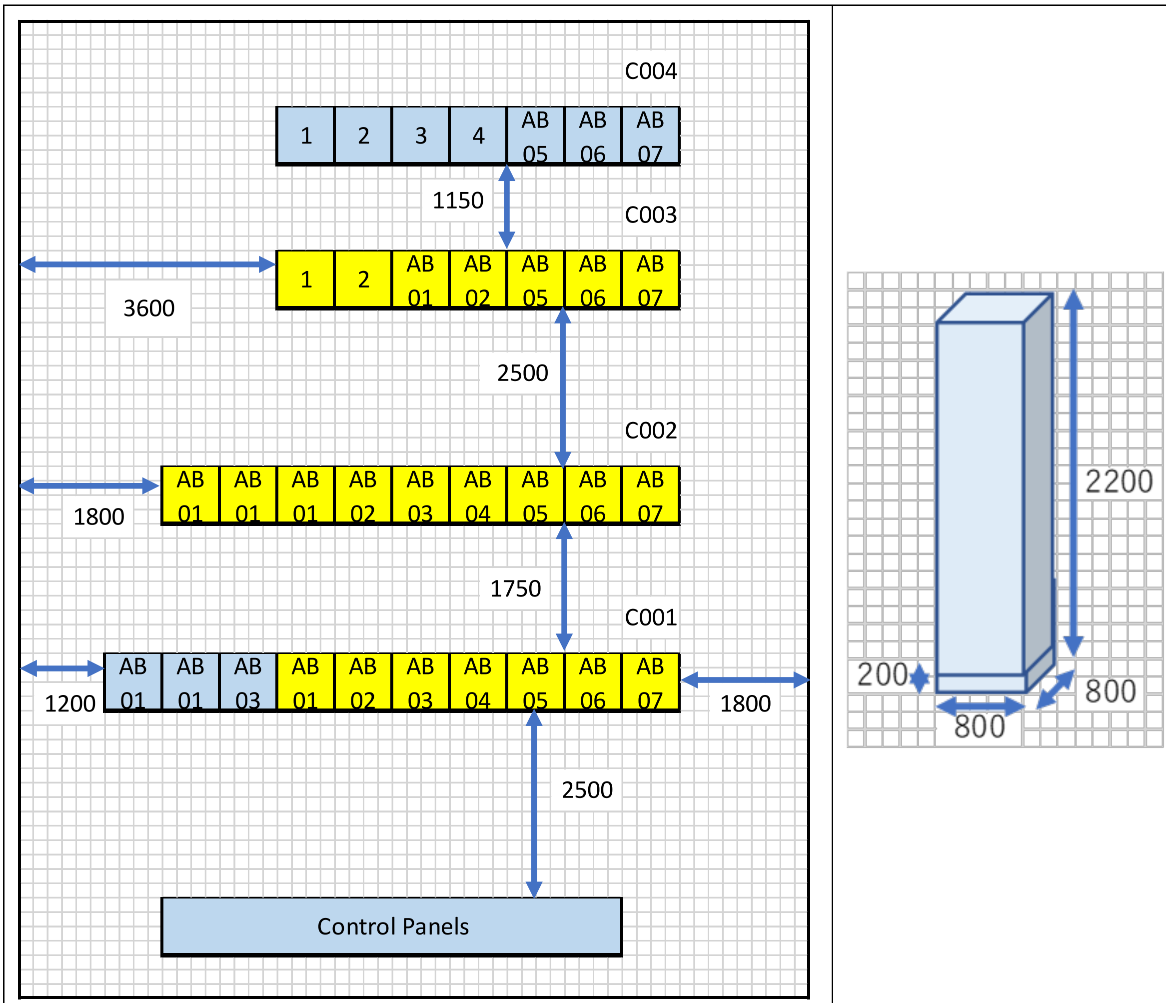
Equipment name	Main/backup	Protection scheme	Remarks
Transmission line protection	Main	Directional comparison	
	Backup	Overcurrent	
Transformer protection 400/132kV	Secondary backup	Overcurrent	
Transformer protection 132kV/33kV	Main	Biased differential	
	Backup	Overcurrent	
Busbar protection	Main	High- Impedance differential	CBF Trip circuits are considered.
Bus coupler, Bus section	Main	Overcurrent	Synchronous confirmation relay built-in

Table 2-10 Protection scheme (Amman South 132kV)

Equipment name	Main/backup	Protection scheme	Remarks
Transmission line protection	Main	Directional comparison	
	Backup	Overcurrent	
Transformer protection 400/132kV	Secondary backup	Overcurrent	
Transformer protection 132kV/33kV	Main	Biased differential	
	Backup	Overcurrent	
Busbar protection	Main	High-impedance differential	
Bus coupler, Bus section	Main	Overcurrent	Synchronous confirmation relay built-in

2-2-3 Outline Design Drawing

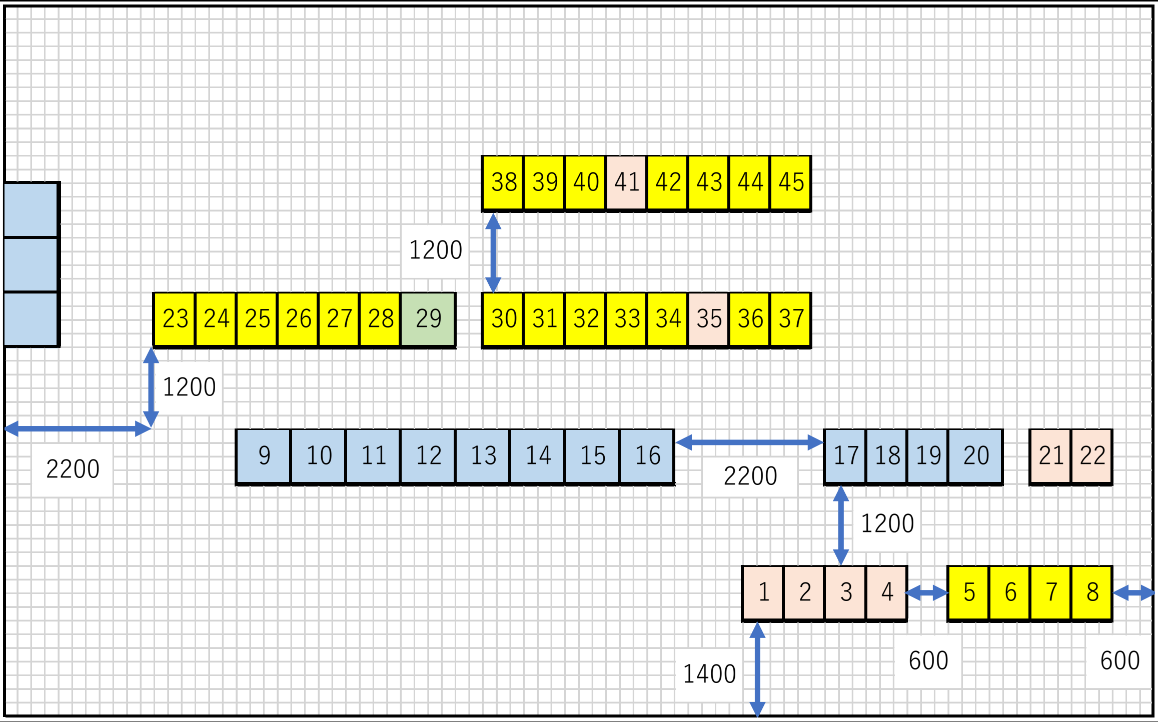
The layout of the 400kV protection relay panel at Amman South substation and the panel dimensions are shown in Figure 2-1. The yellow panels in this diagram indicate the panels to be replaced with new relay units, and the name of each target relay panel is shown at the bottom.



C001	C002	C003
AB01: Transformer T01	AB01: Busbar 1 Protection	1: 400kV Amman East 2 Main1
AB02: Transformer T01	AB02: Busbar 2 Protection	2: 400kV Amman East 2 Main2
AB03: 400kV Qatrana #1 Main1	AB01: 400kV Qatrana #2 Main1	AB01: Transformer T02 Main1
AB04: 400kV Qatrana #1 Main2	AB02: 400kV Qatrana #2 Main2	AB02: Transformer T02 Main2
AB05: 400kV Q01 CB X110	AB03: 400kV Amman East 1 Main1	AB05: 400kV Q01 CB X405
AB06: 400kV Q01 CB X130	AB04: 400kV Amman East 1 Main2	AB06: 400kV Q01 CB X330
AB07: 400kV Q01 CB X105	AB05: 400kV Q01 CB X205	AB07: 400kV Q01 CB X210
	AB06: 400kV Q01 CB X230	
	AB07: 400kV Q01 CB X305	

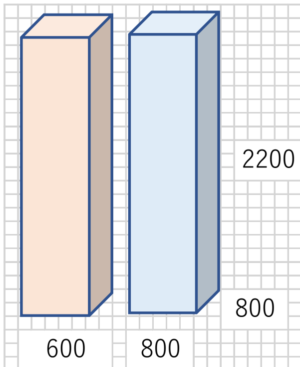
Figure 2-1 Panel layout of Amman South substation in 400kV relay room

The layout of the 400kV protection relay panel at Aqaba substation and the panel dimensions are shown in Figure 2-2. There are 600 mm and 800 mm width panels existed. The yellow and green panels in this diagram indicate the panels to be replaced with new relay units, and the name of each target relay panel is shown at the bottom.



5: Busbar 1 Protection
6: Busbar 1 Protection
7: Busbar 2 Protection
8: Busbar 2 Protection
23: Egypt Interconnector 1 CB X300
24: Egypt Interconnector 1 Main1
25: Egypt Interconnector 1 Main2
26: Common Equipment
27: Egypt Interconnector 1 Shunt Reactor
28: Egypt Interconnector 1 CB X305
29: Power Swing Tripping
30: 400kV CB X110
31: Transformer TR1 HV Protection

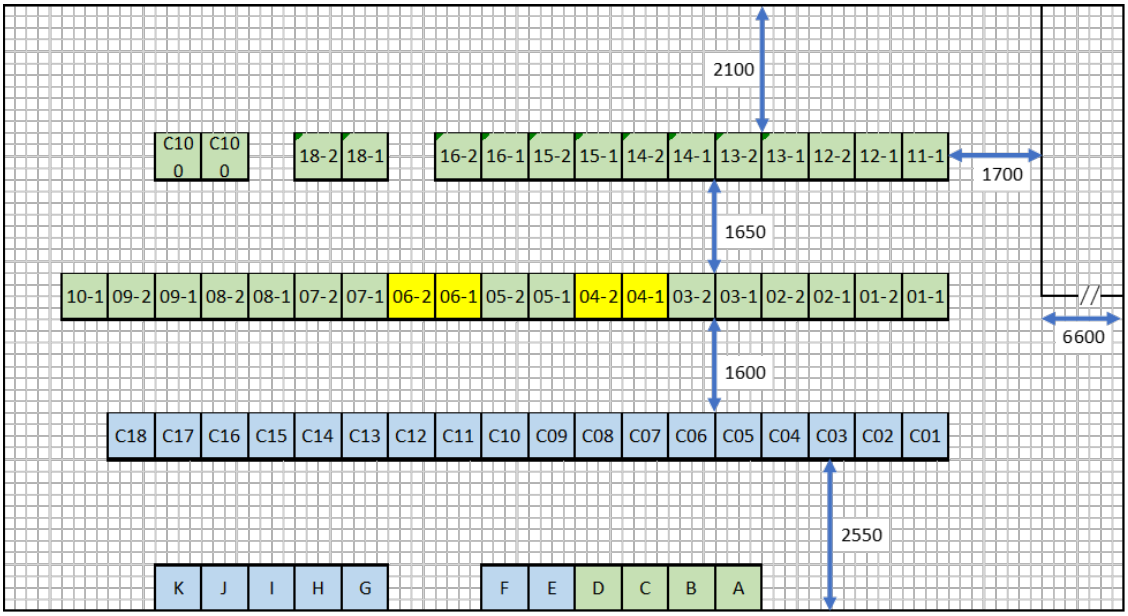
32: 400kV CB X130
33: 400kV New Ma’an 1 Main1
34: 400kV New Ma’an 1 Main2
35: New Ma’an 1 Common
36: New Ma’an 1 Shunt Reactor
37: 400kV CB X105
38: 400kV CB X205
39: 400kV New Ma’an 2 Main1
40: 400kV New Ma’an 2 Main2
41: New Ma’an 2 Common
42: New Ma’an 2 Shunt Reactor
43: 400kV CB X230
44: 400kV Transformer TR2 HV
45: 400kV CB X210



2 types of width:
600 mm and 800 mm

Figure 2-2 Panel layout of Aqaba substation in 400kV relay room

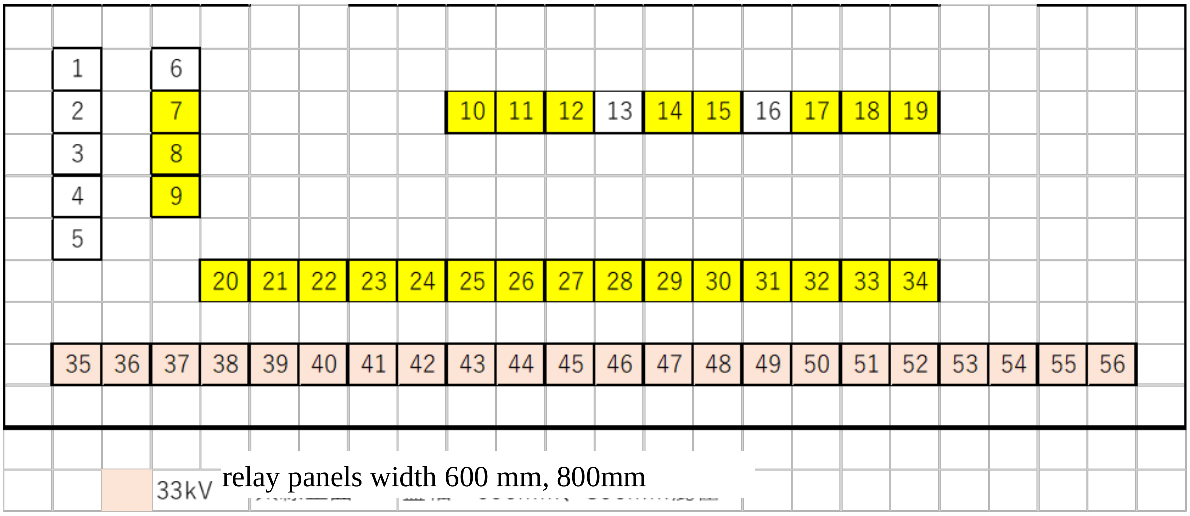
The layout of the 400kV protection relay panel at Amman East substation are shown in Figure 2-3. The panel dimensions are same as Amman South panels, W:800mm x D:800mm x H:2200mm. The yellow panels in this diagram indicate the panels to be replaced with new relay units, and the name of each target relay panel is shown at the bottom.



04-1: 400kV Amman South #1 Main1 04-2: 400kV Amman South #1 Main2 06-1: 400kV Amman South #2 Main1 06-2: 400kV Amman South #2 Main2	Panel width：800mm

Figure 2-3 Panel layout of Amman East substation in 400kV relay room

The layout of the 132kV protection relay panel at Amman South substation is shown in Figure 2-4. There are 600 mm and 800 mm width panels existed. The yellow panels in this diagram indicate the panels to be replaced with new relay units, and the name of each target relay panel is shown at the bottom.



7:132kV Transformer No.4	23: 400/132kV Transformer No.1 Secondary
8: 400/132kV Transformer #.2 Secondary	24: 132kV OHL (Backup)
9: 132kV Q.A.I.A. No.2 (Backup)	25: 132kV OHL (Main)
10: 132/33kV Transformer No.1	26: 132kV Bayader No.2 (Backup)
11: 132/33kV Transformer No.2	27: 132kV Bayader No.2 (Main)
12:132kV MARANAH (Backup)	28: 132kB Bus Section
14: Bus Coupler	29: 132kV Bayader No.1 (Backup)
15: 132kV SAHAB (Backup)	30: 132kV Bayader No.1 (Main)
17: Busbar Protection	31: 132kV AL Bayader No.3 (Main)
18: Busbar Protection	32: 132kV AL Bayader No.3 (Backup)
19: Busbar Protection	33: 132kV SALT 2 (Backup)
20: 132kV Q.A.I.A No.2 (Main)	34: 132kV SALT 2 (Main)
21: 132kV Q.A.I.A No.1 (Backup)	
22: 132kV Q.A.I.A No.1 (Main)	

Figure 2-4 Panel layout of Amman South substation in 132kV/33kV relay room

The 132kV protection relay panel at Aqaba substation would be installed as a new panel at a new location with protection relays for the equipment listed in Table 2-11, and new control and DC power cables would also be laid and connected. This laying and connection work would be carried out directly by NEPCO. The location of the new installation has not yet been determined, and the layout of the relay panel will be decided after the installation site has been finalised.

Table 2-11 Aqaba 132kV protection relay list to be replaced

Facility name (feeder name)	Panel Q'ty
132kV Aqaba Town line #1	1
132kV Aqaba Town line #2	1
132kV Qweira line	1
132kV Aie line	1
400kV/132kV Transformer #1 Secondary	1
400kV/132kV Transformer #2 Secondary	1
132/33kV Transformer ST1	1
132/33kV Transformer ST2	1
132/33kV Transformer ST3	1
132/33kV Transformer ST4	1
132kV Bus Coupler	1
132kV Bus Section	1
132kV Busbar Protection	4

2-2-4 Implementation Plan

2-2-4-1 Implementation Policy

(1) Implementation policy

In this project, new protection relay units or protection relay panels will be provided to NEPCO, and NEPCO itself will carry out the installation work of each provided protection relay unit, the connection of control cables to the protection relay panel and the function test of the protection relay.

As NEPCO has wealthy experience in replacing protection relay units by itself and in replacing protection relays with new panels, this installation work will be carried out cooperatively by NEPCO and technical advisors (supervisor for relay test) from the equipment supplier who will be dispatched to the site.

In addition, the Aqaba 132kV protection relay room will adopt the new panel installation method in line with NEPCO's plan to move to the new building. NEPCO will carry out the installation work, and similarly, a joint work system will be adopted in which technical advisors from the equipment supplier will be dispatched to increase the effectiveness of cooperation, including technology transfer.

In terms of maintenance and operation, spare parts will be provided, and the quantity will be about 10%

of the quantity provided, based on NEPCO's experience in new installation work.

The implementation structure on the NEPCO side is shown in Figure2-5, where the Transmission Maintenance Division will be in charge of studying specifications and implementation methods, while the maintenance departments in Middle and Aqaba will be in charge of implementation work.

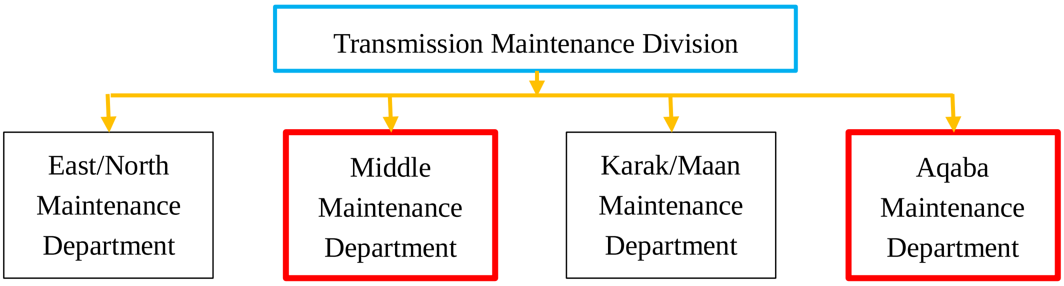


Figure 2-5 NEPCO's implementation structure

(2) Procurement policy

The current differential relay system for the 400kV transmission line to be introduced into NEPCO for the first time has a multi-phase reclosing function, and this multi-phase reclosing function requires a high degree of reliability. Therefore, a condition for procurement is that the relay has a long-term operational track record of around 30 years in the actual grid.

2-2-4-2 Implementation Conditions

(1) Implementation considerations

The protection relay replacement work will need the protected equipment outages, such as the transmission line, transformer, or busbar. For this reason, it is necessary to coordinate the replacement work plan with the maintenance outage plan managed by the National Control Centre (NCC) as early as possible. In particular, the 132kV busbar is a double main busbar and the replacement of the busbar protection relay requires alternating busbar outage on one side. The supply reliability may be reduced during the busbar outage period, so the implementation method should be studied in detail in advance so that the outage period can be as short as possible while prioritising safety. The method of implementation should be studied in detail in advance, not only for busbar protection relays, but also for the replacement of other protection relays.

(2) Procurement considerations

In procurement, the current differential relays with multi-phase-reclosing will be introduced for the first time at NEPCO, so it is necessary to carefully explain the details of the specifications to NEPCO in advance. The replacement of relay units to be carried out this time will involve installing new relays where existing protection relays have been removed, so it is necessary to pay attention to the dimensions of the relay units, and it is necessary to investigate and confirm the space for each panel in advance and include this information in the procurement specifications.

Two locations are being agreed as the delivery destinations of the procured equipment, a materials warehouse adjacent to the Amman South substation and a vacant space in the 400kV switchgear building at the Aqaba substation, and arrangements need to be made to ensure that the equipment is delivered correctly to each location.

2-2-4-3 Scope of Works

The classification of the Japanese side and NEPCO regarding procurement, installation and construction is shown in Table 2-12. In this project, the construction work including installation work will be carried out by NEPCO itself, so the scope of responsibility needs to be clarified.

The attachment boards in the table are necessary to adjust for the difference in size between the existing relay unit and the new relay unit, and need to be designed for each panel, but the prerequisite is that the new relay unit can be accommodated in the existing space.

It is therefore essential to investigate the size of the potential relay unit in advance and confirm with NEPCO in advance how it will be accommodated, so that it is clear whether or not additional support is required.

Table 2-12 Division of work between Japan side and NEPCO in procurement and installation

	Relay unit replace	Panel replace
Procurement of relay units	Japan side	-----
Procurement of relay panels	-----	Japan side
Transportation of units and panels	Japan side	Japan side
Prepare attachment boards	NEPCO	-----
Prepare indication documents of terminal block connections	Japan side	-----
Installation of relay panels	-----	NEPCO
Remove relay units and related wirings	NEPCO	-----
Install relay units and connect wirings	NEPCO	-----
Prepare control cables	-----	NEPCO
Prepare cable schedules	-----	NEPCO
Prepare connection diagrams of cable terminal blocks	-----	NEPCO
Laying control cables	-----	NEPCO
Connect cables to terminal blocks	-----	NEPCO
Primary injection test for CT, VTs	-----	NEPCO
Prepare site test procedure	NEPCO	NEPCO
Relay function test (commissioning test)	NEPCO	NEPCO
Alarm, display test (commissioning test)	NEPCO	NEPCO

2-2-4-4 Consultant Supervision

Preliminary preparation is extremely important for the replacement of protection relays prior to the actual construction work. In particular, as the majority of replacements in this project will be carried out on a relay unit basis, it will be necessary to investigate the details of the wiring connected to the existing relay units, and the quality of the investigation results will have a direct impact on the quality of the installation work. It is envisaged that the survey and making drawings of the wiring will be carried out by NEPCO, with the consultant carrying out the checks.

With regard to construction management, it is assumed that technical guidance by the manufacturer will be arranged for the first installation of the various types of different relays and that the consultant will carry out witness work, after which management will be based on an implementation report for the same type of different relays.

2-2-4-5 Quality Control Plan

The quality control items for the installation of protection relays are listed in Table 2-13 and require accurate and steady connection of the wiring. In order to achieve accurate wiring, correct wiring diagrams must be prepared. In addition to a close study of the existing wiring drawings, the specifications and terminal block arrangement of the new relay unit must be correctly identified, and the drawings must clearly show where the existing wiring is to be connected to the new relay unit.

Table 2-13 Quality control plan

	Relay unit replace	Panel replace
Accuracy of connection for wiring at terminal blocks of unit backboard	Preparation of accurate wiring diagrams based on in-depth preliminary investigations Checking against the wiring diagram at the time of installation	-----
Accuracy of connection for terminal blocks with cable from outside of panel	-----	Preparation of accurate cable wiring diagrams based on in-depth preliminary investigations Checking against the wiring diagram at the time of installation
Certainty of wiring tightening	Visual and tactile checks	Visual and tactile checks
Polarity check	-----	Kick test
CT ratio and phase verification test	-----	Current value and phase angle check

2-2-4-6 Procurement Plan

The multiple-phase-reclosing method, which is planned to be adopted for Amman South – Amman East of the 400kV transmission line protection relays, is an indispensable technology for improving power supply reliability that has been used by Japanese power companies for half a century. In addition, as the multiple-phase-reclosing technology requires high reliability, the relays should have a track record of more than 30 years of operation in the actual system.

In this project, two supply methods of protection relays are being considered, per relay unit basis and per panel basis, but in both cases, if a permanent failure occurs, the relay unit will be replaced and repaired. Therefore, for both supply methods, it is considered appropriate to supply relay units as spare parts. This maintenance concept is not limited to Japanese procurement, but also applies to procurement from protection relay manufacturers in Europe and the USA.

Spare parts should be provided for each relay type, and the quantity should be about 10% of the total quantity for each type, based on NEPCO's experience with other projects.

The warranty (warranty against defects) shall be based on the standards generally adopted by Japanese manufacturers of protection relays, but the following points shall be taken into account in determining the warranty.

i. Installation and commissioning work after the equipment delivered will be carried out directly by NEPCO.
ii. Due to the large quantity, it takes about six months for installation and commissioning.

Therefore, the occurrence of damage due to negligence during installation and commissioning after delivery of the equipment is not included, but defects found during the acceptance test shall be covered by the warranty. The warranty period for defects shall be one year after the project is completed and handed over.

2-2-4-7 Operational Guidance Plan

As various types of relays will be installed in the project, specialist engineers from relay manufacturers will be dispatched to provide technical guidance for the first installation of each type of relay, and initial operational guidance on the operation of human machine interface, etc. will also be provided at the same time.

In addition, as the protection relay setting items and their names may differ depending on the manufacturer, a briefing session by the manufacturer will be held for the NEPCO engineers who will carry out the setting study a few months before the installation starts.

2-2-4-8 Soft Component Plan

The project does not require a soft component, as it is considered that NEPCO itself can be responsible for subsequent maintenance and operation of the project sufficiently through technical guidance during the construction and procurement period.

2-2-4-9 Implementation Schedule

Table 2-14 shows implementation schedule and it is considered as total 24 months.

Table 2-14 Implementation schedule

□ : Work in Japan

■ : Work in Jordan

		1st year												2nd year											
total month		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
Implamation Design	Prepare bid documents	□	□																						
	Approval of bid documents			■																					
	A bid announcement			▼																					
	Hand over bid documents and contents explanation			□																					
	Bidding					▼																			
	Bid evaluation					□																			
	Vender contract						▼																		
	(Approval by JICA)						▼																		
Management of procurement and installation	Meeting with venders						□																		
	Prepare drawings of equipment						□	□																	
	Manufacturing equipment								□	□	□	□	□	□	□	□	□								
	Preconfirmation meeting (connection diagrams etc.)												■												
	FAT for equipment																□								
	Pre-shipment inspection																□								
	Transportation (sea + inland)																	■							
	Hand over Acceptance																		■						
	Supervision for installation, connection and test																		■	■	■	■			
	Final check																								■
Items for counter part (NEPCO) burden	Investigation of existing connections					■	■	■																	
	Prepare new connection diagrams								■	■	■	■													
	Prepare attachement boards													■	■	■	■								
	Setting study												■	■	■	■	■	■							
	Equipment installation, wiring and test																		■	■	■	■	■	■	

2-3 Security Plan

There is essentially no security threat risk.

2-4 Power System Analysis

During the protection relay replacement work of this project, it will be necessary to take outages of the protected equipment, transmission lines, busbars, transformers, etc. In order to confirm the occurrence of issues for the substation voltages or overloaded equipment during the replacement work, power system analyses were conducted. As a result, it was confirmed that there were no overloaded transmission lines or overloaded transformers, and that the substation voltage could be maintained appropriately.

But when it is expected that two lines of the 400kV transmission line of Aqaba-New Ma'an will be outaged, it is necessary to check the power flow situation so that the 400kV/132kV transformers and 132kV transmission lines at Aqaba will not be overloaded. A summary of the results of the analyses is shown in Table 2-15.

Table 2-15 Power system analyses case

Substation name	Outage equipment	Analysis result	Remarks
Amman South, Amman East	400kV Amman South - Amman East, 1 line	No overload. The voltage maintains almost 1.0pu.	There is no problem even if two lines are outage.
Amman South, Qatrana	400kV Amman South-Qatrana, 1 line	No overload. The voltage maintains almost 1.0pu.	There is no problem even if two lines are outage.
Amman south	400/132kV transformers, 1 bank	No overload. The voltage maintains almost 1.0pu.	
Amman south	132kV Abdoun, 1 line	No overload. The voltage maintains almost 1.0pu.	
Amman south	132kV Bayader New, 1 line	No overload. The voltage maintains almost 1.0pu.	
Amman south	132kV Bayader Old, 1 line	No overload. The voltage maintains almost 1.0pu.	
Aqaba New Ma'an	400kV Aqaba-New Ma'an, 1 line	No overload. The voltage maintains almost 1.0pu.	In case of 2 lines outage, Aqaba 400/132kV transformer load factor 75.8%, 132kVTransmission line load factor 59.1%
Aqaba	400/132kV transformers, 1 bank	No overload. The voltage maintains almost 1.0pu.	

Aqaba	132kV Aqaba Town, 1 line	No overload. The voltage maintains almost 1.0pu.	
Aqaba	132kV Aqaba Industrial, 1 line	No overload. The voltage maintains almost 1.0pu.	
Aqaba	132kV Qweria, 1 line	No overload. The voltage maintains almost 1.0pu.	

2-5 Obligations of Recipient Country

In this project, the installation work of protection relays will be implemented by relay unit basis and for the Aqaba 132kV protection relay will be by a relay panel basis. The replacement of the relay unit requires the removal of the old relay from the existing panel, panel modification to install the new relay, and wiring connection and testing. For the relay panel renewal, panel installation work, cable connection work and verification tests are also required. NEPCO will be responsible for installation work and verification test. Specifically, NEPCO's responsibilities are as below.

i Transport equipment from the delivery location (warehouse) to the installation location
ii Removal of the old relay from the existing panel, installation of the new relay and wiring connection
iii Verification testing
iv Reflection on final drawings

In case of panel renewal (132kV Aqaba substation)

v Installation of the panel
vi Connection of external cables for CTs, VTs, power supplies, display connections, etc.
vii Verification tests
viii Disposal of removed items and packaging materials.

NEPCO has experiences of replacing relays and carrying out tests with its own engineers, and is fully capable of doing such replacement and tests

In principle, grant aid projects are tax exempt. According to the results of interviews with NEPCO and customs brokers, there is no replacement of customs duties by NEPCO and customs clearance is carried out with a letter stating that no duty is payable. Budgetary measures for customs duty advances by NEPCO will also not be required.

2-6 Project Operation Plan

Regarding maintenance after completion of the relay renewal, the relays will be replaced with digital relays, which will have enhanced automatic supervision functions and will not require periodic inspections and testing as with the old relays. The same approach as with digital relays that have already been updated will enable a significant reduction in inspection work and a reduction in equipment outage for relay maintenance and inspections.

Handling training will be provided to NEPCO engineers at the time of relay renewal and installation to ensure that they are familiar with the handling of new relays. In the event of a failure or defective relay unit, the relay is replaced with a spare relay, and the manufacturer concerned is informed about the handling of the defective relay and repairs are carried out.

(1) Installation and commissioning tests

During the installation and commissioning test stage of a new relay, technical engineers will be dispatched from the relay manufacturer to provide test guidance to NEPCO engineers, and to ensure that the core members of NEPCO who are responsible for relay maintenance become proficient in relay handling.

(2) Periodic inspections

Conventional analogue relays require annual periodic inspections (relay tests), but by installing digital relays, periodic inspections will basically no longer be necessary. However, it is considered effective for maintaining and succeeding to the technology to conduct periodic inspections of protection relays in conjunction with inspections of primary equipment such as circuit breakers, etc. It is recommended that the need for and frequency of periodic inspections be determined in line with NEPCO's basic policy on relay maintenance.

(3) Taking advantage of training centres (ETCs)

It is considered necessary to incorporate relay testing into the curriculum of ETCs and to succeed to the technology related to the relays adopted in the project.

2-7 Project Cost Estimation

2-7-1 Initial Cost Estimation

(1) Expenses borne by the Jordanian side

NEPCO will carry out work such as relay installation and testing work, preparation attachment boards to relay installation on the existing panels and control cables preparation and installation for Aqaba 132kV system. The summary expenses of this work borne by Jordanian side are as follows.

1) Fees associated with opening a bank account, remittance, etc.

2) Provision of attachment boards to fix the protection relay unit to the existing panel and

implementation of installation work

3) Provision of control cables to the new installation location of the 132kV protection relay at Aqaba Substation and implementation of installation work

According to NEPCO rough estimates, the specific costs are as follows:

Table 2-16 The summary expenses borne by Jordanian side

Expense item		Approximate expenses (million yen)
1)	Commission fees for bank account opening/remittance, etc.	2.0
2)	Attachment boards for fixing protection relays	0.1
3)	Control Cable for Aqaba Substation 132kV Protection Relay Panels	28.0

(2) Estimation conditions

i. Time of estimation: November 2022 (month in which the survey is completed or the month prior to the completion of the survey).
The month in which the survey is completed means the month in which the cooperation preparatory survey is completed and the participants have returned to their home countries.

ii. Exchange rate: 1 US$ = 142.62 yen

iii. Exchange rate: 1 JOD = 200.77yen
The exchange rate for specific calculations shall be the average rate for the past three months (on a monthly basis) starting from the last day of the month prior to the month of return.

iv. Construction and procurement period: The period for detailed design and construction (or equipment procurement) shall be as indicated in the implementation schedule.

v. Others: Estimates shall be made in accordance with the grant aid system of the Japanese Government.

2-7-2 Operation and Maintenance cost

Operation and maintenance costs after the relays are updated and put into operation include the cost of periodic inspections by NEPCO and the cost of technical succession and training related to digital relays in the ETC. Relay equipment can continue to be used for 20-30 years, but considering that it will become difficult to procure parts for continued maintenance due to the modification and obsolescence of semiconductor elements, etc., and that technology will become obsolete, it is advisable to plan for long-term renewal with a target period of around 15 years.

(1) Periodic inspection costs

As digital relays are maintenance-free and uninspected, annual inspections are not required as with conventional analogue relays. It is not necessary to carry out annual inspections of all relay devices, one round of inspections over several years is sufficient. One cost that would be required would be the personnel costs of NEPCO engineers. There are no budgetary issues, as the cost of regular inspections of existing relay equipment, which is currently being carried out, will be reduced.

(2) Training costs

By utilising ETCs and incorporating the testing and handling of relays adopted in the project as part of the curriculum, there is no need to allocate a separate budget at the time.

Chapter 3

Project Evaluation

Chapter 3. Project Evaluation

3-1 Preconditions

The prerequisites for project implementation are the tax exemption for equipment delivery and the work described in chapter 2 (the reuse of existing control cables, the replacement of relay units and the installation of new panels for the reconstruction of the Aqaba 132kV relay room) should be implemented by NEPCO, in order to minimise the necessary outage period and the replacement work period.

3-2 Necessary Inputs by Recipient Country

The following table summarises the items to be borne by NEPCO.

Table 3-1 Summaries of the items to be borne by NEPCO

	Contents		Remarks
Installation and test	i	Transportation from the delivery location (warehouse) to the installation location	
	ii	Removal of old relay from existing panel, installation of new relay and wiring connection	
	iii	Installation of the panel	In the case of a new panel
	iv	Connection of external cables for CT, VT, power supply, display, etc.	
	v	Verification tests	
	vi	Reflection on final drawings	
	vii	Disposal of removal of items and packaging materials	
Operation and maintenance	i	Technical maintenance and succession through periodic testing	
	ii	Technical succession through training centres	

3-3 Important Assumptions

In order to maintain and expand the project's effectiveness, it is desirable to expand the application of the current differential protection relays, which are adopted in this project, to other transmission line protection and interconnection system lines with surrounding countries. It is also desirable to strengthen the communication system infrastructure for this purpose.

3-4 Project Evaluation

3-4-1 Relevance

In Jordan's power sector, the introduction of renewable energy is being promoted as a national policy. However, renewable energy has large output fluctuations, and thermal power generation by synchronous generators have contributed to the stability of the grid. This thermal power generation will decrease in relative terms by increasing renewable energy. NEPCO is required to strengthen the stable operation of the power system, partly because the average outage time per customer is increasing and NEPCO experienced a major outage in May 2021. Old relays of static and electromagnetic types are still used in 400kV/132kV substations, which take important roles of the NEPCO power system, and there are significant concerns about the deterioration of protection performance resulting from the aging and function issues. However due to lack of funds, the replacement of protection relays is not progressing.

In the unlikely event that protection relays fail to operate properly, unstable phenomena may occur in the power system, causing large-scale, prolonged power outages. In addition, the static and electromagnetic relays currently in use require the periodic maintenance which needs outages of the related equipment (transmission lines, transformers and busbars). The depletion of repair parts over time and the difficulty in responding to maintenance problems increase the risk of power outage due to inspection and fault repair. When a power outage occurs, especially if it lasts for a long time, it has a significant impact on the lives of citizens and economic activities, including the shutdown of pumps that pump groundwater to supply water for agriculture, as well as power outages in factories, buildings, etc. This project is expected to reduce these risks, is highly appropriate and will directly contribute to reducing power outages and is expected to be effective.

In addition, in this project to replace old electromechanical and static protection relays with digital protection relays which can quickly and reliably eliminate fault points in the event of a power system fault, improve the reliability of the Jordanian system and contribute to stable operation. Therefore, this project is consistent with Jordan's development strategy of promoting the introduction of renewable energy.

3-4-2 Effectiveness

3-4-2-1 Quantitative Effects

The average outage time, service-out time for maintenance, and man-day required for relay inspection work are used as an indicator as the table below from the NEPCO annual report, as upgrading to digital relays improves the reliability of grid fault removal and reduces equipment outage due to periodic inspections.

Table 3-2 Quantitative effect indicators

index name (Target: whole of Jordan)	Standard value (2022)		Target value (2028) [5 years after project completion]	
	index	economic loss	index	economic loss
Average outage time per customer (minutes/year)	209	4.61 billion yen	<68(*)	1.5 billion yen
Service-outage time required for maintenance (hours/year/line)	12	—	0	—
Man-day required for relay inspection work (man-day/year/line)	6	—	0	—

Note: For the target value, reference is made to the transition of outage time due to the effect of digitisation in Japan.

The average outage time in the 1970s and 1980s, before the digitalisation of protection relays began in earnest, was about 200 minutes, but this was halved to about 100 minutes in 1985 and 1986. Thus, Average annual outage time, which decreases to half or one-third compared with 2022, is set for five years after the project will be completed (2024) when the effects of digitalisation begin to appear.

In Japan, the current average outage time is around 15 minutes.

Reduction in outage hours can be evaluated from perspective of economic loss. NEPCO's annual electricity sales are 19,281 GWh, which divided by 8,760 hours yields an average power of 2,201 MW. If the outage time per customer is 209 minutes, the average annual power outage for all customers is estimated to be 7,667 MWh. Based on the average cost of power outages for Japanese customers (2,346yen/kWh) from the table below, the annual loss due to power outage in Jordan is calculated to be 18 billion yen. Therefore, converting this figure to Jordan would be approximately 4.6 billion yen. If the average power outage time becomes 1/3, a reduction in economic loss of 3.1 billion yen per year can be expected.

The reduction of economic losses due to the occurrence of major power outages is also estimated. The economic losses are calculated based on a power outage that occurred on May 22, 2021, throughout the country of Jordan.

This was a large-scale power outage of 1860 MW with a maximum outage duration of 5 hours, and similar large-scale outages have occurred in 2004 and 2014 though they were on different scales.

First, the amount of power outage was assumed to be 1860 MW x 5 hours ÷ 2 = 4650 MWh, based on the area of the triangle, assuming that the outages were resolved evenly after the outages occurred. The amount of power loss was estimated as shown in the table below by dividing this amount of power outage by demand type and multiplying each by the estimated amount of power outage loss calculated by Central Research Institute of Electric Power Industry, Japan.

Table 3-3 Economic loss due to blackout (Japanese example)

	Ratio (%)	Amount of Power Outage (MWh)	Cost of Outage (Yen/kWh)	Economic Loss (Billion Yen)
General Consumer	44	2,046	2,860	5.9
Industry	26	1,209	1,600	1.9
Commercial	16	744	2,800	2.1
Pumping Water for Water service	14	651	1,600	1.0
Total	100	4,650		10.9

The estimated economic loss that results from power outage across Jordan is 10.9 billion yen when estimated at the cost of blackout in Japan. Converting it to a loss in Jordan at a labour cost ratio approximately 4:1, it would be about 3 billion yen.

The incident used for estimation is caused by instability phenomenon of the generator. Such instability phenomenon can be caused by a defective main protection relay that fails to operate promptly at the time of fault, and the fault is removed by the back-up protection relay, resulting in a delay in fault removal time.

Conversely, this risk of major outage can be reduced by installing highly reliable relays, thus avoiding this loss.

3-4-2-2 Qualitative Effects

In May 2021, there was a blackout that spread to the whole of Jordan, but the occurrence of such major power outage incidents can be suppressed by this replacement of the relays in this project. In addition, as Jordan's water supply is provided by pumping up groundwater, a power outage could also stop the water supply, which could cause major social unrest.

An example of an old type relay (electromechanical type) failing to eliminate a fault and causing a major blackout is the Pakistan-wide blackout in January 2021, when the main protection relay (electromechanical type) failed to operate in response to an earth fault at a 220 kV substation. The fault spread and resulted in the collapse of the entire power system. As a countermeasure, the replacement of protection relays with digital types is urgently required.

The cause of the blackout in Pakistan in 2021 was that, in the event of a three-phase fault, the protection relay that should have operated was an old electromagnetic relay that failed to operate, and the backup protection relay was also an old static type relay that delayed operation and caused power system swing, resulting in the system being split into south and north, with the south side having excess power and no appropriate protection. All of generators were shut down. In addition, the frequency on the north side dropped and the appropriate loadshedding was not done in time, resulting in a total backout.

In NEPCO's grid also a number of old electromagnetic relays are used, and in the event of a fault could cause a similar major outage in Pakistan. By updating the protection relays this risk can be avoided.

Appendices

APPENDIX 1.　Member List of the Study Team

Name	Role	Affiliation
SATO Akira	Project Leader	Director Team1, Energy and Mining Group Infrastructure Management Department JICA
OJIMA Naohiro	Project Management	Deputy Assistant Director Team1, Energy and Mining Group Infrastructure Management Department JICA
YOSHIDA Kazuyoshi	Chief Consultant / Power System Operation	Asia Engineering Consultant Co., Ltd.
KAMINAGA Masanobu	Protection Relay (Construction & Operation)	Tokyo Electric Power Services Co., Ltd.
TAKEUCHI Atsushi	Protection Relay (Scheme Design)	Asia Engineering Consultant Co., Ltd.
TAKASE Hidekazu	Power System Analysis	Tokyo Electric Power Services Co., Ltd.
NAGANO Hideaki	Planning Procurement / Estimation	Nippon Koei Co., Ltd.

APPENDIX 2. Study Schedule

First Survey

No.	Date	Day of week	JICA Officers	investigation			place of stay
				Chief Consultant (Mr.Yoshida)	Team Members (Mr.Kaminaga, Mr.Takeuchi, Mr.Nagano)	Team Member (Mr.Takase)	
1	10/14	Fri		From Narita to Doha	From Narita to Doha	From Narita to Doha	
2	10/15	Sat		Doha to Amman	Doha to Amman	Doha to Amman	Amman
3	10/16	Sun	AM: ①Visit JICA Amman office IC/R explanation (briefly) ②Embassy courtesy call PM: Visit NEPCO (with MEMR) IC/R explanation Confirmation of contractor		AM: Visit JICA Amman office IC/R explanation PM: Visit NEPCO IC/R explanation Confirmation of constractor	AM: Visit JICA Amman office IC/R explanation PM: Visit NEPCO IC/R explanation	Amman
4	10/17	Mon	AM: MD discussions with NEPCO PM: Amman South field survey		AM: survey schedule adjustment with NEPCO PM: Amman South field survey	NEPCO Collection of data for system analysis	Amman
5	10/18	Tue	AM: Amman South field survey PM: MD final confirmation		Amman South field survey	NEPCO Collection of data for system analysis	Amman
6	10/19	Wed	AM: Consultation PM: Scheduled MD signing		Amman East field survey	NEPCO Collection of data for system analysis	Amman
7	10/20	Thu	AM: Report to the embassy PM: Spare MD signing day		Meeting with local contractor	NEPCO Collection of data for system analysis	Amman
8	10/21	Fri		Organize materials	Organize materials	Amman to Doha	Amman
9	10/22	Sat		Organize materials	Organize materials	Doha to Narita	Amman
10	10/23	Sun		Meeting with local contractor	Meeting with local contractor		Amman
11	10/24	Mon		Qatrana field survey	Qatrana field survey		Amman
12	10/25	Tue		Move to Aqaba	Move to Aqaba		Aqaba
13	10/26	Wed		Aqaba field survey	Aqaba field survey		Aqaba
14	10/27	Thu		Aqaba field survey	Aqaba field survey		Aqaba
15	10/28	Fri		Move to Amman	Move to Amman		Amman
16	10/29	Sat		Organize materials	Organize materials		Amman
17	10/30	Sun		Meeting with local transporter	Meeting with local transporter		Amman
18	10/31	Mon		Visit NEPCO Report on field survey results Visit JICA	Visit NEPCO Report on field survey results Visit JICA		Amman
19	11/1	Tue		Amman to Doha	Amman to Doha		
20	11/2	Wed		Doha to Narita	Doha to Narita		

Second Survey Draft 2023/3/10-18

No.	Date	Day of week	JICA Officers	investigation			place of stay
				Chief Consultant (Mr.Yoshida)	Team Members (Mr.Kaminaga, Mr.Takeuchi, Mr.Nagano)	Team Members (Mr.Nagano)	
1	3/10	Fri	Narita to Doha	Narita to Istanbul	Narita to Istanbul	Narita to Istanbul	Istanbul
2	3/11	Sat	Doha to Amman	Istanbul to Amman	Istanbul to Amman	Istanbul to Amman	Amman
3	3/12	Sun	AM: 1030-1130 visit JICA Explanation of survey PM: Visit NEPCO schedule adjustment Explanation of power system anlysys results	AM: 1030-1131 visit JICA Explanation of survey PM: Visit NEPCO schedule adjustment Explanation of power system anlysys results	AM: 1030-1132 visit JICA Explanation of survey PM: Visit NEPCO schedule adjustment Explanation of power system anlysys results	AM: 1030-1133 visit JICA Explanation of survey PM: Visit NEPCO schedule adjustment Explanation of power system anlysys results	Amman
4	3/13	Mon	AM;Visit Custom Office PM;;Visit NEPCO Explanation of M/D	AM;Visit Custom Office PM;;Visit NEPCO Explanation of M/D	Visit NEPCO Amman south sibstation	AM;Visit Custom Office PM;;Amman South substaion	Amman
5	3/14	Tue	Internal Meeting 8-10 PM;Visit NEPCO Explanation of project scope relay replacement construction method	Internal Meeting 8-11 PM;Visit NEPCO Explanation of project scope relay replacement construction method	Internal Meeting 8-12 PM;Visit NEPCO Explanation of project scope relay replacement construction method	Internal Meeting 8-13 PM;Visit NEPCO Explanation of project scope relay replacement construction method	Amman
6	3/15	Wed	Visit NEPCO Explanation of procurement of materials and cost estimation results M/D sign	Visit NEPCO Explanation of procurement of materials and cost estimation results	Visit NEPCO Explanation of procurement of materials and cost estimation results	Visit NEPCO Explanation of procurement of materials and cost estimation results	Amman
7	3/16	Thu	Visit JICA office Explanation of results Amman to Dubai	Visit JICA office Explanation of results	Visit JICA office Explanation of results	Visit JICA office Explanation of results	Amman
8	3/17	Fri	Dubai to Narita	Amman to Istanbul	Amman to Istanbul	Amman to Istanbul	Istanbul
9	3/18	Sat		Istanbul to Narita	Istanbul to Narita	Istanbul to Narita	Narita

APPENDIX 3. List of Parties Concerned in the Recipient Country

Name	Position	Affiliation
Mr. Amjad Rawashdeh	MD	NEPCO
Mr. Ahmad Dohni	AMD	NEPCO
Mr. Mohammad Dawood	AMD	NEPCO
Mr. Kamel Atout	AMD for financial affairs	NEPCO
Ms. Maysoon Rawabdeh	Head of international cooperation and communication section	NEPCO
Mr. Ma’moun M. Hmouze	Head of clearance section procurement department	NEPCO
Mr. Ali Hyasat	Purchasing department manager	NEPCO
Ms. Nisreen Rabbuu	Legal department	NEPCO
Mr. Hussein Momani	Protection engineer	NEPCO
Ms. Hanan Abu Quba	Operational study engineer	NEPCO
Mr. Ahmad Khalaileh	Protection engineer	NEPCO
Mr. Muhannad Abu Saleh	Protection engineer	NEPCO
Mr. Mohammad Momani	Engineer	NEPCO
Mr. Mohammod Qabbaah	Engineer	NEPCO
Mr. Osama Fruiyeet	Engineer	NEPCO
Mr. Musa Amaireh	Engineer	NEPCO
Mr. Mohammad Atyany	Engineer	NEPCO
Mr. Mohammad Flahat	Engineer	NEPCO
Mr. Mohammad Khlefas	Engineer	NEPCO
Mr. Yahya Karajah	Engineer	NEPCO
Mr. Amer S. Reafey	Engineer	NEPCO
Mr. Ali Hani Rousan	Engineer	NEPCO
Mr. Mahmoud Titi	Director of tariff and agreements	Jordan Customs
Mr. Mohammad Obeidat	Head of customs training center	Jordan Customs
Mr. Tariq Ahmad	Head of exemptions	Jordan Customs
Mr. Yahya Faour	General manager / Executive director	ARROW EXPRESS (Transportation company)
Mr. Ayman Faour	Business development executive	ARROW EXPRESS
Mr. Anas Muhaisen	Sales team leader	ARROW EXPRESS

Minutes of Discussions
on the Preparatory Survey for the Project for
Enhancing Power System Operating Capacity
（Explanation on Draft Preparatory Survey Report）

With reference to the minutes of discussions signed between National Electric Power Company and the Japan International Cooperation Agency (hereinafter referred to as "JICA") on October, 2022 and in response to the request from the Government of Hashemite Kingdom of Jordan (hereinafter referred to as "Jordan") dated March, 2023, JICA dispatched the Preparatory Survey Team (hereinafter referred to as “the Team”) for the explanation of Draft Preparatory Survey Report (hereinafter referred to as “the Draft Report”) for the Project for Enhancing Power System Operating Capacity (hereinafter referred to as “the Project”).

As a result of the discussions, both sides agreed on the main items described in the attached sheets.

Amman, March 16th, 2023

SATO Akira	Amjad RAWASHDEH
Leader	Managing Director
Preparatory Survey Team	
Japan International Cooperation Agency	National Electric Power Company
Japan	Jordan

ATTACHEMENT

1. Project site
   Both sides confirmed that the sites of the Project are in Amman South Substation, Aqaba substation, Amman East Substation which is shown in Annex 1.

2. Contents of the Draft Report
   After the explanation of the contents of the Draft Report by the Team, the Jordan side agreed to its contents. JICA will finalize the Preparatory Survey Report based on the confirmed items. The report will be sent to the Jordan side around June 2023.

3. Cost estimate
   Both sides confirmed that the cost estimate explained by the Team is provisional and will be examined further by the Government of Japan for its approval.

4. Confidentiality of the cost estimate and technical specifications
   Both sides confirmed that the cost estimate and technical specifications of the Project should never be disclosed to any third parties until all the contracts under the Project are concluded.

5. Timeline for the project implementation
   The Team explained to the Jordan side that the expected timeline for the project implementation is as attached in Annex 3.

6. Expected outcomes and indicators
   Both sides agreed that key indicators for expected outcomes are as follows. The Jordan side will be responsible for the achievement of agreed key indicators targeted in year 2028 and shall monitor the progress for Ex-Post Evaluation based on those indicators.

[Quantitative indicators]

Indicator name (Target: whole of Jordan)	Reference value (2022)	Target value (2028)
Average annual outage time	209 minutes	68 minutes
Service-out time required for maintenance (hour/year/circuit)	7	0
Man-day required for relay inspection work (man-day/year/circuit)	6	0
Economic loss resulting from outage (Million Yen)	4,610	1,500

[Qualitative indicators]

Improvement of outputs for renewable energy and improvement of accuracy for analysis regarding the cause of accident in the grid

7. Ex-Post Evaluation

JICA will conduct ex-post evaluation after three (3) years from the project completion, in principle, with respect to five evaluation criteria (Relevance, Effectiveness, Efficiency, Impact, Sustainability). The result of the evaluation will be publicized. The Jordan side is required to provide necessary support for the data collection.

8. Undertakings of the Project

Both sides confirmed the undertakings of the Project as described in Annex 4. With regard to exemption of customs duties, internal taxes and other fiscal levies as stipulated in No.5 in (2) During the Project Implementation of Annex 4, both sides confirmed that such customs duties, internal taxes and other fiscal levies, which shall be clarified in the bid documents by the Executing Agency during the implementation stage of the Project.

The Jordan side assured to take the necessary measures and coordination including allocation of the necessary budget which are preconditions of implementation of the Project. It is further agreed that the costs are indicative, i.e. at Outline Design level. More accurate costs will be calculated at the Detailed Design stage.

Both sides also confirmed that the Annex 4 will be used as an attachment of G/A.

9. Monitoring during the implementation

The Project will be monitored by the Executing Agency and reported to JICA by using the form of Project Monitoring Report (PMR) attached as Annex 5. The timing of submission of the PMR is described in Annex 4.

10. Project completion

Both sides confirmed that the Project completes when all the facilities constructed and equipment procured by the Grant are in operation. The completion of the Project will be reported to JICA promptly, by using a format, but in any event not later than six months after completion of the Project.

11. Environmental and Social Considerations

The Team explained that 'JICA Guidelines for Environmental and Social Considerations (April 2010/January 2022)' (hereinafter referred to as "the Guidelines") is applicable for the Project. The Project is categorized as C because the Project is likely to have minimal adverse impact on the environment under the Guidelines.

12. Other Relevant Issues

12-1 Disclosure of Information

Both sides confirmed that the Preparatory Survey Report from which project cost is excluded will be disclosed to the public after completion of the Preparatory Survey. The comprehensive report including the project cost will be disclosed to the public after all the contracts under the Project are concluded.

12-2 Contribution for Climate change

Both sides confirmed that this project contributes to climate change mitigation since the installation of new disital re;ays will result in improvement for reliability, thus indirectly contirubutes to renewable energy penetration.

12-3 Gender Mainstreaming

Both sides confirmed that gender mainstreaming should be duly practiced for the Project implementation as the project is categorized as GIP (Gender Equality Project or Project Targeting Women), or GIS (Gender Integrated Project). In particular, Both sides agreed on the following gender elements to be integrated into the Project.

(a) Implementation of opreration and maintenance that promote women's empowerment.

12-4 Undertaking by NEPCO

As stipulated in Annex 4, both sides agreed that NEPCO will take resposibility for conducting following subjects including securing budget. As for the installation, both sides confirmed that NEPCO would conduct installation work while JICA consoltants and manufacturer will supervise the instllation work.

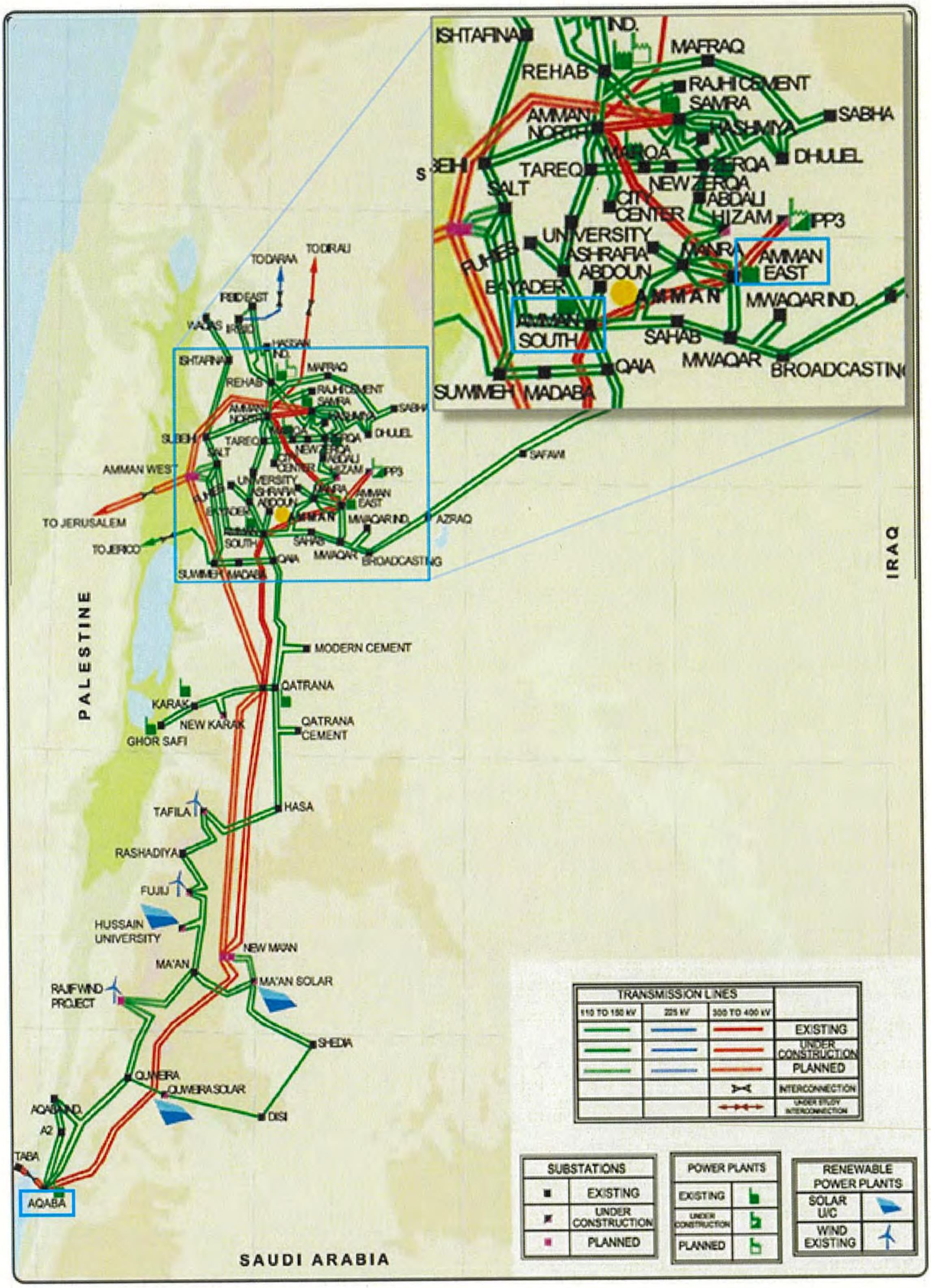
- To prepare steel cover for the relay panels for relay unit installation
- To remove old relay from existing panel and install new relay
- To install all new panel for Aqaba
- To prepare the control cable and connect new external cables for CT, VT, power supply, display etc.with relay unit for Aqaba
- To couduct verification tests
- To reflect New Sequence Diagram on final drawings

12-5 Monitering for the installation work

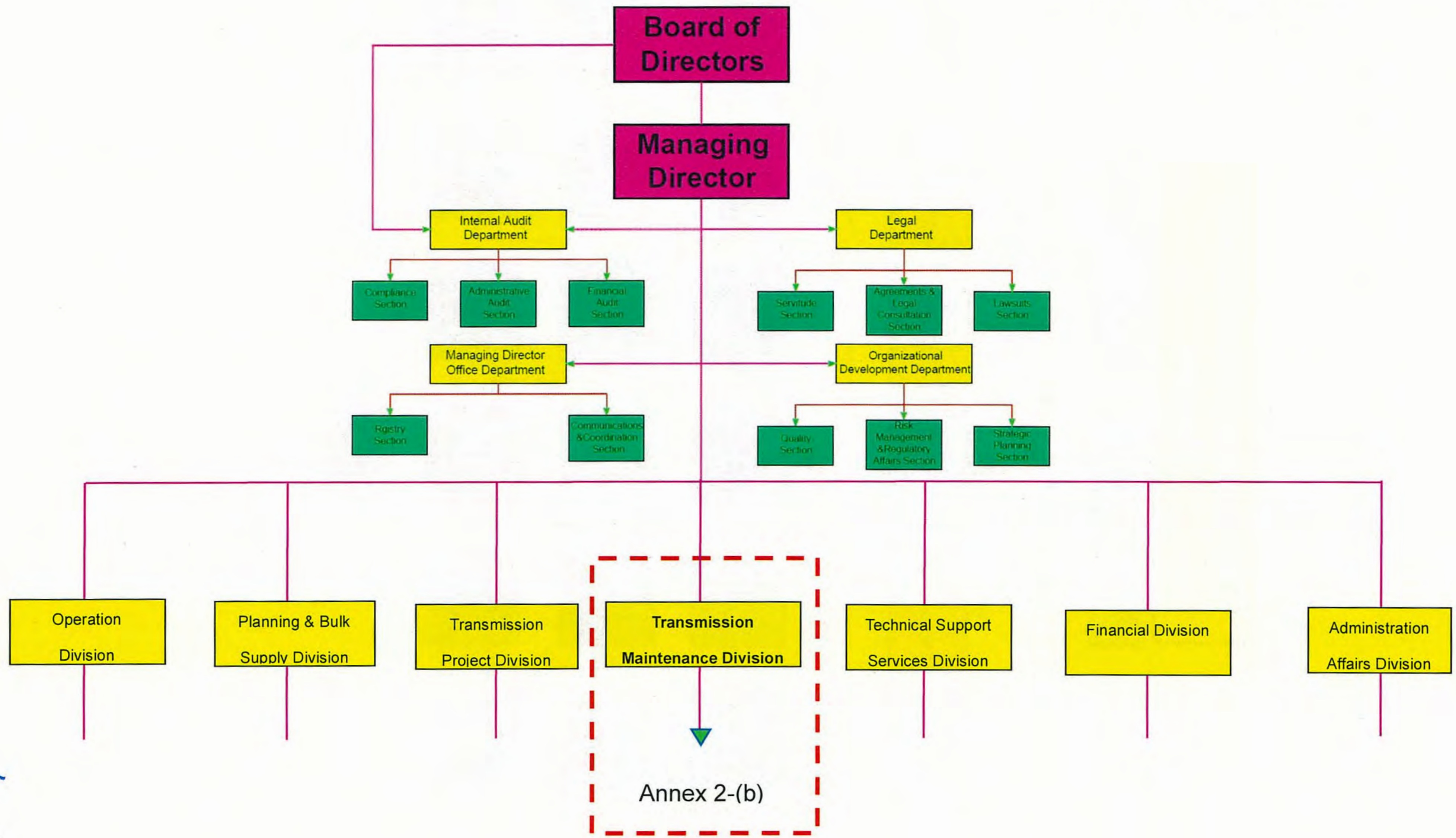
In order to monitor if the installation work are conducted as planned, NEPCO will submit the annual progress report and completion report based on the Record of Discussion, which will be signed between JICA and NEPCO. Timing for the signature is scheduled at the same time as the signing Grant Agreement.

Annex 1 Project Site
Annex 2 Organization Chart
Annex 3 Project Implementation Schedule
Annex 4 Major Undertakings to be taken by the Government of Jordan
Annex 5 Project Monitoring Report (template)

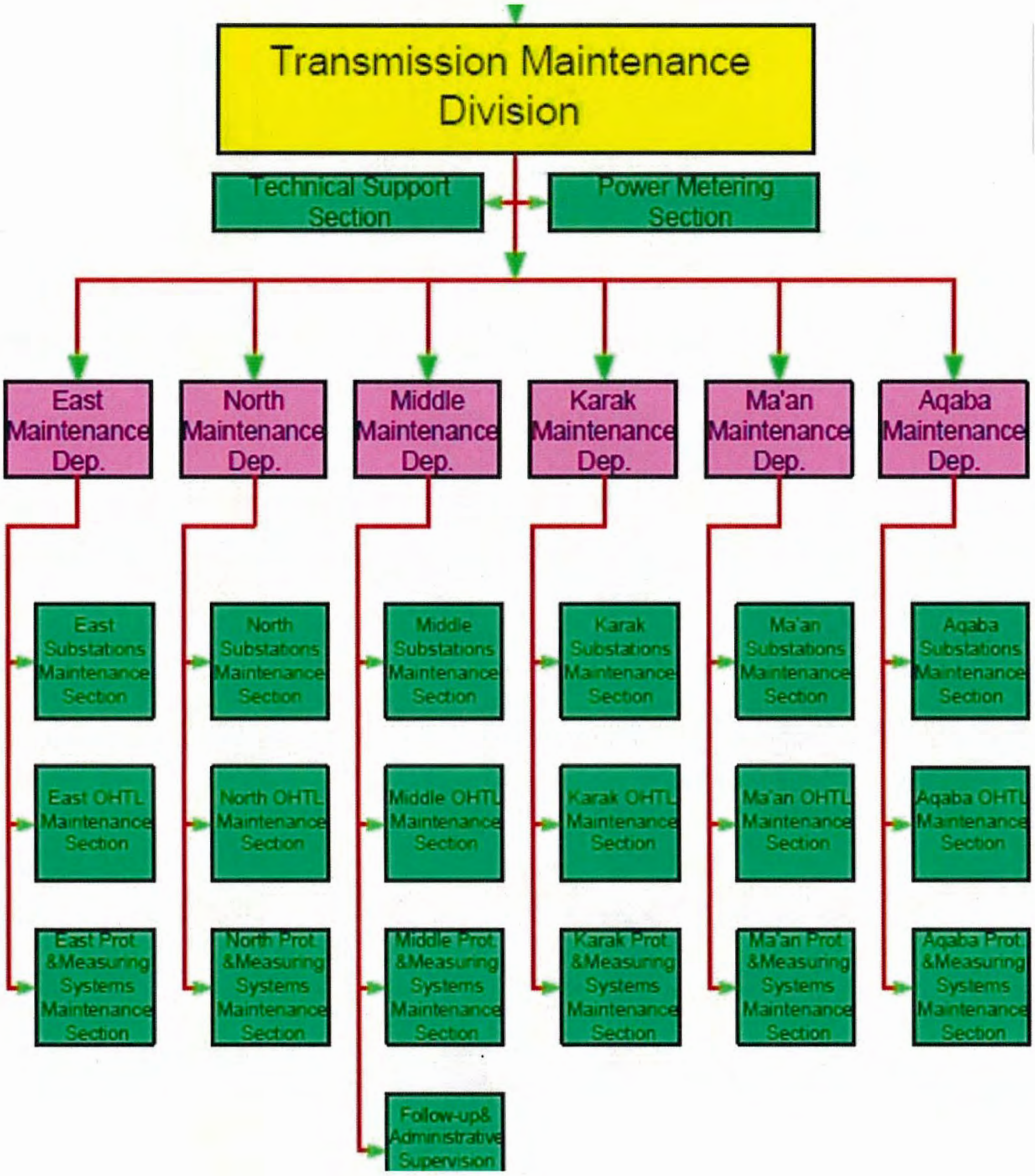
Annex 1 Project Site



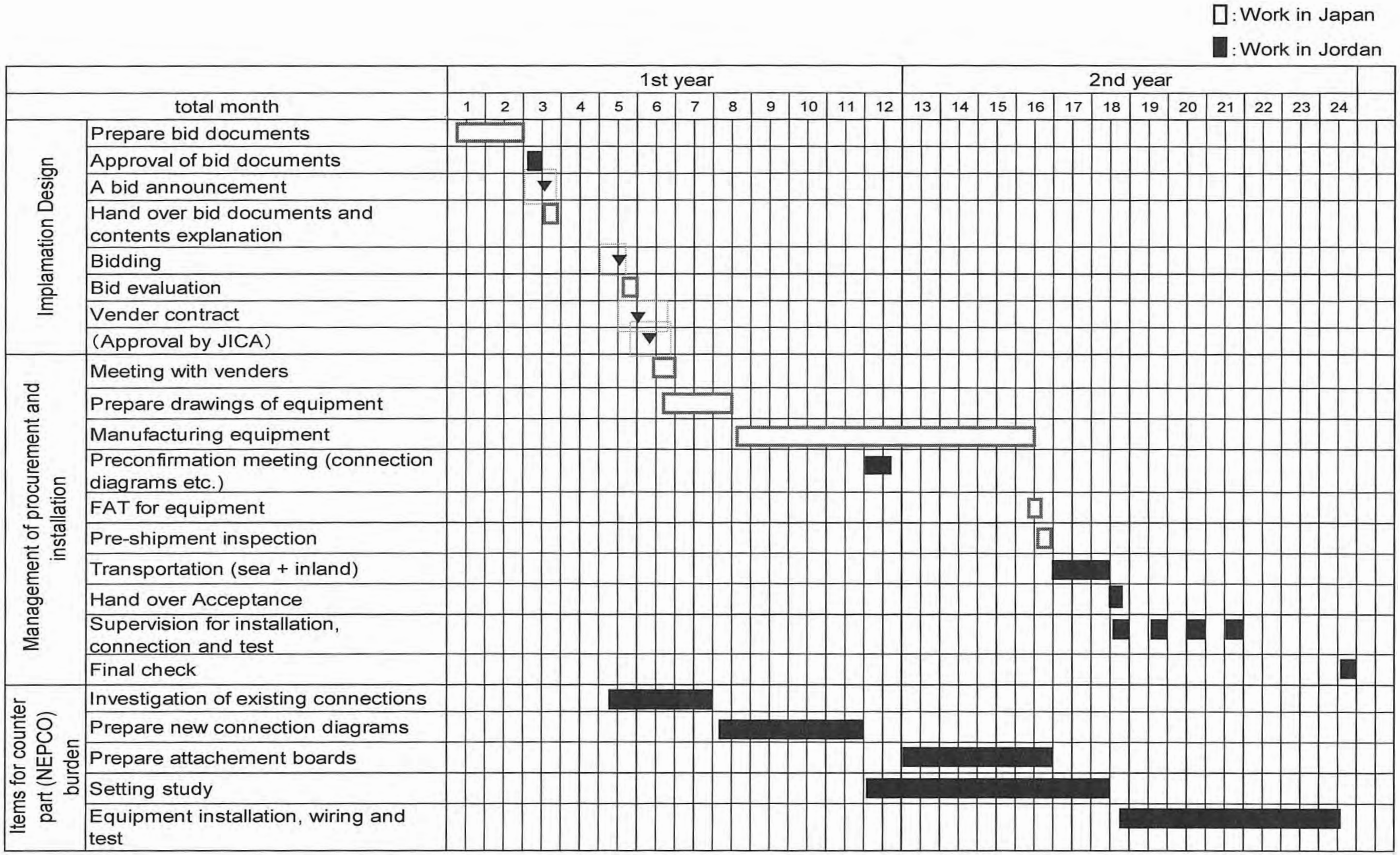
Annex 2-(a) Organization Chart



Annex 2-(b) Organization Chart



Annex 3



□ : Work in Japan
■ : Work in Jordan
1st year
2nd year
total month
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24
Implamation Design
Prepare bid documents
Approval of bid documents
A bid announcement
Hand over bid documents and contents explanation
Bidding
Bid evaluation
Vender contract
(Approval by JICA)
Management of procurement and installation
Meeting with venders
Prepare drawings of equipment
Manufacturing equipment
Preconfirmation meeting (connection diagrams etc.)
FAT for equipment
Pre-shipment inspection
Transportation (sea + inland)
Hand over Acceptance
Supervision for installation, connection and test
Final check
Items for counter part (NEPCO) burden
Investigation of existing connections
Prepare new connection diagrams
Prepare attachement boards
Setting study
Equipment installation, wiring and test

Annex 4

Major Undertakings to be taken by the Government of Jordan

1. Specific obligations of the Government of Jordan which will not be funded with the Grant

(1) Before the Bidding

NO	Items	Deadline	In charge	Estimated Cost	Ref.
1	To sign the banking arrangement (B/A) with a bank in Japan (the Agent Bank) to open bank account for the Grant	within 1 month after the signing of the G/A	NEPCO CBJ		
2	To issue A/P to the Agent Bank for the payment to the consultant	within 1 month after the signing of the contract(s)	NEPCO CBJ		
3	To bear the following commissions to the Agent Bank for the banking services based upon B/A		NEPCO CBJ		
	1) Advising commission of A/P	within 1 month after the signing of the contract(s)	NEPCO CBJ	2,620JOD	
	2) Payment commission for A/P	every payment	NEPCO CBJ	2,620JOD	
4	To secure the following space in the substations 1) Storage space for the new protection relays until the installation 2) Space for the installation of the busbar protection relay in substations to avoid the busbar stopping for a long period of time, if neccesary.	before notice of the bidding documents	NEPCO		
5	To submit Project Monitoring Report (with the result of Detailed Design)	before preparation of the bidding documents	NEPCO		

(B/A: Banking Arrangement, A/P: Authorization to pay, N/A: Not Applicable, NEPCO:National Electricity Power Company, CBJ: Central Bank of Jordan)

(2) During the Project Implementation

NO	Items	Deadline	In charge	Estimated Cost	Ref.
1	To issue A/P to the Agent Bank for the payment to the supplier and the contractor	within 1 month after the signing of the contract(s)	NEPCO CBJ		
2	To bear the following commissions to the Agent Bank for the banking services based upon the B/A		NEPCO CBJ		
	1) Advising commission of A/P	within 1 month after the signing of the contract(s)	NEPCO CBJ	2,620JOD	
	2) Payment commission for A/P	every payment	NEPCO CBJ	2,620JOD	
3	To ensure prompt unloading and customs clearance at ports of disembarkation in the country of the Recipient and to assist the Supplier(s) with internal transportation therein	during the Project	NEPCO		
4	To accord Japanese physical persons and/or physical persons of third countries whose services may be required in connection with the supply of the products and the services such facilities as may be necessary for their entry into the country of the Recipient and stay therein for the performance of their work	during the Project	NEPCO		
5	To ensure that customs duties, internal taxes and other fiscal levies which may be imposed in the country of the Recipient with respect to the purchase of the products and/or the services be exempted/ be borne by its designated authority without using the Grant	during the Project	NEPCO		
6	To deliver the equipment from the warehouse to the installation location	during the Project	NEPCO		
7	To prepare steel cover for the relay panels for relay unit installation	Before installation	NEPCO	700USD	
8	To remove old relay from existing panel and install new relay	During the Project	NEPCO		
9	To install all new panel for Aqaba	During the Project	NEPCO		
10	To prepare the control cable and connect new external cables for CT, VT, power supply, display etc.with 132 kv relay for Aqaba	During the Project	NEPCO	200,000 USD	
11	To conduct verification tests	Before installation	NEPCO		
12	To reflect New Sequence Diagram on final drawings	Before installation	NEPCO		
13	To bear all the expenses, other than those covered by the Grant, necessary for the implementation of the Project	during the Project	NEPCO		
14	To notify JICA promptly of any incident or accident, which has, or is likely to have, a significant adverse effect on the environment, the affected communities, the public or workers.	during the installation	NEPCO		
15	To submit Project Monitoring Report after each work under the contract(s) such as shipping, hand over, and installation	within 1 month after completion of each work	NEPCO		

16	To submit Project Monitoring Report (final) (including as-built drawings, equipment list, photographs, etc.)	within 1 month after issuance of Certificate of Completion for the works under the contract(s)	NEPCO		
17	To submit a report concerning completion of the Project	within 6 months after completion of the Project	NEPCO		
18	To ensure the safety of persons engaged in the implementation of the Project	during the Project	NEPCO		
19	To take necessary measures for security and safety of the Project site	during the Project	NEPCO		
20	To secure the budget in the case of malfunction of protection relay	Before completion of the project	NEPCO		
21	To prepare the training course for the multi-pole reclosing by the current differential relay	Before completion of the project	NEPCO		

(3) After the Project

NO	Items	Deadline	In charge	Estimated Cost	Ref.
1	To maintain and use properly and effectively the equipment provided under the Grant Aid	After completion of the installation	NEPCO		

2. Other obligations of the Government of Jordan funded with the Grant

NO	Items	Deadline	Amount (Million Japanese Yen)*
1	1) To conduct the following transportation a) Marin (Air) transportation of the products from Japan to the country of the Recipient b) Internal transportation from the port of disembarkation to the warehouse 2) To provide equipment ● 400kv and 132kv protection relay for Amman South substation ● 400kv protection relay for Aqaba substation ● 132kv protection panel for Aqaba substation ● 400kv protection relay for Amman East substation	By the completion of the project	
2	To implement detailed design, bidding support and procurement supervision (Consulting Service)		
	Total		

*The Amount is provisional. This is subject to the approval of the Government of Japan.

Project Monitoring Report
on
Project Name
Grant Agreement No. XXXXXXX

20XX, Month

Organizational Information

Signer of the G/A (Recipient)	Person in Charge Contacts	(Designation) Address: Phone/FAX: Email:
Executing Agency	Person in Charge Contacts	(Designation) Address: Phone/FAX: Email:
Line Ministry	Person in Charge Contacts	(Designation) Address: Phone/FAX: Email:

General Information:

Project Title	
E/N	Signed date: Duration:
G/A	Signed date: Duration:
Source of Finance	Government of Japan: Not exceeding JPY ________ mil. Government of (_________): ______________

1: Project Description

1-1 Project Objective

1-2 Project Rationale

- Higher-level objectives to which the project contributes (national/regional/sectoral policies and strategies)
- Situation of the target groups to which the project addresses

1-3 Indicators for measurement of "Effectiveness"

Quantitative indicators to measure the attainment of project objectives		
Indicators	Original (Yr)	Target (Yr)
Qualitative indicators to measure the attainment of project objectives		

2: Details of the Project

2-1 Location

Components	Original *(proposed in the outline design)*	Actual
1.		

2-2 Scope of the work

Components	Original* *(proposed in the outline design)*	Actual*
1.		

Reasons for modification of scope (if any).

(PMR)

2-3 Implementation Schedule

Items	Original		Actual
	(proposed in the outline design)	*(at the time of signing the Grant Agreement)*	

Reasons for any changes of the schedule, and their effects on the project (if any)

2-4 Obligations by the Recipient

2-4-1 Progress of Specific Obligations

See Attachment 2.

2-4-2 Activities

See Attachment 3.

2-4-3 Report on RD

See Attachment 11.

2-5 Project Cost

2-5-1 Cost borne by the Grant(<u>Confidential until the Bidding</u>)

Components			Cost (Million Yen)	
	Original *(proposed in the outline design)*	Actual *(in case of any modification)*	Original[1),2)] *(proposed in the outline design)*	Actual
	1.			
Total				

Note: 1) Date of estimation:
2) Exchange rate: 1 US Dollar = Yen

2-5-2 Cost borne by the Recipient

Components			Cost (1,000 Taka)	
	Original *(proposed in the outline design)*	Actual *(in case of any modification)*	Original[1),2)] *(proposed in the outline design)*	Actual
	1.			

Note: 1) Date of estimation:
2) Exchange rate: 1 US Dollar =

Reasons for the remarkable gaps between the original and actual cost, and the countermeasures (if any)

(PMR)

2-6 Executing Agency

- Organization's role, financial position, capacity, cost recovery etc,
- Organization Chart including the unit in charge of the implementation and number of employees.

Original *(at the time of outline design)* name: role: financial situation: institutional and organizational arrangement (organogram): human resources (number and ability of staff):
Actual *(PMR)*

2-7 Environmental and Social Impacts

- The results of environmental monitoring based on Attachment 5 (in accordance with Schedule 4 of the Grant Agreement).
- The results of social monitoring based on in Attachment 5 (in accordance with Schedule 4 of the Grant Agreement).
- Disclosed information related to results of environmental and social monitoring to local stakeholders (whenever applicable).

3: Operation and Maintenance (O&M)

3-1 Physical Arrangement

- Plan for O&M (number and skills of the staff in the responsible division or section, availability of manuals and guidelines, availability of spareparts, etc.)

Original *(at the time of outline design)*
Actual *(PMR)*

3-2 Budgetary Arrangement

- Required O&M cost and actual budget allocation for O&M

Original *(at the time of outline design)*

Actual *(PMR)*

4: Potential Risks and Mitigation Measures

- Potential risks which may affect the project implementation, attainment of objectives, sustainability
- Mitigation measures corresponding to the potential risks

Assessment of Potential Risks *(at the time of outline design)*

Potential Risks	Assessment
1. (Description of Risk)	Probability: High/Moderate/Low
	Impact: High/Moderate/Low
	Analysis of Probability and Impact:
	Mitigation Measures:
	Action required during the implementation stage:
	Contingency Plan (if applicable):
2. (Description of Risk)	Probability: High/Moderate/Low
	Impact: High/Moderate/Low
	Analysis of Probability and Impact:
	Mitigation Measures:
	Action required during the implementation stage:
	Contingency Plan (if applicable):
3. (Description of Risk)	Probability: High/Moderate/Low
	Impact: High/Moderate/Low
	Analysis of Probability and Impact:
	Mitigation Measures:
	Action required during the implementation stage:

	Contingency Plan (if applicable):
Actual Situation and Countermeasures	
(PMR)	

5: Evaluation and Monitoring Plan (after the work completion)

5-1 Overall evaluation

Please describe your overall evaluation on the project.

5-2 Lessons Learnt and Recommendations

Please raise any lessons learned from the project experience, which might be valuable for the future assistance or similar type of projects, as well as any recommendations, which might be beneficial for better realization of the project effect, impact and assurance of sustainability.

5-3 Monitoring Plan of the Indicators for Post-Evaluation

Please describe monitoring methods, section(s)/department(s) in charge of monitoring, frequency, the term to monitor the indicators stipulated in 1-3.

Attachment

1. Project Location Map
2. Specific obligations of the Recipient which will not be funded with the Grant
3. Monthly Report submitted by the Consultant

Appendix - Photocopy of Contractor's Progress Report (if any)
- Consultant Member List
- Contractor's Main Staff List

4. Check list for the Contract (including Record of Amendment of the Contract/Agreement and Schedule of Payment)
5. Environmental Monitoring Form / Social Monitoring Form
6. Monitoring sheet on price of specified materials (Quarterly)
7. Report on Proportion of Procurement (Recipient Country, Japan and Third Countries) (PMR (final)only)
8. Pictures (by JPEG style by CD-R) (PMR (final)only)
9. Equipment List (PMR (final)only)
10. Drawing (PMR (final)only)
11. Report on RD (After project)
12. Report on the Management of Safety for Construction Works

Monitoring sheet on price of specified materials

1. Initial Conditions (Confirmed)

	Items of Specified Materials	Initial Volume A	Initial Unit Price (¥) B	Initial total Price C=A×B	1% of Contract Price D	Condition of payment Price (Decreased) E=C−D	Condition of payment Price (Increased) F=C+D
1	Item 1	●●t	●	●	●	●	●
2	Item 2	●●t	●	●	●		
3	Item 3						
4	Item 4						
5	Item 5						

2. Monitoring of the Unit Price of Specified Materials
(1) Method of Monitoring : ●●

(2) Result of the Monitoring Survey on Unit Price for each specified materials

	Items of Specified Materials	1st ●month, 2015	2nd ●month, 2015	3rd ●month, 2015	4th	5th	6th
1	Item 1						
2	Item 2						
3	Item 3						
4	Item 4						
5	Item 5						

(3) Summary of Discussion with Contractor (if necessary)
-
-
-

Report on Proportion of Procurement (Recipient Country, Japan and Third Countries)
(Actual Expenditure by Construction and Equipment each)

	Domestic Procurement (Recipient Country) A	Foreign Procurement (Japan) B	Foreign Procurement (Third Countries) C	Total D
Construction Cost	(A/D%)	(B/D%)	(C/D%)	
Direct Construction Cost	(A/D%)	(B/D%)	(C/D%)	
others	(A/D%)	(B/D%)	(C/D%)	
Equipment Cost	(A/D%)	(B/D%)	(C/D%)	
Design and Supervision Cost	(A/D%)	(B/D%)	(C/D%)	
Total	(A/D%)	(B/D%)	(C/D%)	

Attachment 12

Report on the Management of Safety for Construction Works

Month/Year 2022 年×月	Cumulative number of labor 労働延人数	Cumulative number of public accident 公衆災害件数	Cumulative hours worked 延べ実労働時間数	Number of deaths and injuries due to industrial accidents 労働災害による死傷者				Frequency rate 度数率	Severity rate 強度率
					Death and injuries 死傷者数	Aggregated number of calendar days absent 延べ休業日数	Aggregated number of work-days lost 延べ労働損失日数		
This Month 当月				Death 死者					
				More than 4 calendar days absent 休業 4 日以上					
				1 to 3 calendar days absent 休業 1～3 日					
				Total 計					
Total including this month 当月迄累計				Death 死者					
				More than 4 calendar days absent 休業 4 日以上					
				1 to 3 calendar days absent 休業 1～3 日					
				Total 計					

Note 注)

1. Frequency rate is the frequency of occurrence of industrial accidents.
   Frequency rate = (Number of deaths and injuries due to industrial accidents ÷ Cumulative hours worked) × 1,000,000
   度数率＝（労働災害による死傷者数÷延べ実労働時間数）×100 万時間
2. Severity rate is degree of seriousness of the industrial accident.
   Severity rate = (Aggregated number of work-days lost ÷ Cumulative hours worked) × 1,000
   強度率＝（延べ労働損失日数÷延べ実労働時間数）1000 時間
3. Aggregated number of work-days lost = Aggregated number of calendar days absent ×(300÷365)
   Death（7,500 days）: death as a result of an industrial accident includes not only instantaneous death but also death as a result of occupational injury or disease.
   延べ労働損失日数＝延べ休業日数×（300÷365）・・・死亡 7500 日（即死のほか負傷が原因で死亡したものを含む）
4. Frequency rate and severity rate are rounding off the third decimal place.
   度数率・強度率は小数点第 3 位以下四捨五入

APPENDIX 5. Power System Analysis

Preparatory Survey for the Project for Enhancing Power System Operating Capacity in the Hashemite Kingdom of Jordan

Power system analysis result

March, 2023

JAPAN INTERNATIONAL COOPERATION AGENCY (JICA)
ASIA ENGINEERING CONSULTING CO., LTD. (AEC)
TOKYO ELECTRIC POWER SERVICES CO., LTD. (TEPSCO)
NIPPON KOEI CO., LTD

Purpose of power system analysis

1. Confirmation of Jourdan electricity
2. Confirmation of power flow on rely replacement constriction term

1. Confirmation of Jourdan electricity

Demand

The demand in Jordan is growing at an average annual rate of 5.57% from 2019 to 2021, as shown in the following table. The demand in Jordan is characterized by a widening gap between the maximum and minimum electricity demand at the lighting peak.

Unit : MW

Year	Peak Load		Growth rate	Minimum Load
	Moring.	Evening		
2017	3,320	3,220	---	1,350
2018	3,100	3,205	-3.46%.	1,290
2019	3,260	3,380	5.46%	1,195
2020	3,530	3,630	7.40%	1,040
2021	3,540	3,770	3.86%	1,090

Source) NEPCO ANNAUL REPORT 2021

1. Confirmation of Jourdan electricity

Power supply

The power supply capacity in Jordan has been increasingly adopting renewable energy generation equipment. The renewable energy supply capacity was 28.42% in 2021 on whole of power supply capacity.

Unit : MW

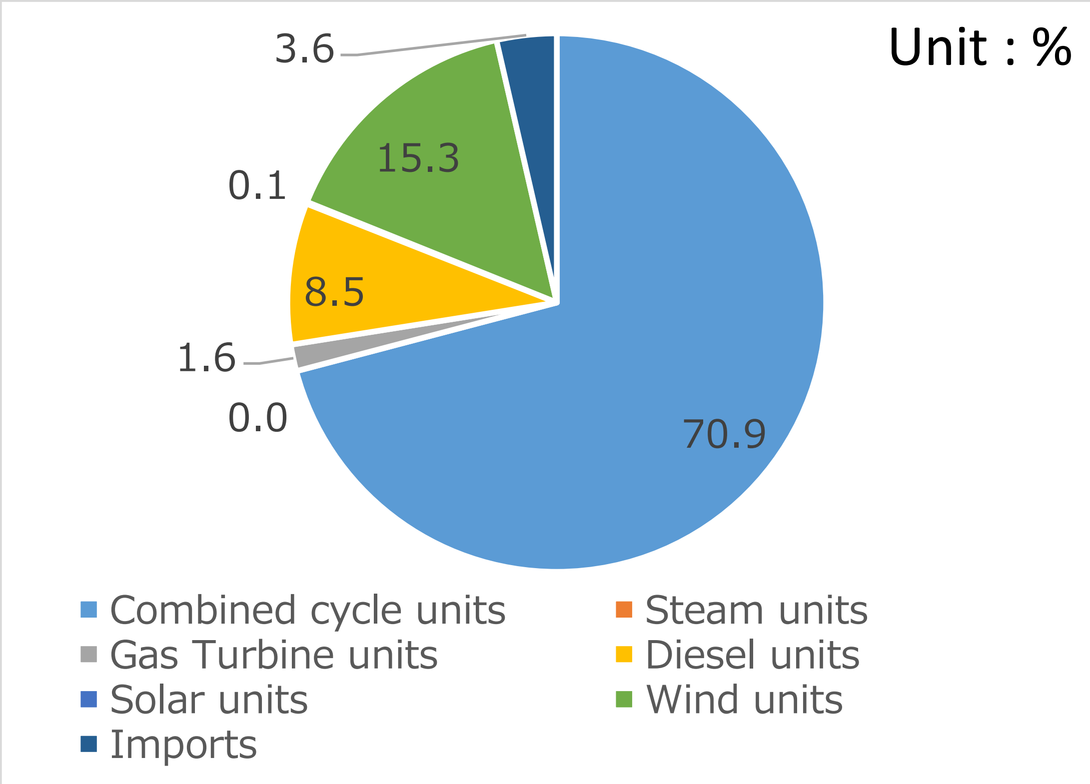
Year	Steam	Gas Turbines	Com-bined Cycle	Diesel	Renewable Energy			Total	
					Hydro	wind	Solar	Renewable	Traditional
2017	605	228	2,044	814	6.0	198	204	408	3,691
2018	605	83	2,740	814	6.0	280	449	735	4,242
2019	605	83	2,740	814	6.0	369	637	1,012	4,242
2020	363	83	2,740	814	6.0	518	900	1,424	4,000
2021	363	60	2,740	814	3.6	622	953	1,579	3,977

Source) NEPCO ANNAUL REPORT 2021

1. Confirmation of Jourdan electricity

Generation composition at maximum demand in 2021

The composition of supply power when maximum demand in 2021 shown as below figure. Combined cycle power generation accounts for 70.9% of the total. The maximum demand occurs in the evening, which reduces the supply capacity of photovoltaic power generation.



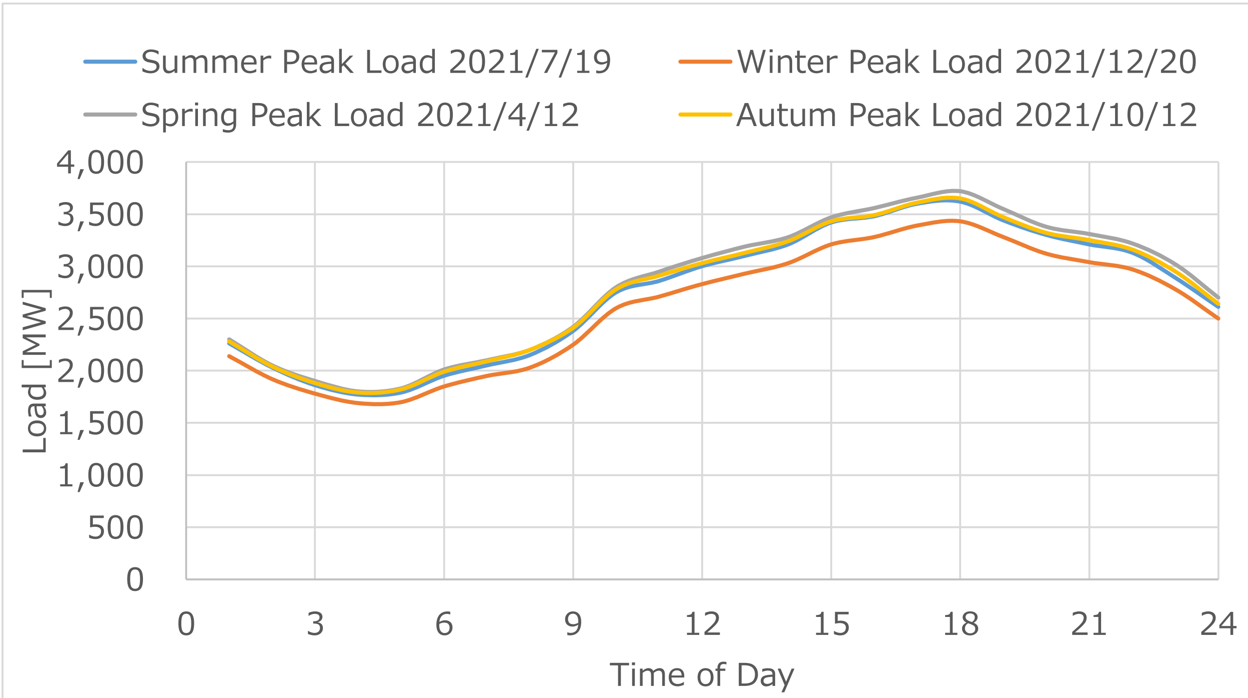
Source) NEPCO ANNAUL REPORT 2021

1. Confirmation of Jourdan electricity

Characteristics of the demand

The demand is characterized by no seasonal variation, although the demand is slightly lower in the spring season than in other seasons.

Replacement of protective relaying needs to stop 400kV and 132kV transmission or transformer. There is no seasonal request for replacement work because there is no seasonal characteristics.

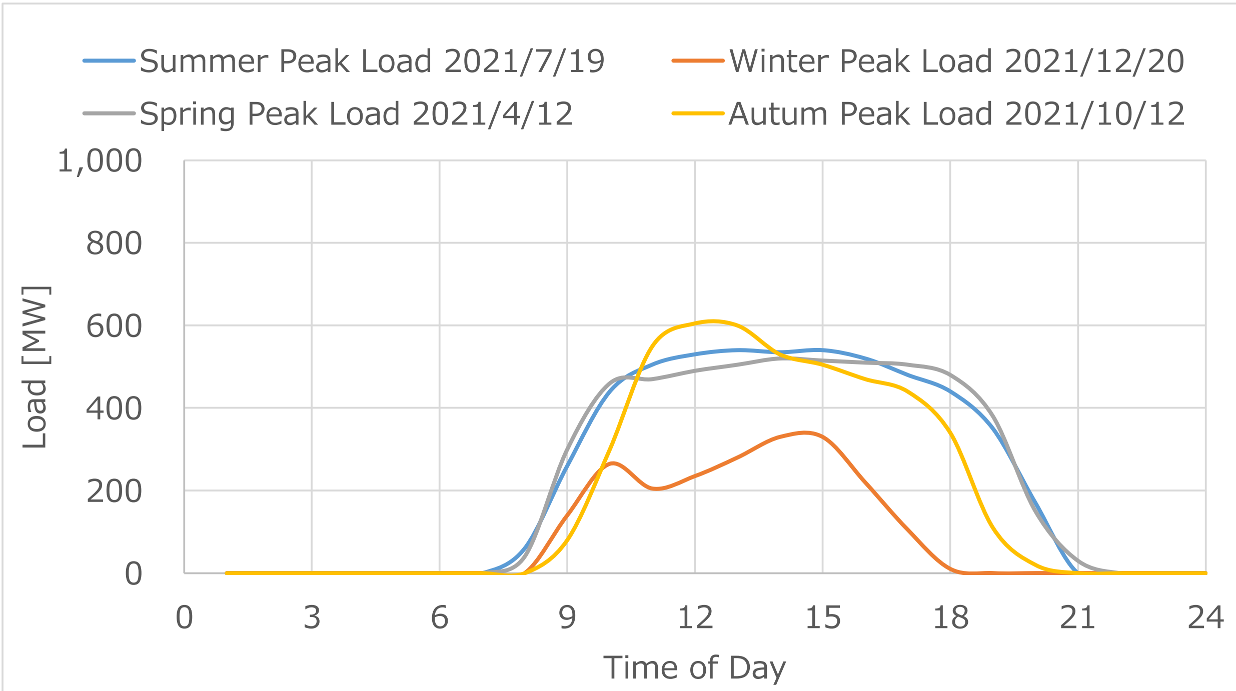


Source) NEPCO ANNAUL REPORT 2021

1. Confirmation of Jourdan electricity

Power generation characteristics of renewable energies

The installed capacity of solar power in 2021 was 953 MW. The amount of power generation of solar power was about 60 % of the actual installation capacity at the maximum generation.

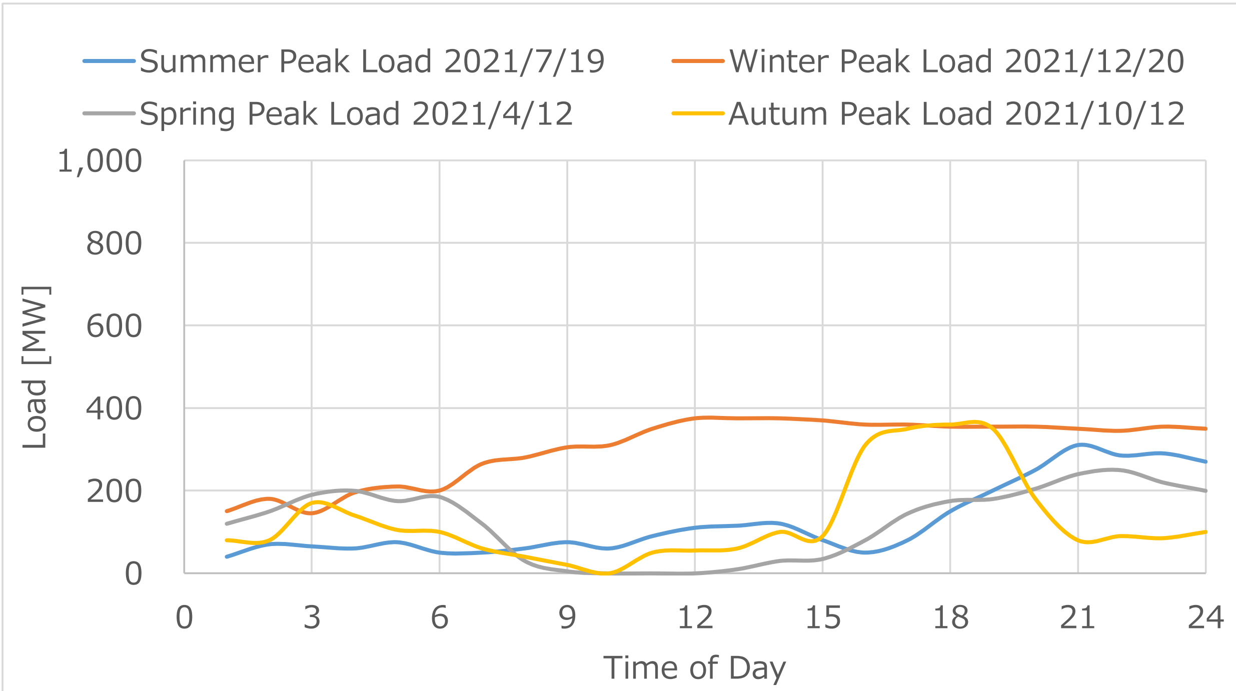


Source) NEPCO ANNAUL REPORT 2021

1. Confirmation of Jourdan electricity

Power generation characteristics of renewable energies

The installed capacity of wind power in 2021 was 622 MW. The amount of power generation of wind power was about 70 % of the actual installation capacity at the maximum generation.



Source) NEPCO ANNAUL REPORT 2021

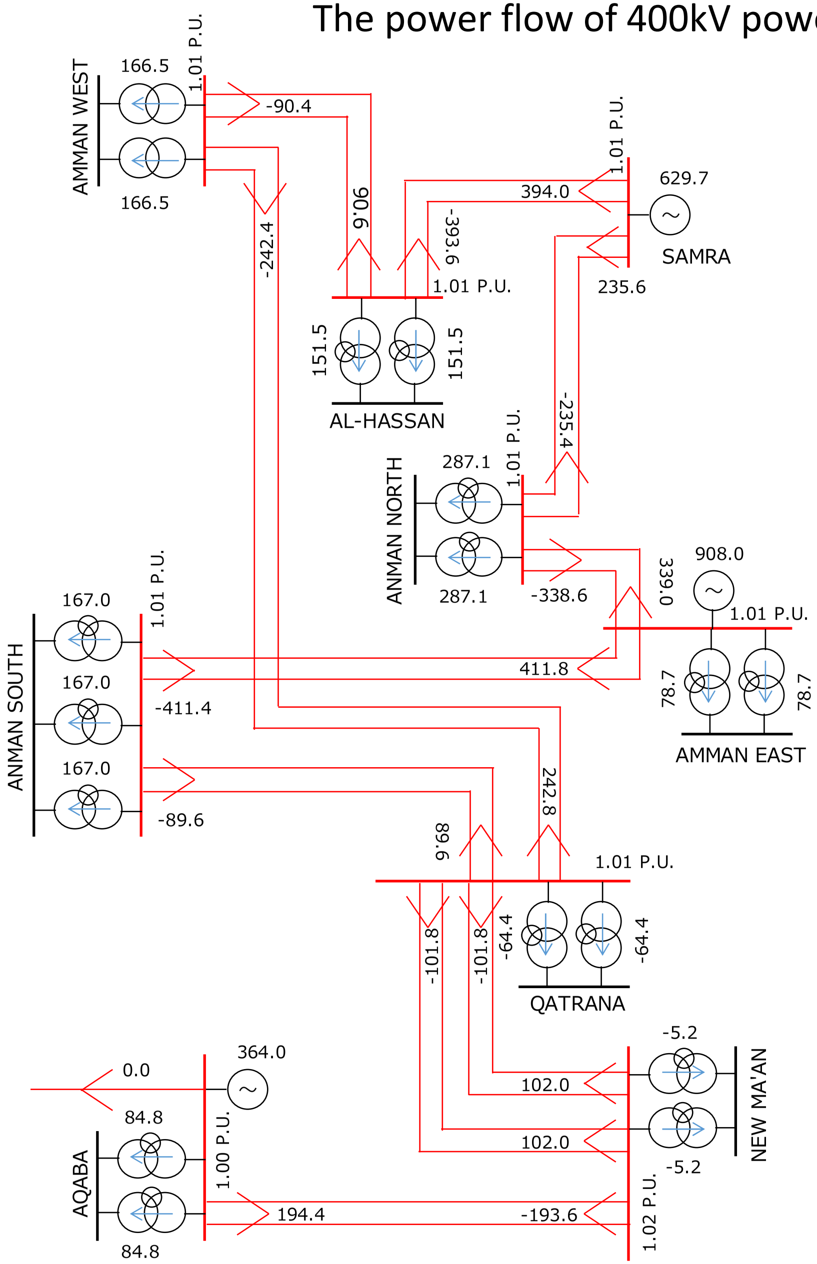
Current situation of power system

The power flow analysis of the power system uses PSS/E data received from NEPCO. This data is assumed from the file name as the data for the maximum power generation in winter in 2025.

The total demand of the power system is 4,500 MW, which is 21.62% higher than the maximum demand of 3,770 MW in 2021.

This calculation result is no overloaded in power network system on 400kV and 132kV, and substation voltage is stable.

The power flow of 400kV power system



Amman South Substation Protective Relay Replacement

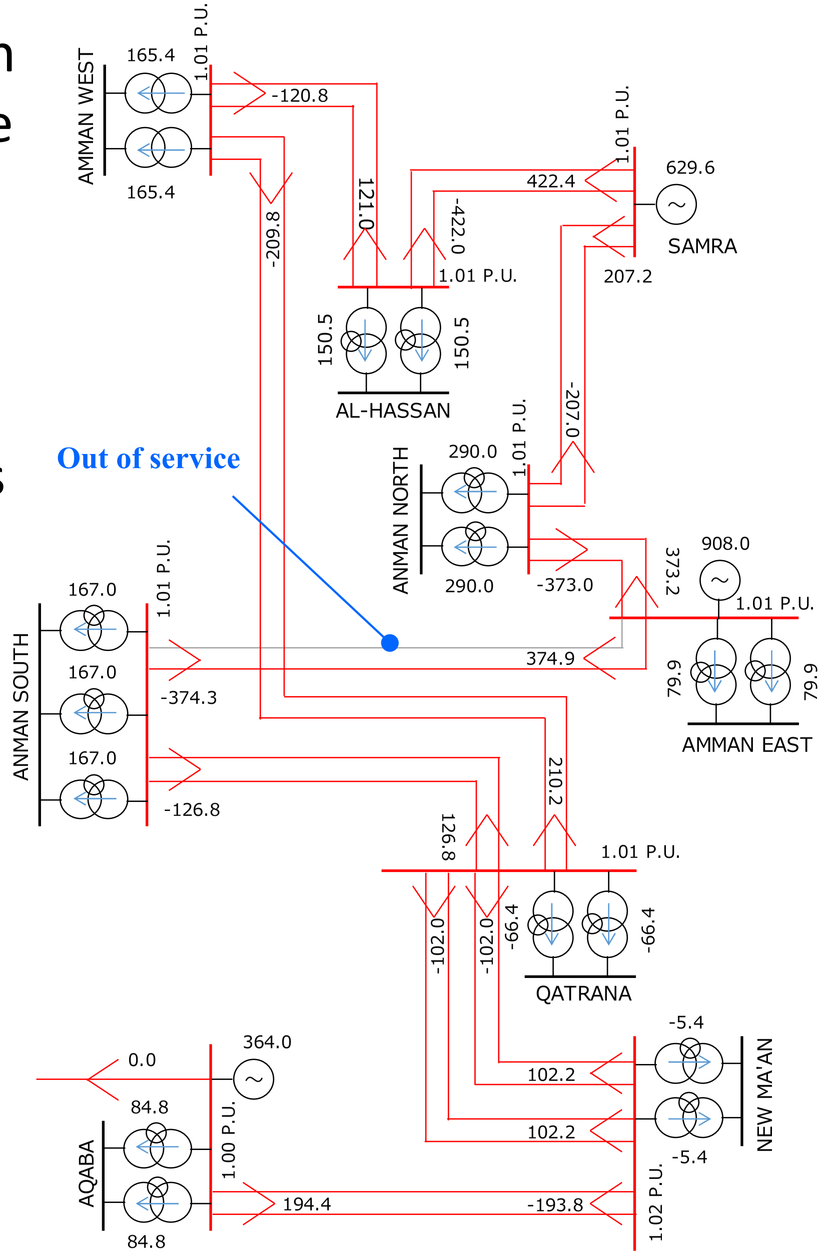
The equipment to be replaced with protective relays at the Amman South substation is as follows

- ✓ Amman South substation to Amman East substation 400kV transmission line
- ✓ 400kV/132kV transformers
- ✓ 132kV transmission lines

Amman South Substation Protective Relay Replacement

Amman South substation to Amman East substation 400kV transmission line outage (One circuit)

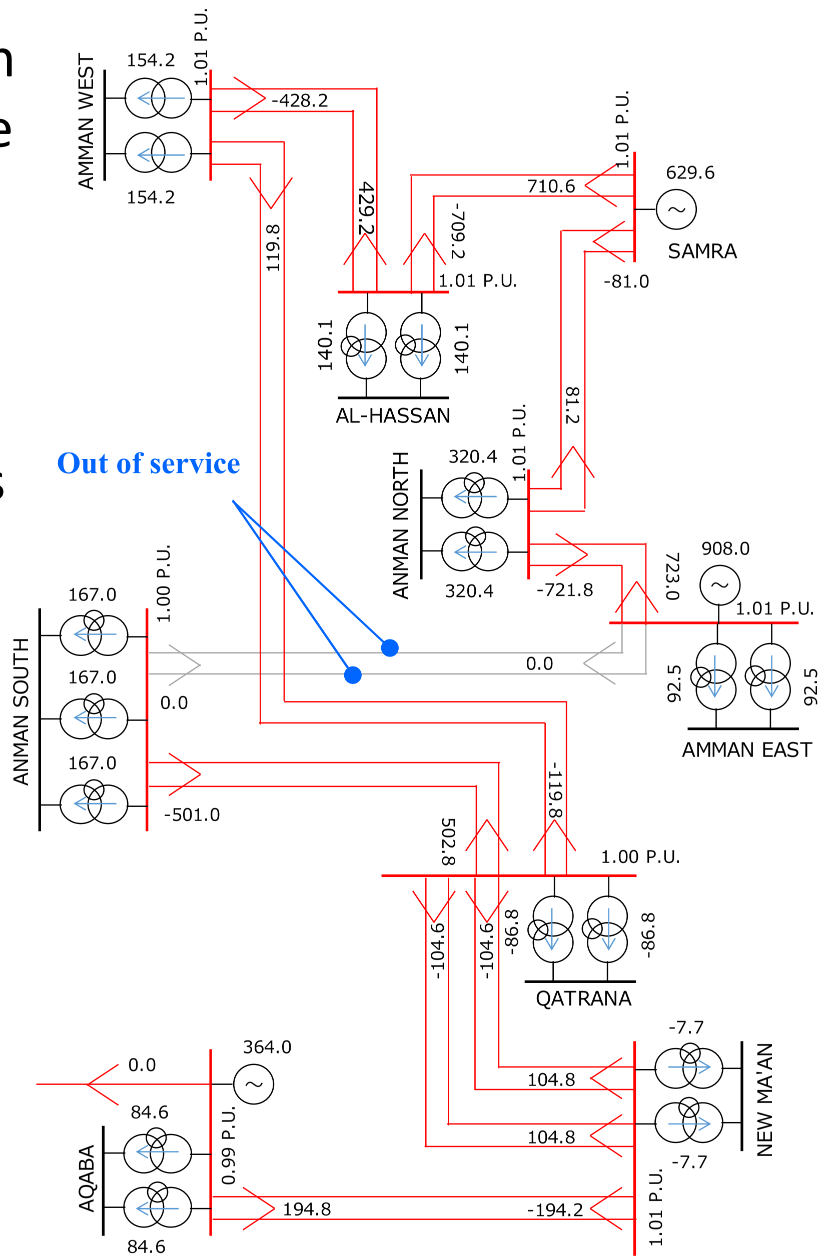
- ✓ No overloaded on transmission lines
- ✓ No overloaded on transformers
- ✓ Voltage is stable



Amman South Substation Protective Relay Replacement

Amman South substation to Amman East substation 400kV transmission line outage (Two circuit)

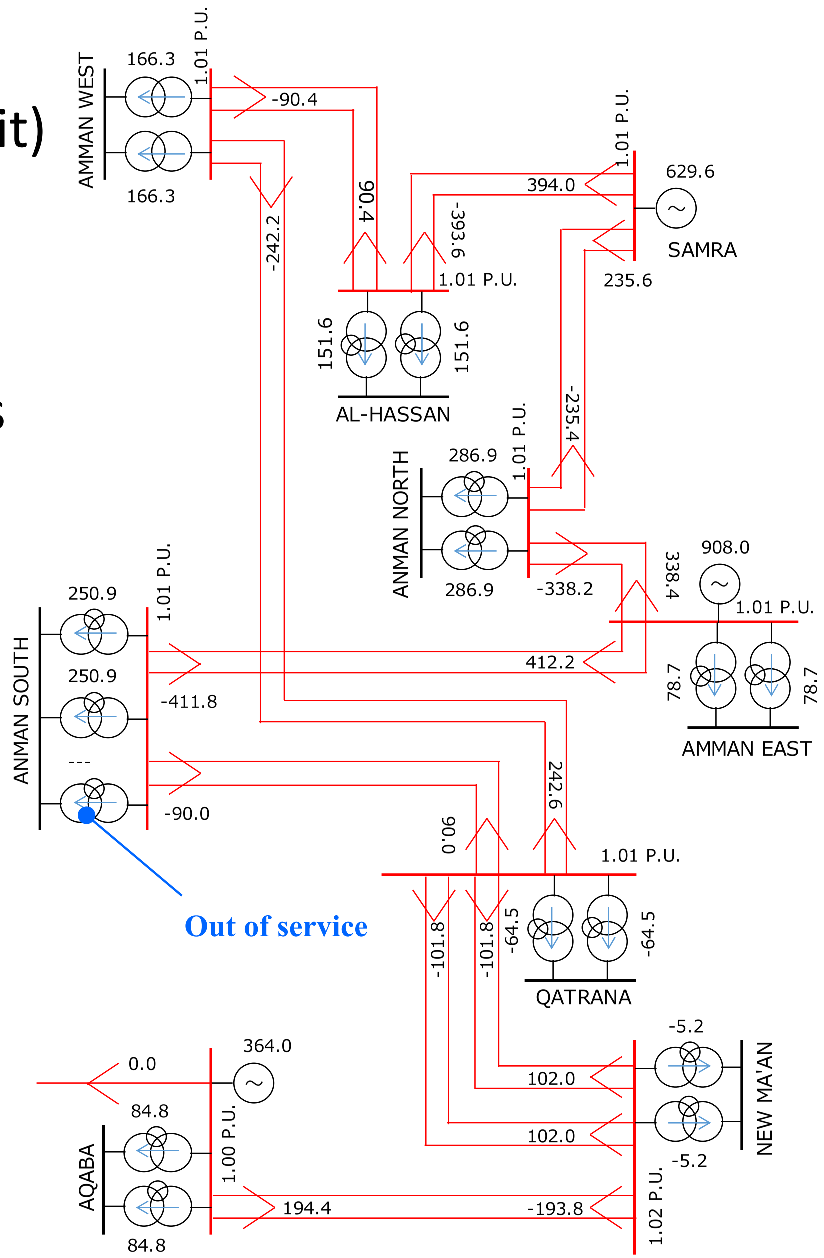
- ✓ No overloaded on transmission lines
- ✓ No overloaded on transformers
- ✓ Voltage is stable



Amman South Substation Protective Relay Replacement

Amman South substation
400kV/132kV transformer outage(1 unit)

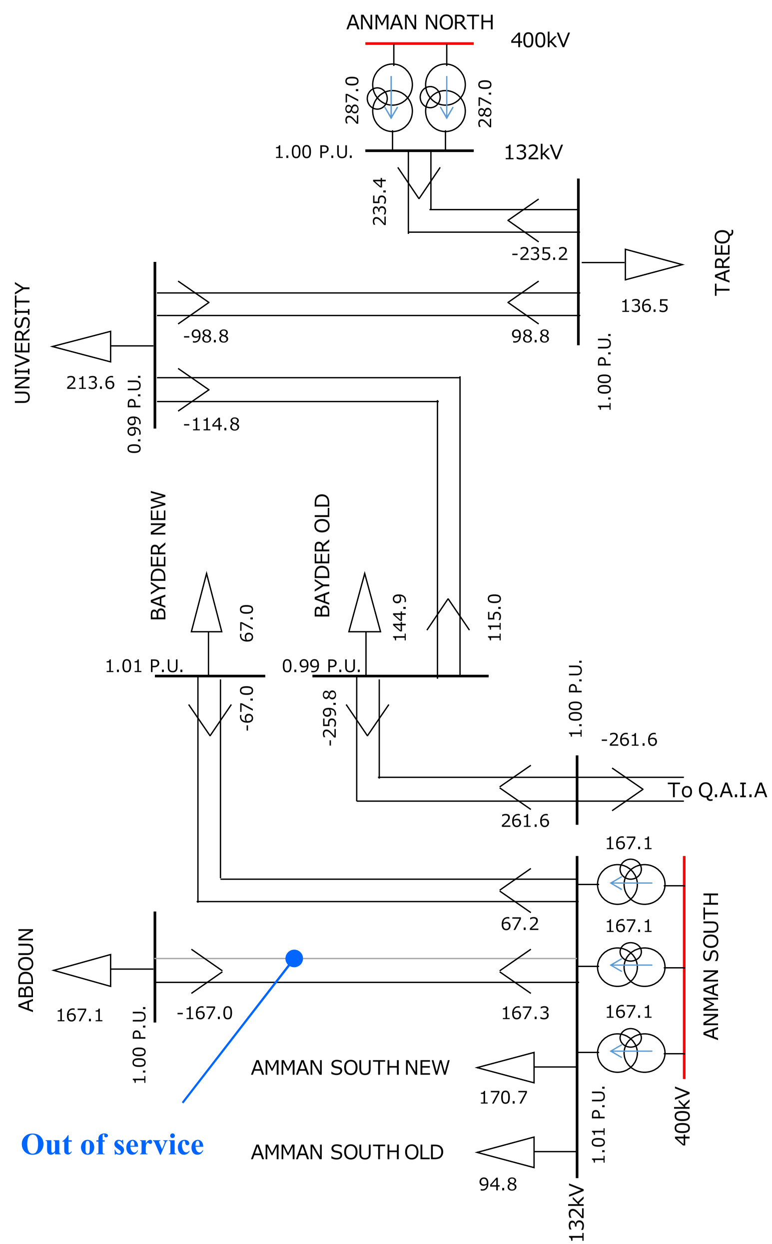
- ✓ No overloaded on transmission lines
- ✓ No overloaded on transformers
- ✓ Voltage is stable



Amman South Substation Protective Relay Replacement

Amman South substation 132kV transmission line - Abdoun substation line

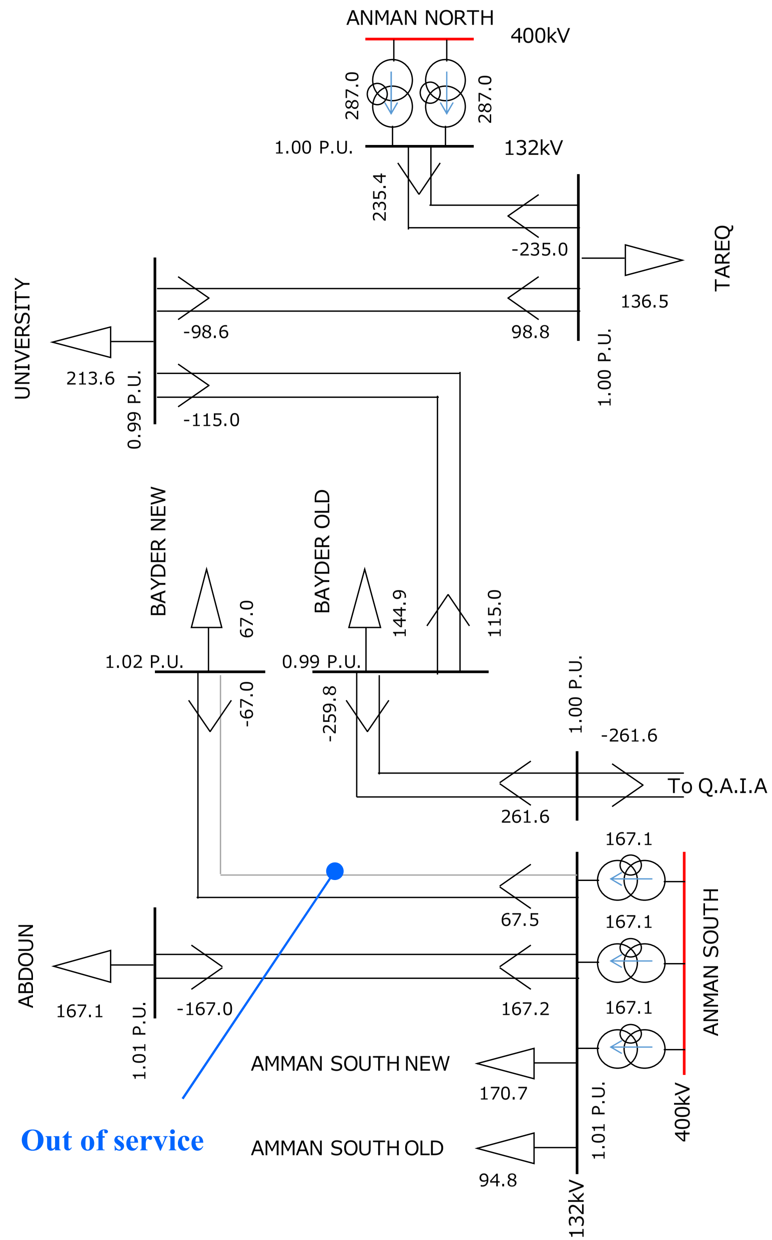
- ✓ No overloaded on transmission lines
- ✓ No overloaded on transformers
- ✓ Voltage is stable



Amman South Substation Protective Relay Replacement

Amman South substation 132kV transmission line - Bayader New substation line

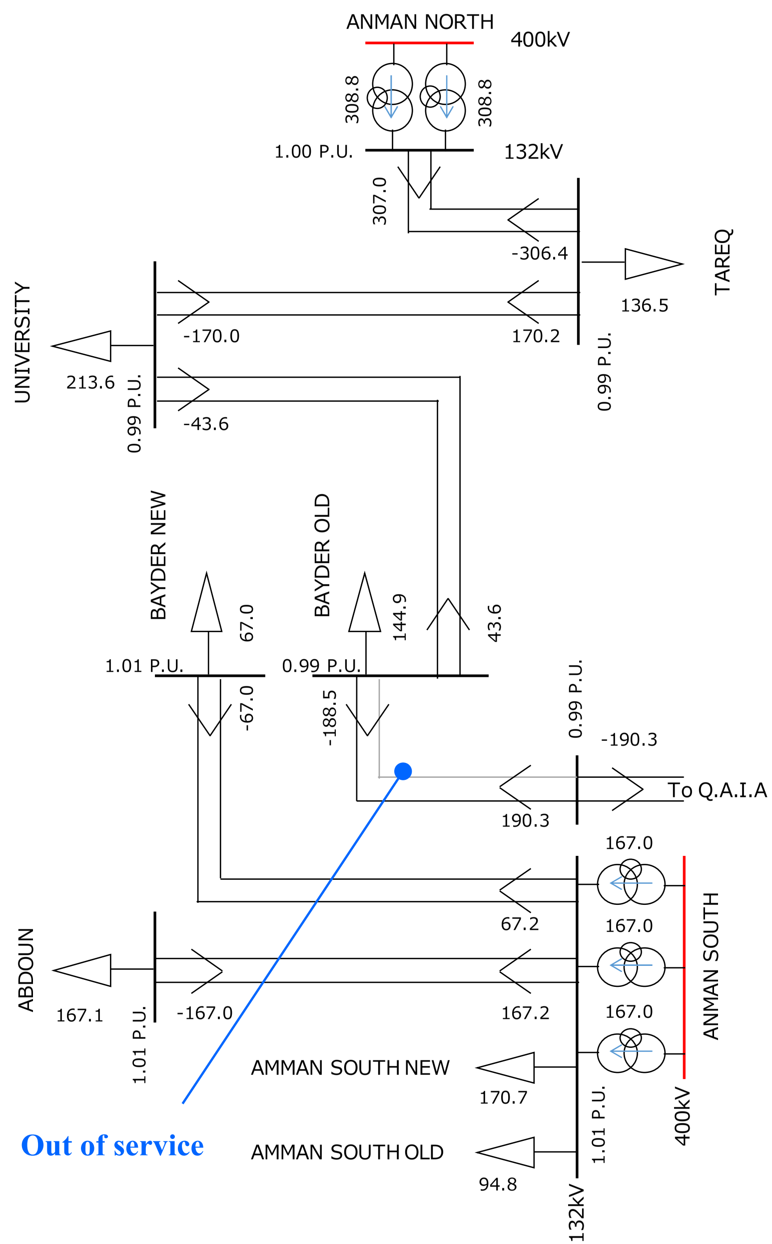
- ✓ No overloaded on transmission lines
- ✓ No overloaded on transformers
- ✓ Voltage is stable



Amman South Substation Protective Relay Replacement

Amman South substation 132kV transmission line - Bayader New substation line

- ✓ No overloaded on transmission lines
- ✓ No overloaded on transformers
- ✓ Voltage is stable



2. Confirmation of power flow on rely replacement constriction term

Aqaba substation Protective Relay Replacement

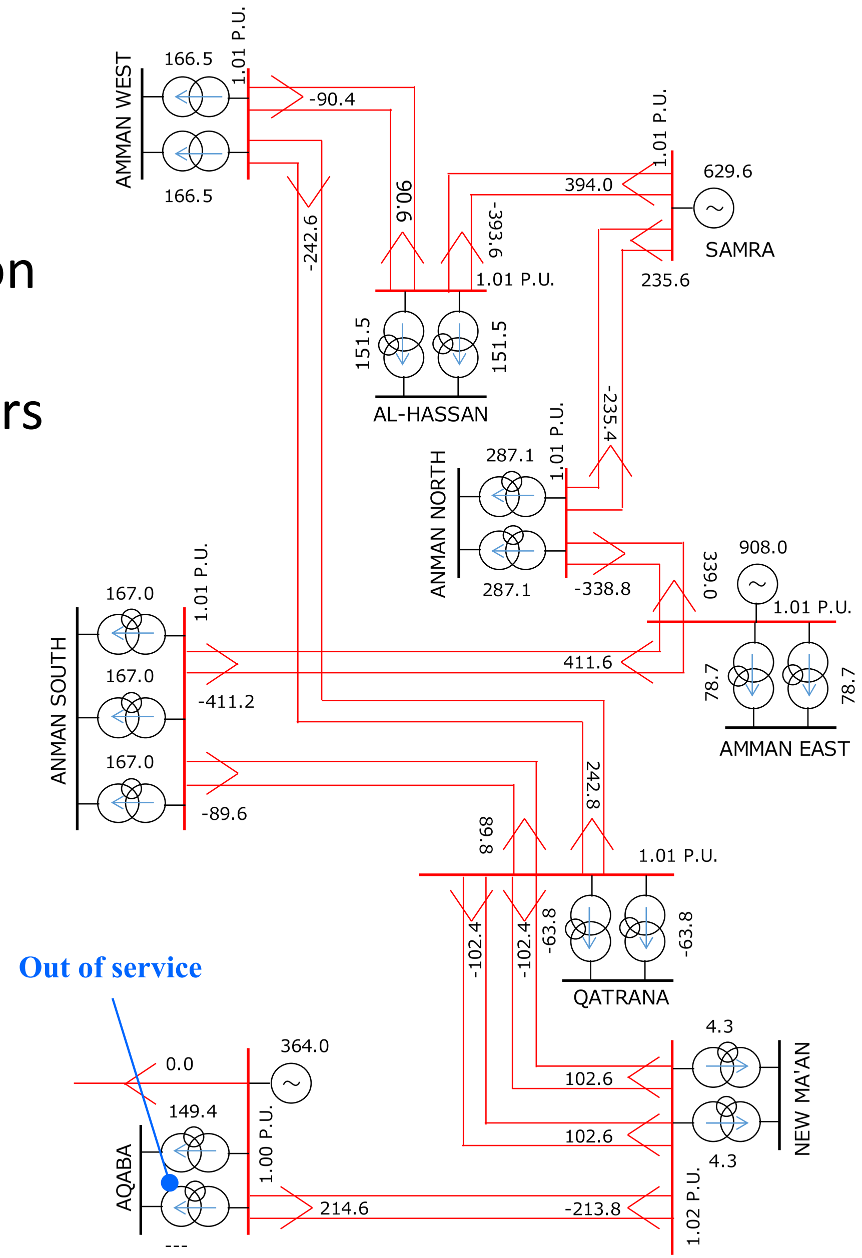
The equipment to be replaced with protective relays at the Aqaba substation is as follows

- ✓ Egypt interconnection line from Aqba substation
- ✓ 400kV/132kV transformers
- ✓ 132kV transmission lines

Aqaba substation Protective Relay Replacement

Aqba substation 400kV/132kV transformer outage (1 unit)

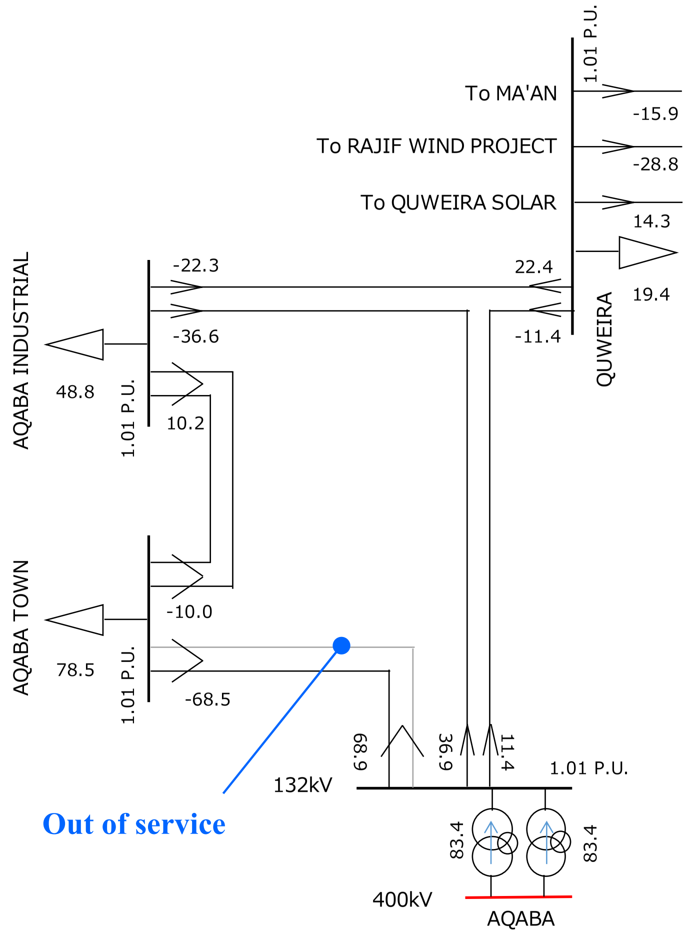
- ✓ No overloaded on transmission lines
- ✓ No overloaded on transformers
- ✓ Voltage is stable



Aqaba substation Protective Relay Replacement

Aqba substation 132kV transmission line - Aqba Town substation line

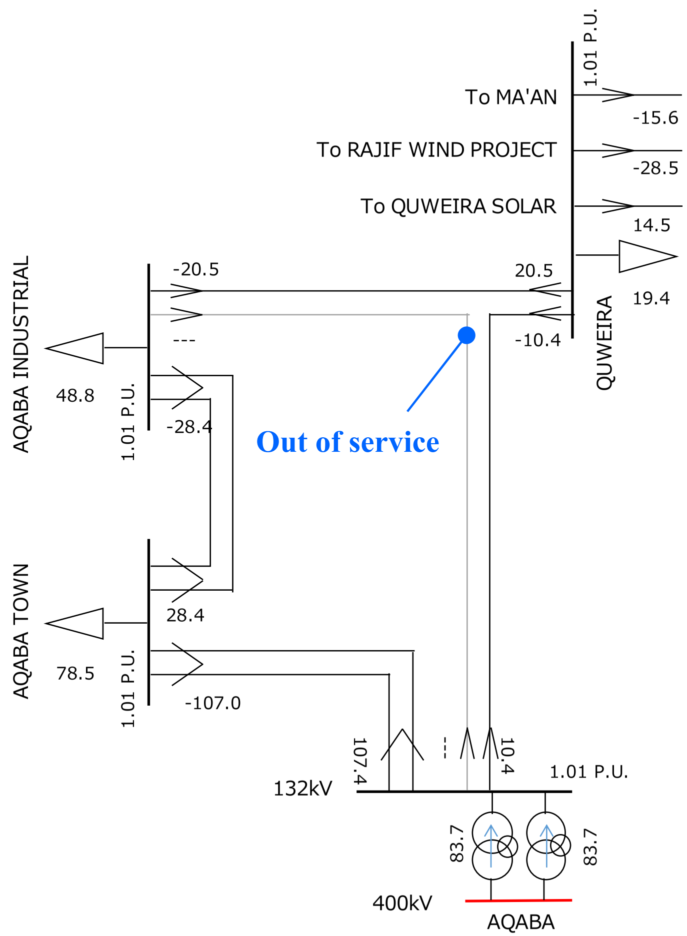
- ✓ No overloaded on transmission lines
- ✓ No overloaded on transformers
- ✓ Voltage is stable



Aqaba substation Protective Relay Replacement

Aqba substation 132kV transmission line - Aqba Industrial substation line

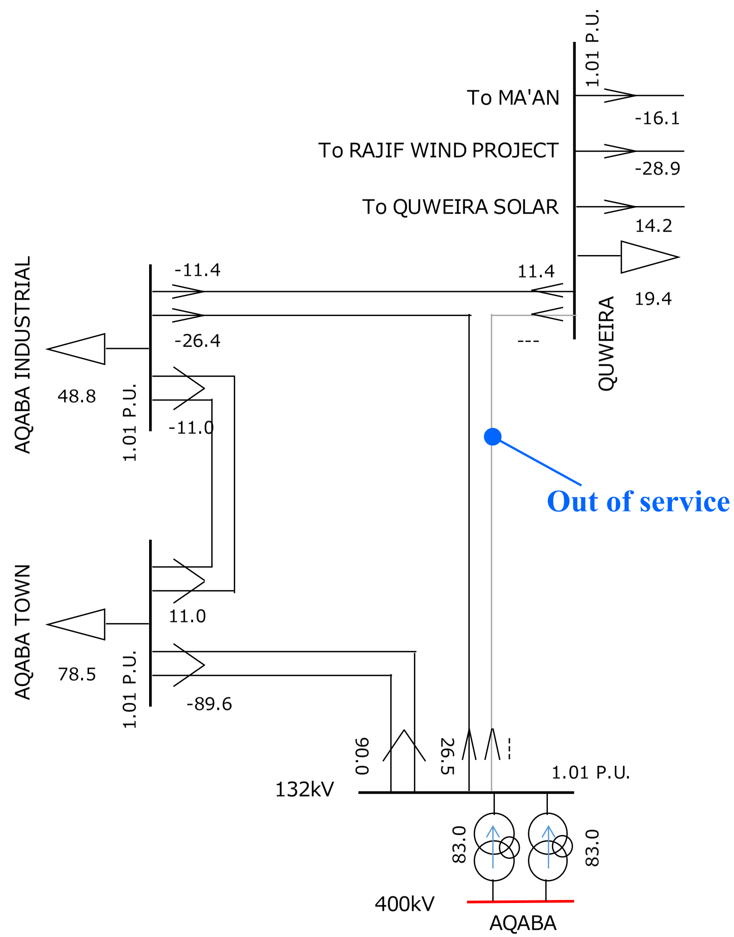
- ✓ No overloaded on transmission lines
- ✓ No overloaded on transformers
- ✓ Voltage is stable



Aqaba substation Protective Relay Replacement

Aqba substation 132kV transmission line
- Quweira substation line

- ✓ No overloaded on transmission lines
- ✓ No overloaded on transformers
- ✓ Voltage is stable



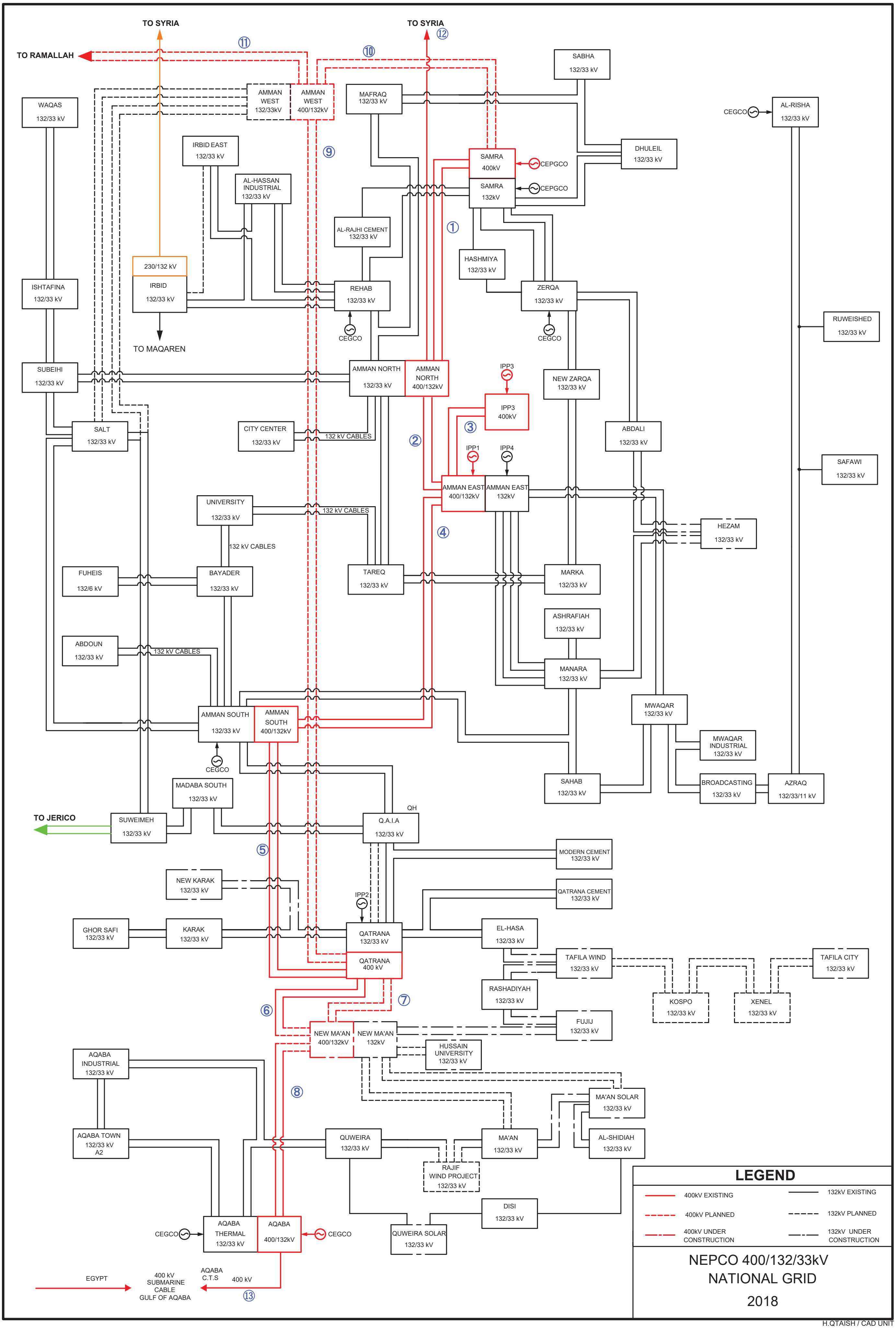
2. Confirmation of power flow on rely replacement constriction term

Conclusion

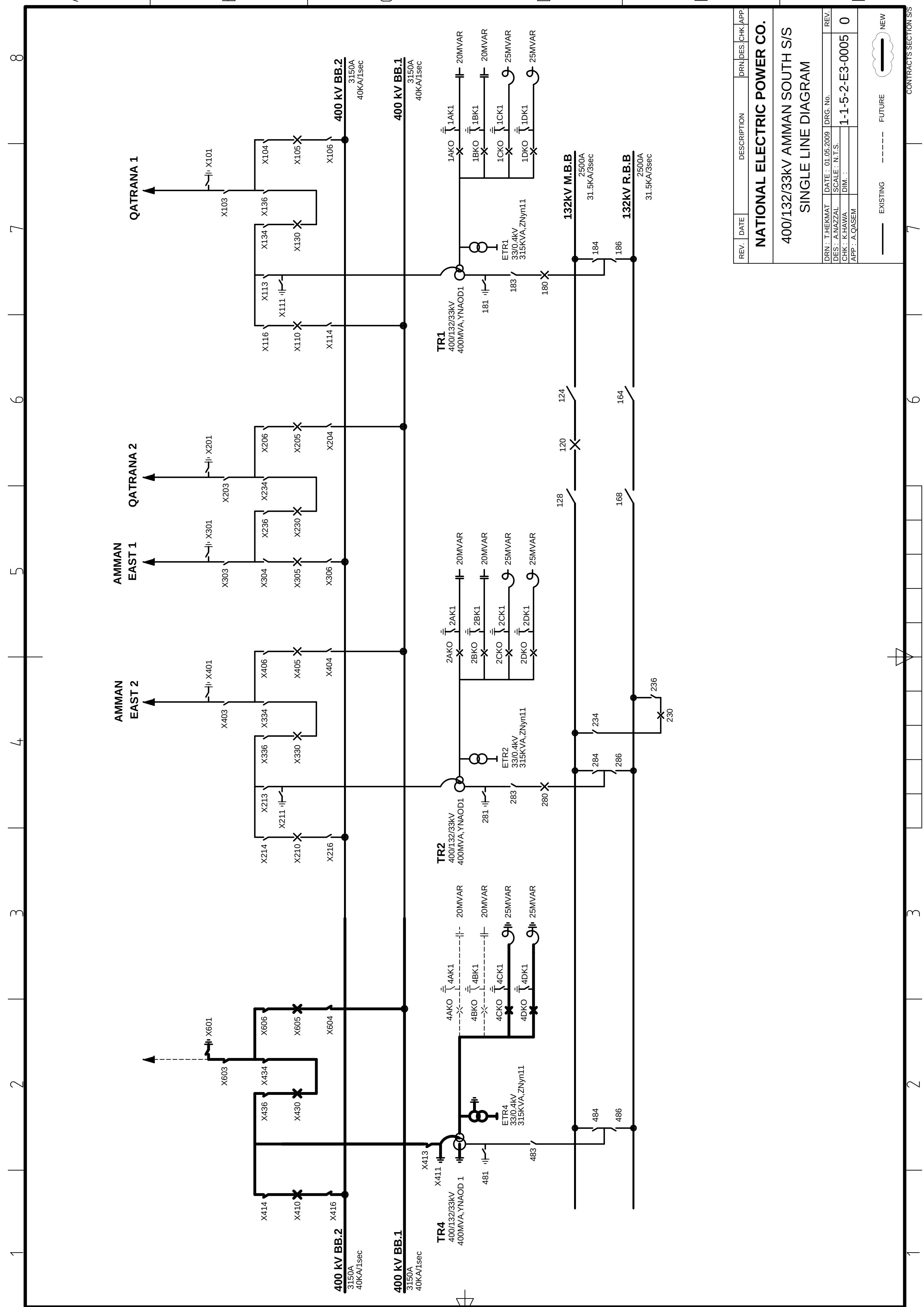
Power system conditions during the replacement of protective relays were analyzed to check for overloaded transmission lines, overloaded transformers, and substation voltages.

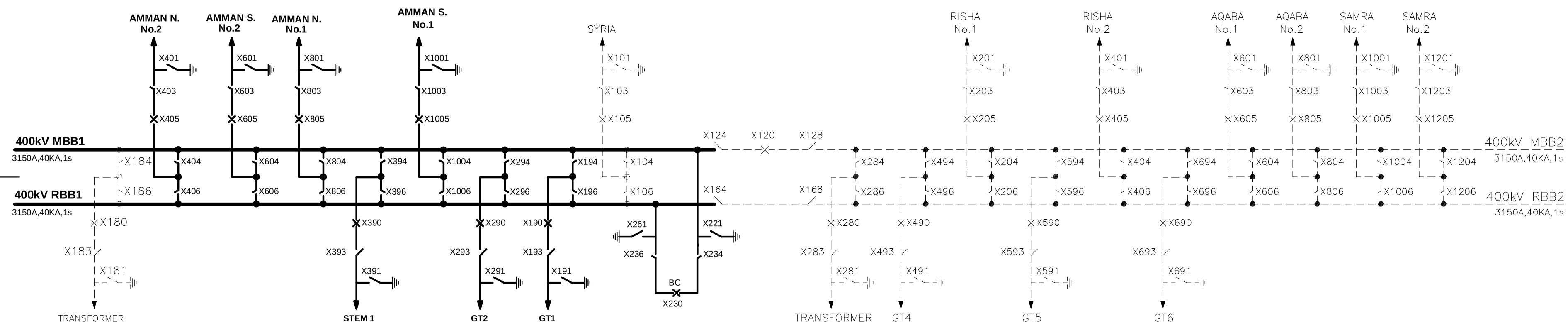
As a result, it was confirmed that there were no overloaded transmission lines or overloaded transformers, and that the voltage at the substation could be maintained properly.

APPENDIX 6. Jordan Power System Diagram



APPENDIX 7. Substation Single Line Diagrams





REV.	DATE	DESCRIPTION	DRN.	DES.	CHK.	APP.

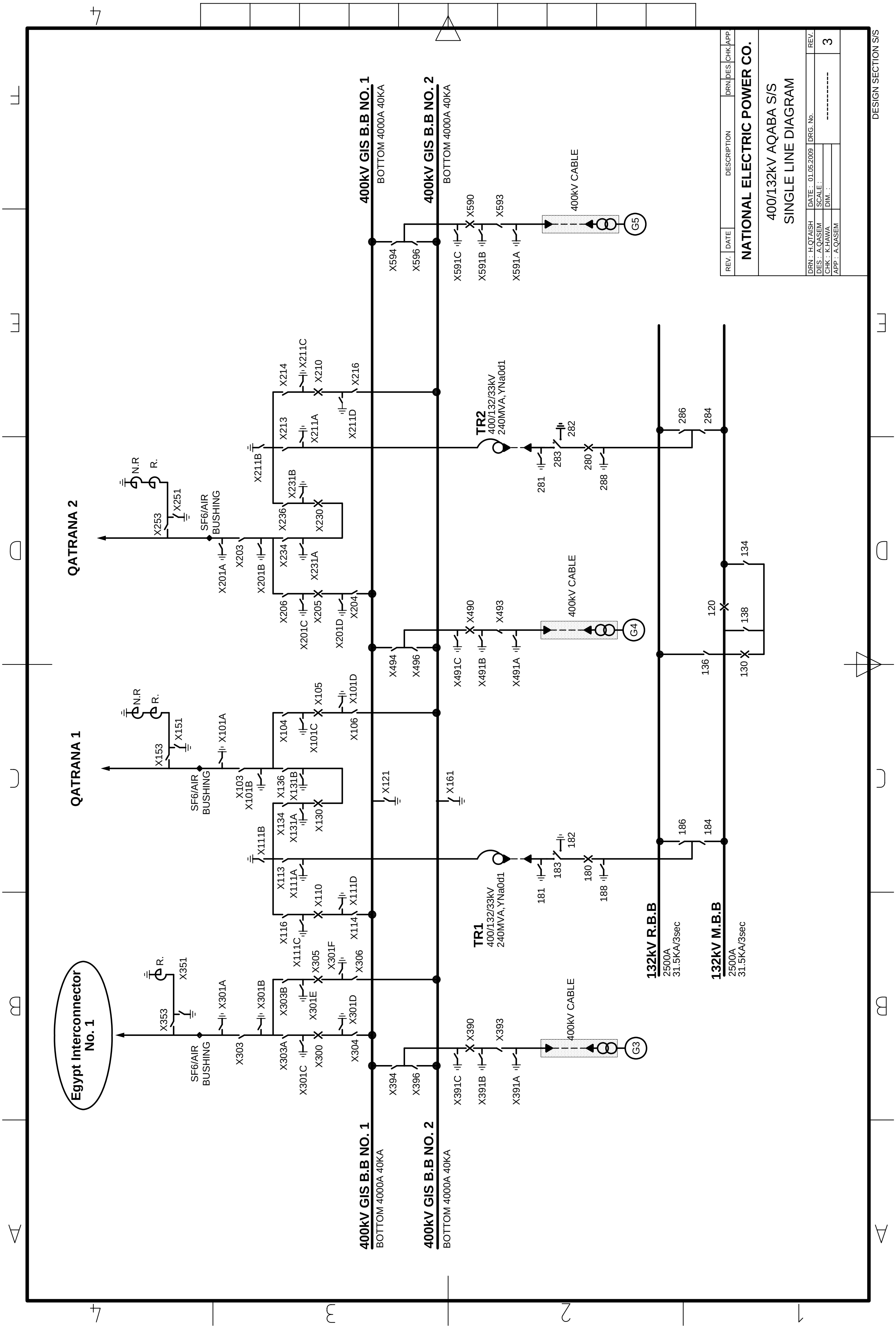
NATIONAL ELECTRIC POWER CO.

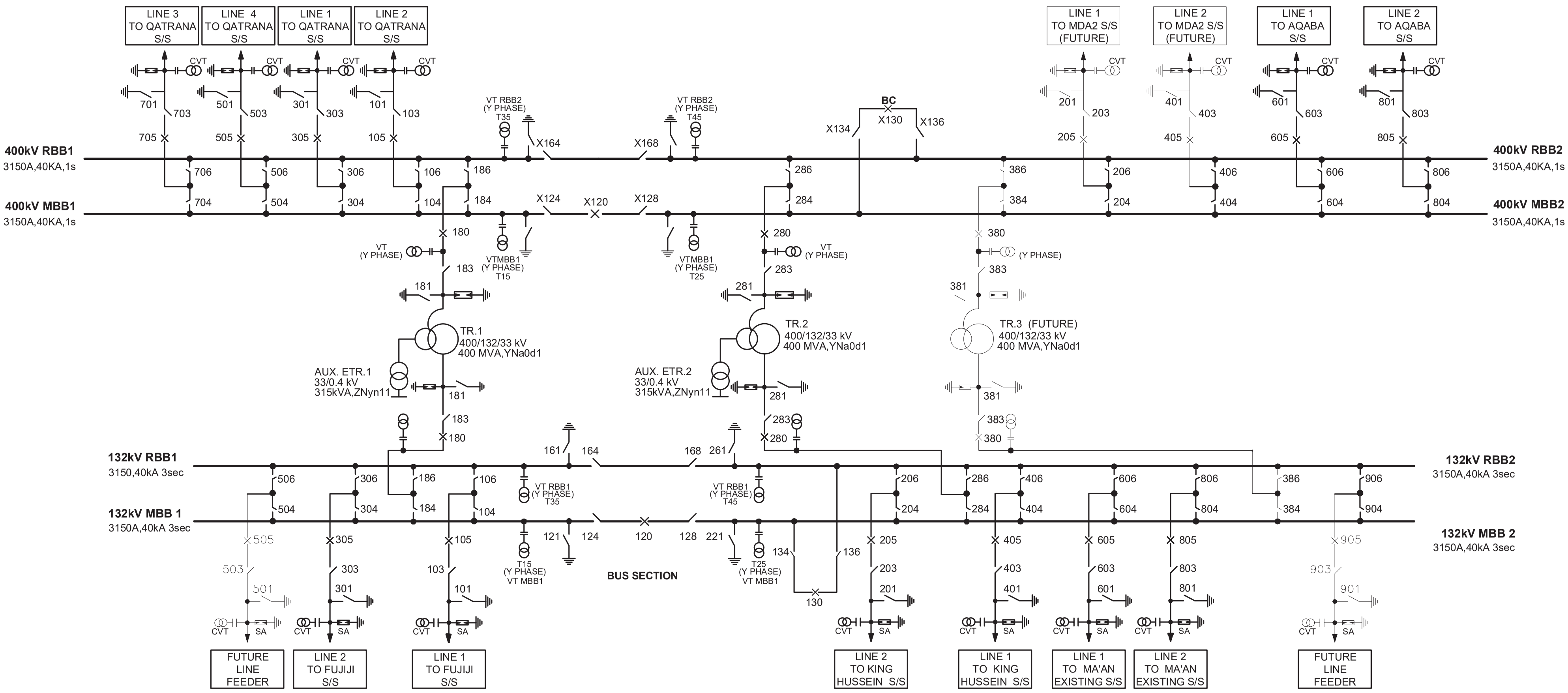
400kV AMMAN EAST S/S
SINGLE LINE DIAGRAM

DRN : H.QTAISH	DATE : 01.05.2009	DRG. No.	REV.
DES : K.HAWA	SCALE : N.T.S.	-----------	1
CHK : K.HAWA	DIM.IN :		
APP : A.QASEM			

EXISTING — FUTURE — NEW

CONTRACTS SECTION S/S


NATIONAL ELECTRIC POWER CO.
400/132kV AQABA S/S
SINGLE LINE DIAGRAM
REV. DATE DESCRIPTION DRN. DES. CHK. APP
DRN : H.QTAISH
DES : A.QASEM
CHK : K.HAWA
APP : A.QASEM
DATE : 01.05.2009
SCALE :
DIM. :
DRG. No.
REV. 3
DESIGN SECTION S/S
400kV GIS B.B NO. 1
BOTTOM 4000A 40KA
400kV GIS B.B NO. 2
BOTTOM 4000A 40KA
132kV R.B.B
2500A
31.5KA/3sec
132kV M.B.B
2500A
31.5KA/3sec
QATRANA 1
QATRANA 2
Egypt Interconnector No. 1
SF6/AIR BUSHING
400kV CABLE
G3
G4
G5
TR1
400/132/33kV
240MVA,YNa0d1
TR2
400/132/33kV
240MVA,YNa0d1
N.R
R.



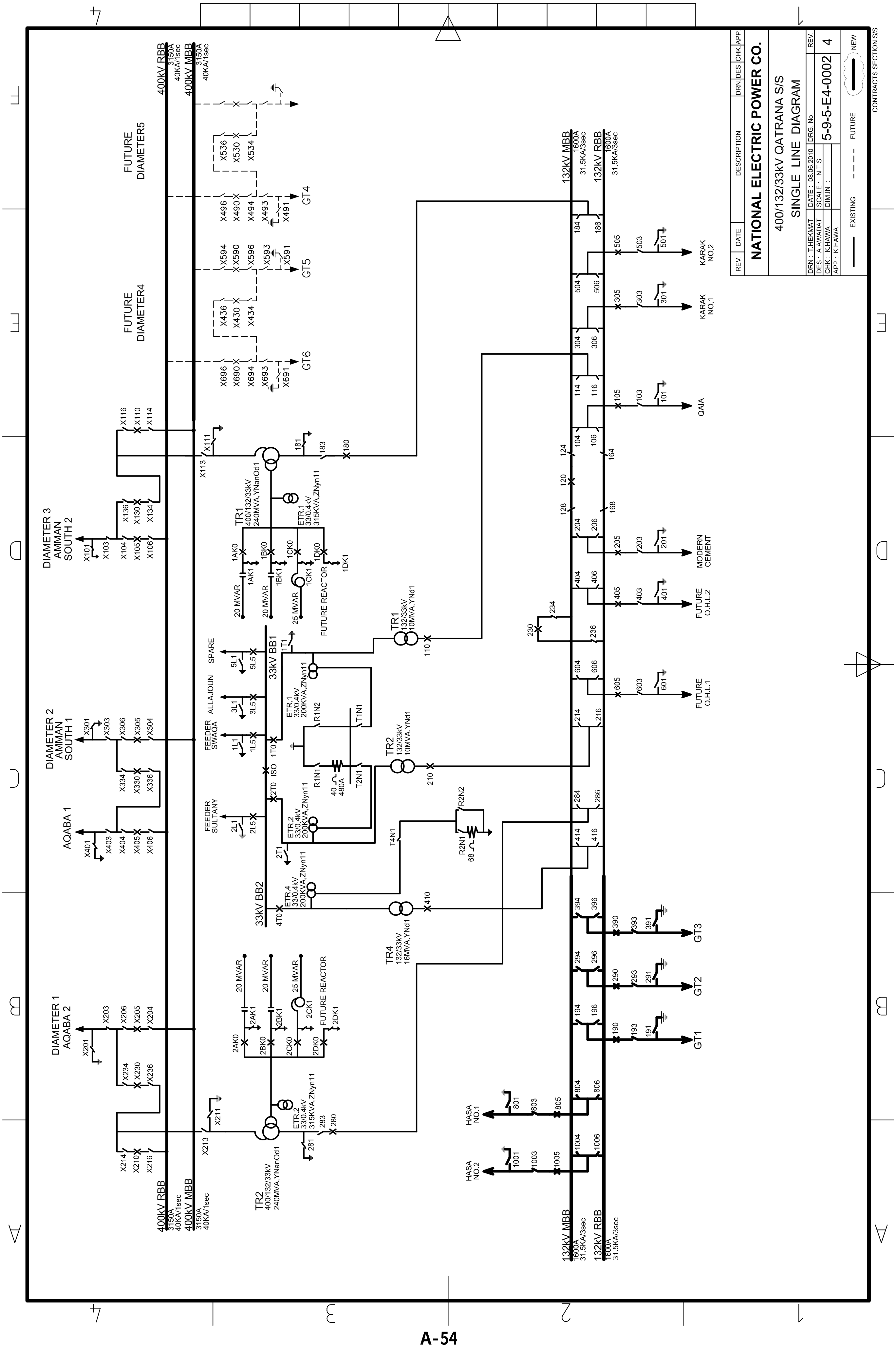
REV.	DATE	DESCRIPTION	DRN.	DES.	CHK.	APP.
01	14.03.2016					

NATIONAL ELECTRIC POWER CO.

400/132kV NEW MA'AN S/S
SINGLE LINE DIAGRAM

DRN : H.QTAISH	DATE : 04.09.2016	DRG. No.	REV.
DES :N.PARGHOUTHY	SCALE : N.T.S	6-13-E3-0005	0
CHK : M.ZAYYAD	DIM. :		
APP : A.ZOU'BI			

TENDER No.62/2015


NATIONAL ELECTRIC POWER CO.
400/132/33kV QATRANA S/S
SINGLE LINE DIAGRAM
DRN : T.HEKMAT
DES : A.AWADAT
CHK : K.HAWA
APP : K.HAWA
DATE : 08.06.2010
SCALE : N.T.S.
DIM.IN :
DRG. No.
5-9-5-E4-0002
REV.
4
EXISTING
FUTURE
NEW
CONTRACTS SECTION S/S
400kV RBB
400kV MBB
3150A
40KA/1sec
132kV MBB
132kV RBB
1600A
31.5KA/3sec
33kV BB1
33kV BB2
DIAMETER 1
AQABA 2
DIAMETER 2
AMMAN
SOUTH 1
DIAMETER 3
AMMAN
SOUTH 2
AQABA 1
FUTURE
DIAMETER4
FUTURE
DIAMETER5
GT1
GT2
GT3
GT4
GT5
GT6
TR1
400/132/33kV
240MVA,YNanOd1
TR2
400/132/33kV
240MVA,YNanOd1
TR1
132/33kV
10MVA,YNd1
TR2
132/33kV
10MVA,YNd1
TR4
132/33kV
16MVA,YNd1
ETR.1
33/0.4kV
315KVA,ZNyn11
ETR.2
33/0.4kV
315KVA,ZNyn11
20 MVAR
25 MVAR
FUTURE REACTOR
SPARE
ALLAJOUN
FEEDER
SWAQA
FEEDER
SULTANY
KARAK
NO.1
KARAK
NO.2
QAIA
MODERN
CEMENT
FUTURE
O.H.L.1
FUTURE
O.H.L.2
HASA
NO.1
HASA
NO.2

APPENDIX 8. Meeting Results of the List of Replacement Relay

Preparatory Survey for the Project for Enhancing Power System Operating Capacity in the Hashemite Kingdom of Jordan

2nd Survey, Equipment list &Confirmation Items

March., 2023 （15 Mar. Revision)

JAPAN INTERNATIONAL COOPERATION AGENCY (JICA)
ASIA ENGINEERING CONSULTING CO., LTD. (AEC)
TOKYO ELECTRIC POWER SERVICES CO., LTD. (TEPSCO)
NIPPON KOEI CO., LTD

Contents

1. Summary of the equipment to be renewed

Substation	Classification of protection	Renewal method	Work spot
Amman South	400kVTransmission line	Replace relay units	Existing relay panel
	400kV/132kVTransformer	ditto	ditto
	400kVBusbar	ditto	ditto
	132kVTransmission line	ditto	ditto
	132kV/33kVTransformer	ditto	ditto
	132kVBusbar	ditto	ditto
Aqaba	400kVTransmission line	ditto	ditto
	400kV/132kVTransformer	ditto	ditto
	400kVBusbar	ditto	ditto
	132kVTransmission line	Replace relay panel	New relay room
	132kV/33kVTransfiormer	ditto	ditto
	132kVBusbar	ditto	ditto
Aqaba Cable End terminal	400kV Cable line (Egypt interconnector)	Replace relay panel	Existing panel space
Amman East	400kV Transmission line (Amman South line)	Replace relay units	Existing relay panel

2. Quantity of 400kV protection relays

Protection type	Kind of Relays	remarks	unit quantity				total	panel	Spare relay
			amman south	amman east	Aqaba	aqaba cable end		aqaba cable ends	
Transmission line protection	current differential relay	Integrated type such as distance relay, overcurrent relay, voltage relay,	4	4		1	9		3
	distance relay	Integrated overcurrent relay, voltage relay, overload protection,	4		6		10		2
	Hig-impedance differential relay	Stub protection	8		6		14		4
	Autorecloser				3				1
	undervoltage relay	grounding interlock				0	0		0
Out-of-step protection	Distance type out-of-step relay	Egypt interconnector			1		1		
Shunt reactor (ShR) protection	overcurrent relay				5		5		1
	High-impedance differential relay				6		6		
Breaker failure protection & control (DIAMETER)	Overcurrent relay (CBF)		18		22		40		5
	Synchronization confirmation relay		9		8		17		2
Transformer protection (400kV/132kV transformers, generator transformers)	Biased differential relay		4		7		11		2
	High-impedance differential relay		4		4		8		
	overcurrent relay		2		0		2		
	undervoltage relay				0		0		
Busbar protection	High-impedance differential relay		8		8		16		
Overvoltage protection	overvoltage relay				0		0		0
Relay setting tool (laptop PC)			1	1	1	1	4		

2. 1-1 400kV Amman South S/S Qatrana 1, 2L

Q’ty /1L

Functions	Series	Manufacture	Model#	Type	Replacement with functions	Type	Remarks	Q'ty
Distance	Main1	ALSTOM	SHNB 102	STATIC	Distance	numerical	AR, FL, Mutual coupling, DOC, DEF,OV integrated	1
Circulating		ALSTOM	MCAG34	STATIC	High-imp Diff.	numerical		1
Overvoltage		ALSTOM	KVFG142	STATIC				
Distance	Main2	MERLIN GERIN	SEL S21	STATIC	Distance	numerical	ditto	1
AR		MERLIN GERIN	S79	STATIC				
FL		GEC ALSTOM	DLDS 3000	STATIC				
Mutual coupling		GEC ALSTOM	BCHMore	STATIC				
Current flow checking		MCTI	MCTI39	STATIC				
Circulating		ALSTOM	MCAG34	STATIC	High-imp Diff.	numerical		1
Overvoltage		ALSTOM	KVFG142	STATIC				

- A numerical distance relay includes “AR, FL, Zero-phase-sequence coupling compensation, DOC, OV, DEF etc”. Distance protection will be used for zone1 to zone3 for forward direction and zone4 for reverse direction.
- Qatrana 2L has SEL-321 numerical distance relay. It will be replaced.

2. 1-2 400kV Amman South S/S Amman East 1, 2L

Q’ty /1L

Functions	Series	Manufacture	Model#	Type	Replacement with functions	Type	Remarks	Q'ty
Distance	Main1	ALSTOM	SHNB 102	STATIC	Current Differential	numerical	Distance, AR, FL, Mutual coupling, OC, OV integrated	1
Circulating		ALSTOM	MCAG34	STATIC	High-imp Diff.	numerical		1
Overvoltage		ALSTOM	KVFG142	STATIC				
Distance	Main2	MERLIN GERIN	SEL S21	STATIC	Current Differential	numerical	Distance, AR, FL, Mutual coupling, OC, OV integrated	1
AR				STATIC				
FL				STATIC				
Current flow checking		MCTI	MCTI39	STATIC				
Circulating		ALSTOM	MCAG34	STATIC	High-imp Diff.	numerical		1
Overvoltage		ALSTOM	KVFG142	STATIC				

- A numerical current differential relay includes “Distance, AR, FL, Zero-phase-sequence coupling compensation, DOC, DEF, OV etc”.

2. 1-3 400kV Amman South S/S Transformer 1T, 2T

Q'ty /1T

Functions	Series	Manufacture	Model#	Type	Replacement with functions	Remarks	Q'ty
Differential	Main1	ALSTOM	MBCH13	STATIC	Differential		1
Physical							
OC	Main2	ALSTOM	MGCC82	STATIC	Differential	OC, Overfluxing, Neutral OC, 33kV OC integrated	1
Overfluxing				STATIC			
Neutral OC		ALSTOM	MCGG22	STATIC			
33KV OC		ALSTOM	MCGG63	STATIC			
Earth fault over current (for earthing transformer)		ALSTOM	MCGG22	STATIC	OC		1
HV CIRCULATING CURRENT		ALSTOM	MCAG34	STATIC	High Imp.		1
Circulating current		ALSTOM	MCAG34	STATIC	High Imp.		1

- A numerical differential relay (Bias) includes "Overfluxing (overexcitation), OC (primary, secondary, tertiary and neutral) etc".
- A numerical differential relay can provide trip orders and display for physical relay operation from BI input.
- It is O.K that overfluxing have 1-phase VT input.

7

2. 1-4 400kV Amman South S/S Busbar protection

Existing relays					New relays		
Functions	Series	Manufacture	Model#	Type	Replacement with functions	Remarks	Q'ty
High Imp.	Main1	ALSTOM	MCAG34	Electro Mech.	High Imp.		4
High Imp.	Main2	ALSTOM	MCAG34	Electro Mech.	High Imp.		4

Q'ty /1Bus+2Bus total

- A numerical high-impedance differential relay can reuse existing the varistor (nonlinear resistance may be Metrosil®) and the stabilizing resistor.

8

2. 1-5 400kV Amman South S/S DIAMETER CB

Functions	Series	Manufacture	Model#	Type	Replacement with functions	Remarks	Q'ty
CBF-A	Main1	ALSTOM	MCTI		OC (CBF)		1
CBF-B	Main2	ALSTOM	MCTI		OC (CBF)		1
Short zone A					OC		0
Short zone B					OC		0
Synchro checking					Synchro checking		1
OC	Main1	ALSTOM	MCTI		OC (CBF)		1
OC	Main2	ALSTOM	MCTI		OC (CBF)		1
Short zone A					OC		0
Short zone B					OC		0
Synchro checking					Synchro checking		1
OC	Main1	ALSTOM	MCTI		OC (CBF)		1
OC	Main2	ALSTOM	MCTI		OC (CBF)		1
Short zone A					OC		0
Short zone B					OC		0
Synchro checking					Synchro checking		1

Q'ty /1DIAMETER

- OC for CBF and Short zone is common IED. (One OC relay has CBF function and OC functions.)
- Timers for CBF and Short zone are separated from each other.

2. 2 400kV Amman East S/S Amman South 1, 2L

Existing relays					New relays		Q'ty /1L
Functions	Series	Manufacture	Model#	Type	Replacement with functions	Remarks	Q'ty
Distance	Main1	SIEMENS	7SA522	Numerical	Current Differential	Distance, AR, FL, Mutual coupling, OC, OV integrated	1
BF		SIEMENS	7VK611	Numerical			
Distance	Main 2	AREVA	P437	Numerical	Current Differential	Distance, AR, FL, Mutual coupling, OC, OV integrated	1
BF		SIEMENS	7VK611	Numerical			
AR		SIEMENS	7VK611	Numerical			

- A numerical current differential relay includes “Distance, AR, FL, Zero-phase-sequence coupling compensation, DOC, DEF, OV etc”.

2. 3-1 400kV AQABA S/S Egypt Interconnector 1L

Functions	Series	Manufacture	Model#	Type	Replacement with functions	Type	Remarks	Q'ty
Distance	Main1	Alstom	Shnb102	Static	Distance	numerical		1
Distance	Main 2	ABB	REZ	Static	Distance	numerical		1
DIFF-1, STUB		REYROLL	B3	Static	DIFF-1, STUB	numerical	High-Imp.	1
DIFF-2, STUB		REYROLL	B3	Static	DIFF-2, STUB	numerical	High-Imp.	1
SYNC	Common	ABB	RES010	Static			~~Integrated in distance~~	
AR		GEC ALSTOM	LFAA102	Static			~~Integrated in distance~~	1
OVR1		REYROLL	TEB/AR111	Static			Integrated in distance	
OVR2		REYROLL	TEB/AR111	Static			Integrated in distance	
85−1		REYROLL	TR112	Static				
85-2		REYROLL	TR112	Static				

A numerical distance relay includes “AR, FL, Zero-phase-sequence coupling compensation, DOC, DEF, OV etc”. AR should be installed on a common panel because of complicated wirings.

2. 3-2 400kV AQABA S/S Egypt Interconnector 1L

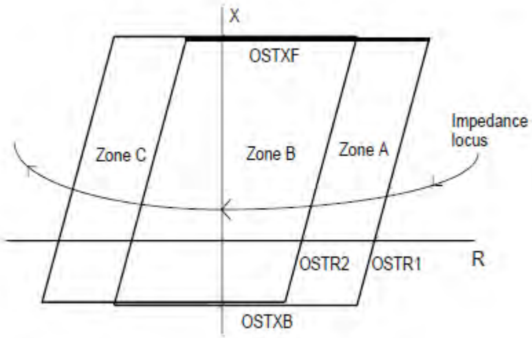
Functions	Series	Manufacture	Model#	Type	Replacement with functions	Type	Remarks	Q'ty
OLR	CB X300	SIEMENS	7SR5111	Static			Integrated in distance	
132kV feeder								
OLR		REYROLL	2DAB	Static			Integrated in distance	
400kV Syria								
CBF-1		REYROLL	2DAB	Static	OC-CBF-1	numerical		1
CBF-2		REYROLL	2DAB	Static	OC-CBF-2	numerical		1
SYNC		REYROLL		Static	SYNC	numerical		1
CBF-1	CB X305	REYROLL	2DAB	Static	OC-CBF-1	numerical		1
CBF-2		REYROLL	2DAB	Static	OC-CBF-2	numerical		1
SYNC		REYROLL		Static	SYNC	numerical		1

- A numerical distance relay includes “Thermal overload function” and it is acceptable.

2. 3-2 400kV AQABA S/S Egypt Interconnector 1L (continued)

An example of out-of-step protection as impedance type that can be included in distance relay for transmission line protection.
But it may not be same function of impedance type.
Please tell us the function and scheme of the existing relay by sending manual.

out-of-step locus passes from Zone A → Zone B → Zone C (or Zone C → Zone B → Zone A) and remains in Zones A and C for the detection time (TOST).



2. 3-3 400kV AQABA S/S ShR for Egypt Interconnector 1L

Existing relays					New relays		
Functions	Series	Manufacture	Model#	Type	Replacement with functions	Remarks	Q'ty
OC51-OC	SHR	REYROLL	2DCC	Static	OC		1
DIFF-1		REYROLL	B3	Static	DIFF	High-Imp.	1
87-1 CC							
DIFF-2		REYROLL	B3	Static	DIFF	High-Imp.	1
87-2 CC							

- A numerical high-impedance differential relay can reuse existing the varistor (nonlinear resistance may be Metrosil®) and the stabilizing resistor.

Could you clarify the type of Metrosil® and value of stabilizing resistor which existing relay panel applied, and also, existing high-impedance diff. relays' settings.

2. 3-4 400kV AQABA S/S New Ma'an 1L,2L

Q'ty /1L

Functions	Series	Manufacture	Model#	Type	Replacement with functions	Type	Remarks	Q'ty
Distance	Main1	Alstom	Shnb102	Static	Distance	numerical		1
Distance	Main 2	ABB	REZ	Static	Distance	numerical		1
DIFF-1, STUB		REYROLL	B3	Static	OC1-Stub	numerical	High-Imp.	1
DIFF-2, STUB		REYROLL	B3	Static	OC2-Stub	numerical	High-Imp.	1
AR	Common	GECs	LFAA 102	Static			~~Integrated in distance~~	1
50-AR		REYROLL	2DAB	Static			~~Integrated in distance~~	
OC51-OC	SHR	REYROLL	2DCC	Static	OC	numerical		1
DIFF-1 87CC		REYROLL	B3	Static	DIFF	numerical	High-Imp.	1
DIFF-2 87CC		REYROLL	B3	Static	DIFF	numerical	High-Imp.	1
THMAL OC		ABB	RAVK1	Static			Nutural OC	1

- A numerical distance relay includes "AR, FL, Zero-phase-sequence coupling compensation, DOC, DEF, OV etc".
- Could you clarify the type of Metrosil® and value of stabilizing resistor which existing relay panel applied, and also, existing high-impedance diff. relays' settings.
- A numerical OC relay (for SHR) has 50, 51 and thermal OC element. But THAML OC uses natural CT.
- AR should be installed on a common panel.

2. 3-4 400kV AQABA S/S New Ma'an 1L,2L

Functions	Series	Manufacture	Model#	Type	Replacement with functions	Type	Remarks	Q'ty
CBF-1	CB X130	REYROLL	2DAB	Static	OC-CBF-1	numerical		1
CBF-2	X230	REYROLL	2DAB	Static	OC-CBF-2	numerical		1
SYNC		REYROLL		Static	SYNC	numerical		1
CBF-1	CB X105	REYROLL	2DAB	Static	OC-CBF-1	numerical		1
CBF-2	X205	REYROLL	2DAB	Static	OC-CBF-2	numerical		1
SYNC		REYROLL		Static	SYNC	numerical		1

2. 3-5 400kV AQABA S/S INTER BUS TR1, TR2

Q'ty /1T

Bias Diff. (P, S)	Main1	REYROLL	DUOBIAS	Static	Bias. Diff	numerical		1
Hi Imp DIFF 87HVC (P, S)	MAIN 2	REYROLL	B3	Static	High-Imp.	numerical		1
87CC (P, S, N)		REYROLL	B3	Static	High-Imp.	numerical		1
(Bias. Diff)					Bias. Diff	numerical		1
OC EF		REYROLL	2DCC	Static	OC EF		included in Bias Diff.	
EF 50T		REYROLL	SEF	Static	EF		included in Bias Diff.	
EF51		REYROLL	SEF	Static	EF		included in Bias Diff.	
CBF-1	X110	REYROLL	2DAB	Static	OC-CBF-1	numerical		1
CBF-2	X210	REYROLL	2DAB	Static	OC-CBF-2	numerical		1
SYNC		REYROLL		Static	SYNC	numerical		1

- A numerical differential relay (Bias) includes "Overfluxing (overexcitation), OC (primary, secondary, tertiary and neutral) etc".
- Bias Diff has OC elements and EF elements for primary, secondary and tertiary circuit.
- Could you clarify the type of Metrosil® , value of stabilizing resistor and relay setting value for B3 relays?

2. 3-6 400kV AQABA S/S Busbar 1, 2

Existing relays					New relays		
Functions	Series	Manufacture	Model#	Type	Replacement with functions	Remarks	Q'ty
High Imp.	87 1/1	REYROLL	DAD3	Static	High Imp.	High Imp.	2
Trip 1	87 2/1	REYROLL	DAD3	Static	High Imp.	High Imp.	2
High Imp.	87 1/2	REYROLL	B3	Static	High Imp.	High Imp.	2
Trip 2	87 2/2	REYROLL	B3	Static	High Imp.	High Imp.	2

Q'ty /1BUS+2BUS total

- Could you clarify the type of Metrosil® , value of stabilizing resistor and relay setting value for B3 relays?

2. 3-7 400kV AQABA S/S Voltage Protection & Generator TR1,2,3

Facility Name	Functions	Series	Manufacture	Model#	Type	Replacement with functions	Type	Remarks	Q'ty
Voltage protection	Over voltage		REYROLL	B68	Static				0
			SIEMENS						0
Generator Transformer	Bias. Diff	Main1	REYROLL	DUOBIAS	Static	Bias. Diff	numerical		3
3, 4, 5	27-MR		REYROLL	B68	Static	Undervoltage	numerical		0
(3 transformers, 2 windigs)	50-1 CBF		REYROLL	2DAB	Static		numerical		3
	50-2 CBF		REYROLL	2DAB	Static		numerical		3

Q’ty /1TR

- Voltage protection is not needed.
- 27MR is not needed.

2. 4 400kV AQABA Cable end station

Functions	Series	Manufacture	Model#	Type	Replacement with functions	Type	Remarks	Q'ty
Current Differential	Main1	GEC ALSTOM	LFCB 102	Numerical	Current Differential	numerical		1
voltage for Interlok		Reyrolle	B68	static	voltage			0

- Voltage relay is not needed.
- Relay unit replacement, not panel replacement.

3. Quantity of 132kV protection relays

Protection type	Relay method	remarks	unit quantity amman south	unit quantity Aqaba	total unit Q'ty	Panel Q'ty Aqaba	Spare relay
Transmission line protection	distance relay	Integrated overcurrent relay, voltage relay, overload protection,	7	4	11	4	2
	overcurrent relay	OC/EF/SEF	9	4	13		1
	Control	BCU		4	4		1
Transformer protection (400kV/132kV transformer secondary, 132kV/33kV transformer)	Biased differential		3	4	7	6	1
	High-impedance differential relay	Restricted EF	3		3		
	Current/voltage relay	OC/EF/SEF/UV/25	9	10	19		3
	Control	BCU		6	6		
Busbar protection	High-impedance differential relay	High Imp	4	4	8	4	2
	current differential relay	Low Imp.			0		0
Buscoupler Bussection	Current/voltage relay	OC/EF/SEF/UV/25	2	2	4	2	
	Control	BCU		2	2		
Relay setting tool (laptop)			1	1	2		

21

3. 1 132kV AQABA S/S

Feeder name	Main relays	Functions	type	Remarks	Relay unit Q'ty	Panel Q'ty
transmission lines	Main	Distance	numerical	AR, 25, CBF integrated	1/each	4
LINE 1 TO AQABA TOWN		or Current Diff				
LINE 2 TO AQABA TOWN	Backup	OC/EF/SEF	numerical		1/each	
LINE TO QWEIRA						
LINE TO AIE						
INTERBUS TRANSFORMER	Backup	OC/EF/OV/UV/OL	numerical	CBF Independent	1/each	2
400kV/132kV				CBF1, CBF2	2/each	
TR1, TR2						
SUBSTATION TRANSFORMER	Main	Biased DIFF	numerical	CBF integrated	1/each	4
132/33kV	Backup	OC/EF	numerical		1/each	
ST1 to ST4						
BUS COUPLER	Main	OC	numerical		1/each	1
	Voltage selection	UV/25	numerical	integrated into OC trlay	0/each	
BUS SECTIONALIZER		OC/EF/25	numerical		1/each	1
BUSBAR PROTECTION	Main	~~Low Impedance DIFF (Centralized type)~~ High Imprdance	numerical	Check zone & Discretion zone	4	4

22

3. 1 132kV AQABA S/S continued

1) For Busbar protection, high impedance differential protection can be applied. As distance, bias diff, OC relays for feeder protection have CBF function, CBF trip signal from above relays connect to busbar protection and busbar protection issues trip command to the related CBs.

2) Panel configuration

800W x 800D x 2000H mm (exclude channel base hight) with front door and rear door.

3) MIMIC

BCU is considered to apply for MIMIC display.

4) Bias Diff for 132/33kV transformer has REF as low impedance zero-sequence-phase differential with neutral current. Then, high impedance diff for REF is not needed.

3. 2-1 132kV Amman South S/S

	Existing Relays				New Relays	
Feeder name		Scheme	Type	Remarks	To be replaced with	Q'ty
1105 132kV RELAY PANEL ABDOUN No.2	Main	DIF	ABB REL551		NA	
	Backup	DZ	ABB REL521		NA	
		DOC/DEF	ABB REX521		NA	
	Reclose		SPAU140C		NA	
805 132kV RELAY PANEL ABDOUN No.1	Main	DIF	ABB REL551		NA	
	Backup	DZ	ABB REL521		NA	
		DOC/DEF	ABB REX521		NA	
	Reclose		SPAU140C		NA	

Above relays have already been replaced with new relays. They are out of replace target.

3. 2-2 132kV Amman South S/S

Feeder name		Scheme	Type	Remarks	To be replaced with	Type	Q'ty
410 132kV RELAY PANEL 45MVA TRANSFORMER No.4	Main	DIF, HV/LV REF	ABB SPAD346C1	2012 not active product	Biased Diff	numerical	1
		Restricted Earth Fault (High Imp)	CAF		High Imp	nimerical	1
	Backup	OC, EF	ABB SPAJ140C		OC/EF	numerical	1
400/132kV SGTR No.2	Secondary backup	OC, OV	MCGG, MVTD		OC/EF/OV/UV/OL/BF	numerical	1
		BF (OC)	MCT1	BF1, BF2			2
		OL	MCGG				
		Trip/Lockout	MVAJ		NA		
QAIA No.2 (BACK UP PROT)		SEF	CTU		OC/EF/SEF/25	numerical	1
		Trip CC SV	VAX				
		Tripping Relay	VAJ				
		DEAD LINE CHARGING RELAY	VAR				

CBF (BF) of SGTR is duplicated (2pcs of OC relays) which is same as AQABA Interbus Transformer 132kV side.

3. 2-2 132kV Amman South S/S

Feeder name		Scheme	Type	Remarks	To be replaced with	Q'ty
132/33kV 45MVA TRANSFIRMER No.1	Main	DIF	GEC DTH31DFA1D		Biased Diff	1
		Restricted Earth Fault (High Imp)	CAF		High Imp	1
	Backup	OC	CDG		OC/EF	1
		EF	CDG			
			VAT			
132/33kV 45MVA TRANSFIRMER No.2	Main	DIF	GEC DTH31DFA1D		Biased Diff	1
		Restricted Earth Fault (High Imp)	CAF		High Imp	1
	Backup	OC	CDG		OC/EF	1
		EF	CDG			
			VAT			

Restricted EF can be included in numerical biased differential relay as low impedance diff. But it is necessary to, apply high impedance differential relays because of existing CT circuit connections.

3. 2-3 132kV Amman South S/S

Feeder name		Scheme	Type	Remarks	To be replaced with	Q'ty
MANARAH (BACK UP)		DOC	CDD		OC/EF/25	1
		DEF	CDD			
		25	VAR			
MANARAH (Main)	Main	DZ	YTG (analog-no use)			
		DZ	AREVA Micom P443		NA	
BUS COUPLER		OC	CDG		OC/EF	1
		Voltage selection	VARx2		UV/25	0
605 1 SAHAB (132kVOHL)	Back Up	OC.EF	CDD x4		OC/EF/25	1
		79	2 VARs			
605 1 SAHAB	Main	DZ	YTG (analog-no use)			
		DZ	AREVA Micom P443		NA	
BUSBAR PROTECTION		Tripping Relay	VAJ x12 (number of feeders?)			
BUSBAR PROTECTION		High-Imp DIF	FACx4(Discrimination)		High Imp.	4
BUSBAR PROTECTION		Tripping Relay	VAJ x8			

- Voltage selection for Bus coupler is integrated into OC relay.

27

3. 2-4 132kV Amman South S/S

Feeder name		Scheme	Type	Remarks	To be replaced with	Q'ty
QAIA No.2 (MAIN)	Main	DOC	CDD x3		Distance	1
		FL	analog		(FL, DOC included)	
		DZ	GEC ALSTOM OPTIMHO	old digital		
QAIA No.1 (BACK UP PROT)		SEF	CTU		OC/EF/SEF/25	1
		Trip CC SV	VAX			
		Tripping Relay	VAJ			
		DEAD LINE CHARGING RELAY	VAR			
QAIA No.1 (MAIN)	Main	DOC	CDD x3		Distance	1
		FL	analog		(FL, DOC included)	
		DZ	GEC MICHROMHO(analog)			
400/132kV SGTR No.1	Secondary backup	OC, OV	MCGG, MVTD		OC/EF/OV/UV	1
		BF1,2 (OC)	2 xMCT1			2
		OL	MCGG			
		Trip/Lockout	MVAJ			

- CBF (BF) of SGTR is duplicated (2pcs of OC relays) which is same as AQABA Interbus Transformer 132kV side.
- OL for 400/132kV SGTR can be acceptable as integrated in OC.

28

3. 2-5 132kV Amman South S/S

Feeder name	Existing Relays				New Relays	
		Scheme	Type	Remarks	To be replaced with	Q'ty
' - (OHL) not applied	Backup	OC	CDD x3		OC/EF/SEF/25	1
		SEF				
		79	VAR			
		DEAD LINE CHARGING RELAY	VAR			
		Tripping Relay	VAJ			
' - (OHL) not applied	Main	Composite time relay	CTR		Distance	1
		Tripping Relay	DTRMore			
		analog DZ	Reyrolle THR			
Bayader No.2	Backup	25 synchro check	BBC mechanical		OC/EF/SEF/25	1
		deadline charging	BBC mechanical			
		Distance	L8b, mechanical, no use			
Bayader No.2	Main	Distance repeat	BBC mechanical		Distance	1
		DOC	BBC mechanical			
		DEF	BBC mechanical			
		SEF	mechanical			
		FL	analog			
		DZ	Alstom OPTIMHO	Static		

- OC relay has AR function.

3. 2-6 132kV Amman South S/S

Feeder name		Scheme	Type	Remarks	To be replaced with	Q'ty
BUS SECTION		OC	BBC mechanical		OC/EF/25	1
		25 check synchro	BBC mechanical			
		Dead bus charging	BBC mechanical			
Bayader No.1	Backup	25 check synchro	BBC mechanical		OC/EF/SEF/25	1
		deadline charging	BBC mechanical			
		Distance	L8b, mechanical, no use			
Bayader No.1	Main	Distance repeat	BBC mechanical		Distance	1
		DOC	BBC mechanical			
		DEF	BBC mechanical			
		SEF	mechanical			
		FL	analog			
		DZ	Alstom OPTIMHO	Static		

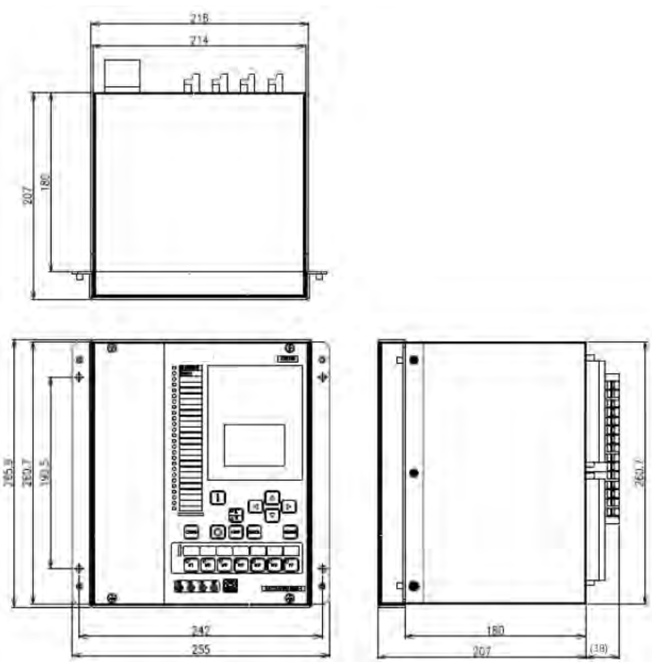
3. 2-7 132kV Amman South S/S

	Existing Relays				New Relays	
Feeder name		Scheme	Type	Remarks	To be replaced with	Q'ty
AL Bayader No.3		25 check synchro	BBC mechanical		OC/EF/SEF/25	1
		deadline charging	BBC mechanical			
		Distance	L8b, mechanical, no use			
		DZ	GEC Alstom OPTIMHO	Static		
(maybe AL Bayader No.3)		Distance repeat	BBC mechanical		Distance	1
		DOC	BBC mechanical			
		DEF	BBC mechanical			
		SEF	mechanical			
		FL	SEL351A	digital		
Salt 2		25 check synchro	BBC mechanical		OC/EF/SEF/25	1
		deadline charging	BBC mechanical			
		Distance	L8b, mechanical, no use			
Salt 2		Distance repeat	BBC mechanical		Distance	1
		DOC	BBC mechanical			
		DEF	BBC mechanical			
		SEF	mechanical			
		FL	SEL351A	digital		
		DZ	GEC Alstom OPTIMHO	static		

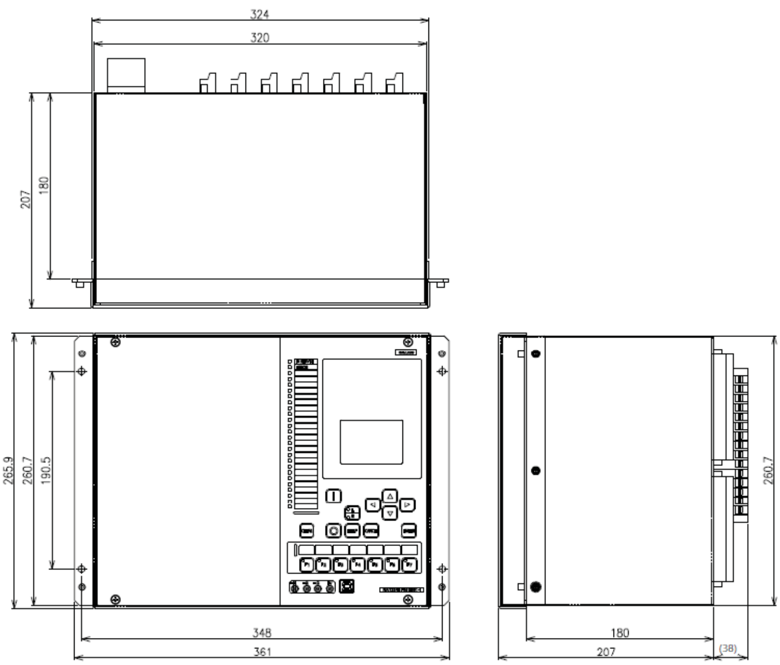
- "Salt 2" is "Bayader No.4".

4. Relay Unit Dimensions (typical examples)

Following figures show the dimensions of relay unit. Please consider replacement work.

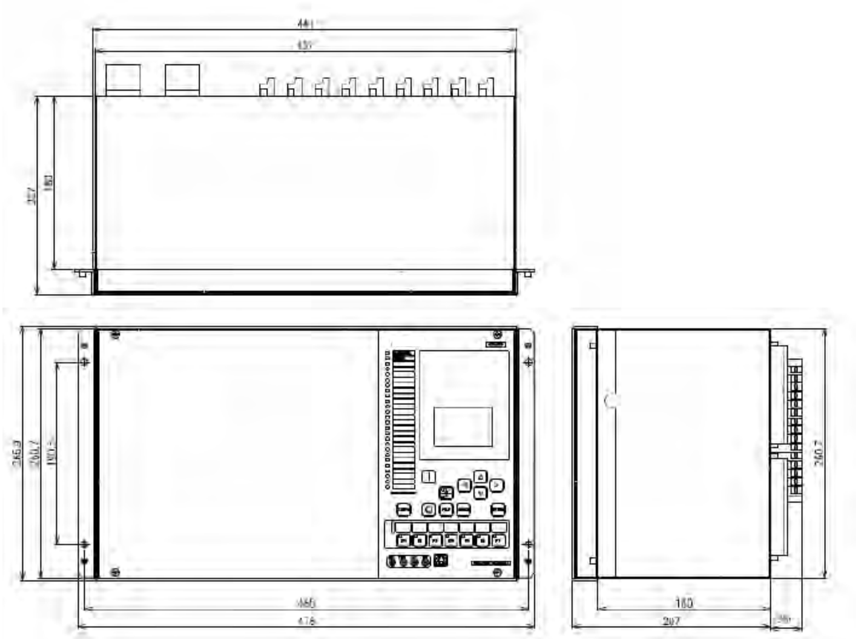


1/2 Size



3/4 Size

4. Relay Unit Dimensions (typical examples)



1/1 Size   Size is depends on number of BIO boards.

5. Test equipment and Relay setting tools (PC software)

- The installation work of the protection relay will be carried out directly by NEPCO, and it is envisaged that the installation work will be carried out simultaneously at several substations. The testing equipment listed in Table 5-1 will be the provided equipment.

Table 5-1   Test equipment

Equipment name	Quantity
Relay test equipment CMC356	2
Primary injection tester CPC100	1

- Relay setting tools (PCs and Software) will be supplied.
  Laptop PCs: 6 pcs (Amman South 2, Amman East 1, Aqaba 2, Aqaba cable station 1)
  Software   : 11 packages (for installation above PCs and spare 5)

END

35

Role and specifications of protection relay

Project for Integration of Variable Renewable Energy into Electric Power Network System and Enhancing Supply Reliability in Hashemite Kingdom of Jordan

- Transmission line protection -

Current differential protection

【WG1: Power Network Facilities】

March, 2022

JICA study team

1

Contents

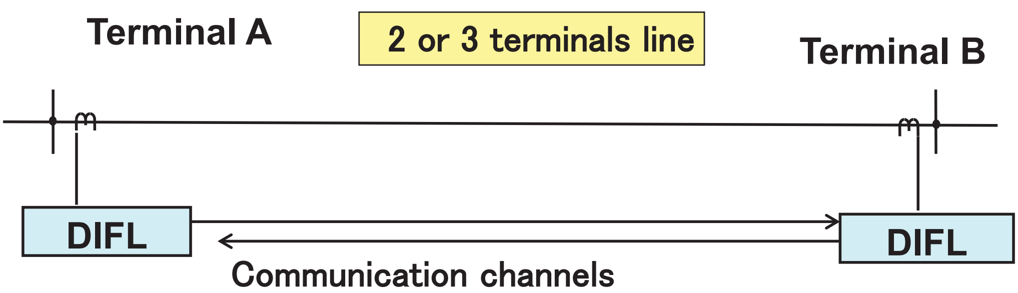
2

Current Differential Protection

Theory and Characteristics

Applications

<System configuration>



Communication equipment or fiber optic

This system converts instantaneous values of current, measured at each terminal into digital values which are then transmitted to the remote terminal; the differential current is calculated from the instantaneous values of current from each terminal through digital computation.

1. Theory and characteristics

Basic theory of Current Differential Protection

〈Principle〉

[Normal state]

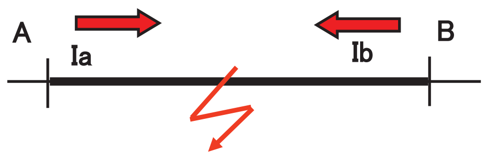
$Ia + Ib = 0$

(Kirchhoff' s low)

Bold lines: Zone of protection

Ia, Ib : Inflow, outflow current

[Internal fault]



$Id = Ia + Ib \neq 0$

Id: Fault current

Theory equation of operation: $Id \geqq k1 \cdot Ir + k0$

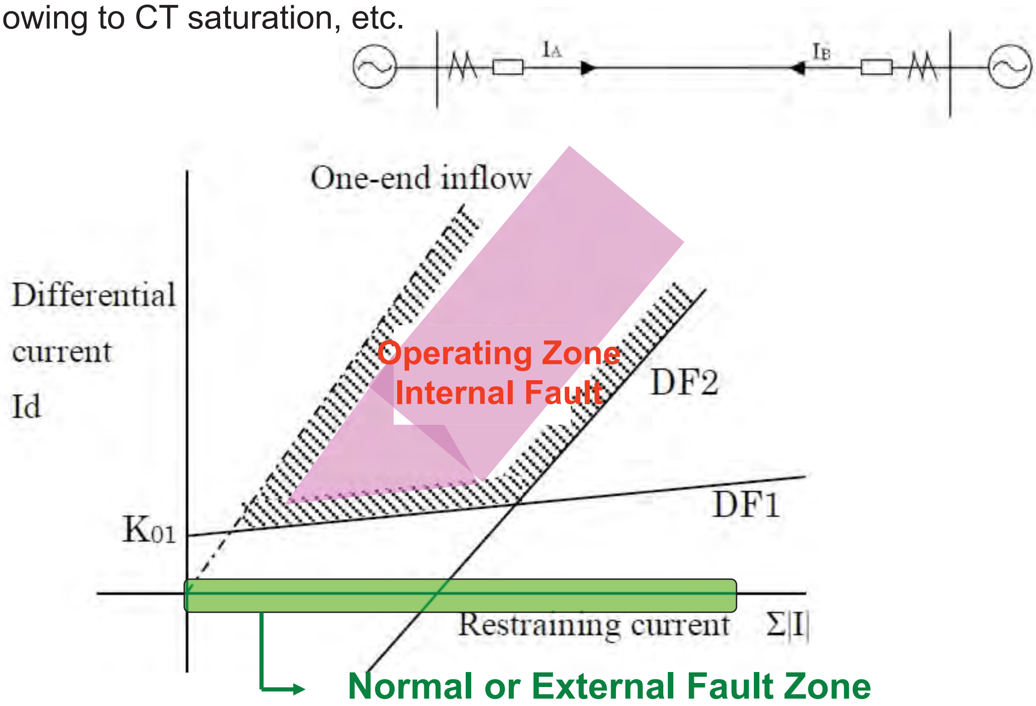
Operating current: $Id = | Ia + Ib |$, vector sum

Restraint current: $Ir = |Ia| + |Ib|$, k1, k0: constants

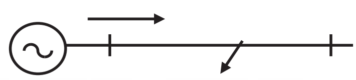
5

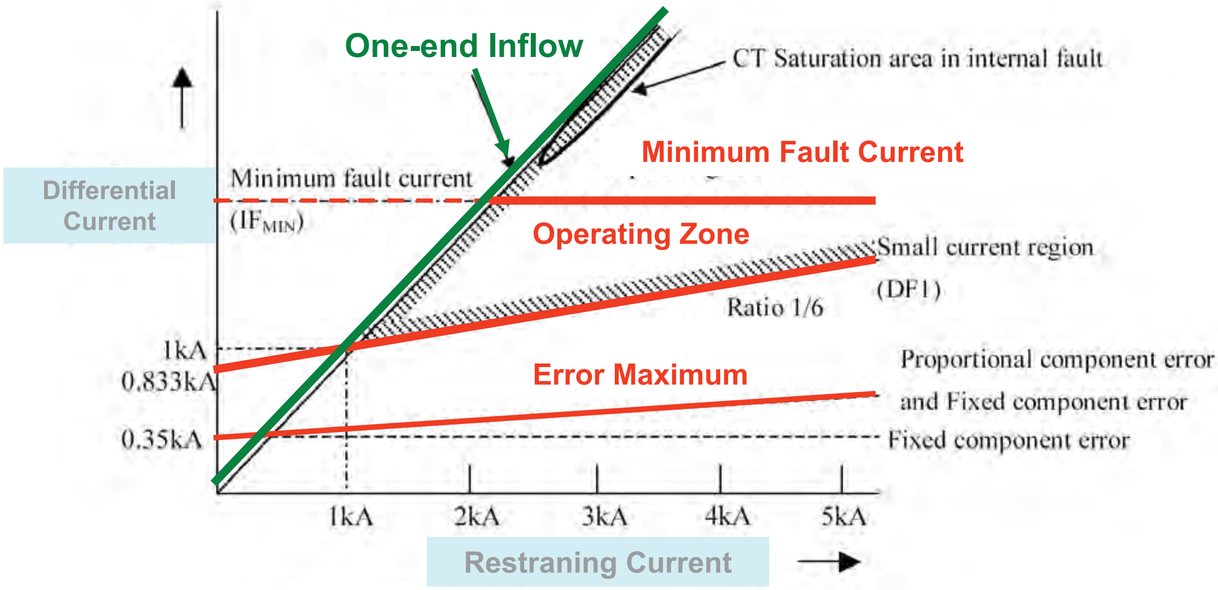
1. Theory and characteristics (Characteristics of DIFL)

The characteristic for the large current region (DF2) is provided to restrain in this region of operation because the proportional component error increases owing to CT saturation, etc.



The percentage slope is determined from the required sensitivity for the detection of internal faults and the error current which is generated in the event of external faults.

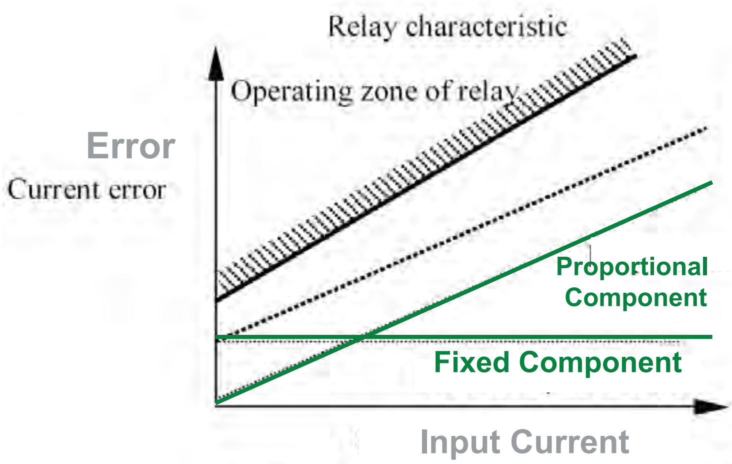




Example: characteristic of small current region
Settings: DIFL–I = 1kA, k1= 17% (1/6)

1. Theory and characteristics (DIFL small current zone)

Error Component Analysis



Errors relating to differential protection

Error:
Fixed Component
- Input Transformer
- Drift of Analogue Filter
- Quantizing Error

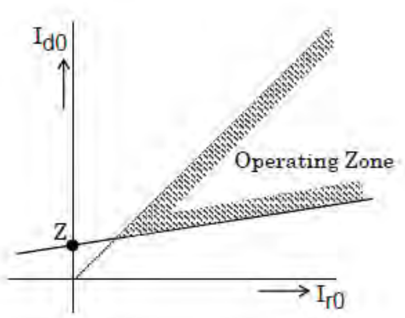
Proportional Component
- CT Error
- Input Transformer
- Gain Error of Analogue Filter
- Data Transmission Delay
- Sampling Timing

Zero-sequence Current Differential (DIFGL)

DIFGL (87G)

Zero Sequence Diff. Characteristic

- High sensitivity by use of residual current
- Sensitivity not affected by load current



Theory equation of operation: $I_{d0} \geqq k_0 \cdot I_{r0} + k_n$

Operating current: $I_{d0} = | I_{a0} + I_{b0} |$, vector sum

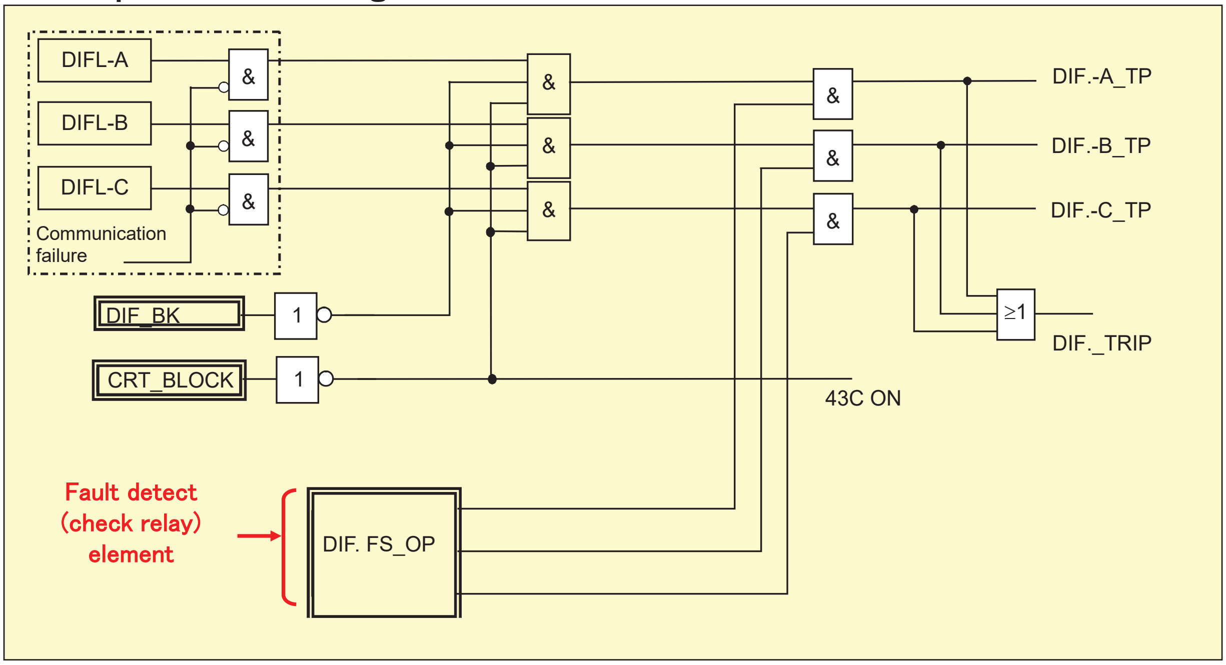
Restraint current: $I_{r0} = |I_{a0}| + |I_{b0}|$, scalar sum, k_0, k_n: constants

Scheme Logics of Current Differential Protection

2. Scheme Logics of Current Differential Protection

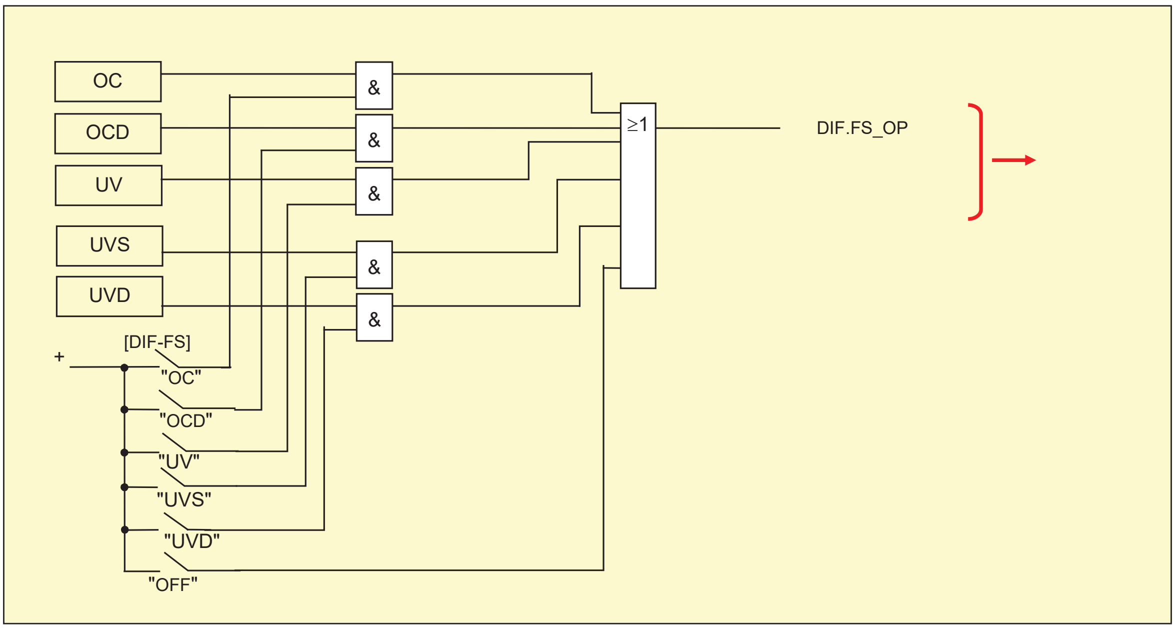
< Segregated-phase current differential protection (DIFL) >

Example of scheme logic



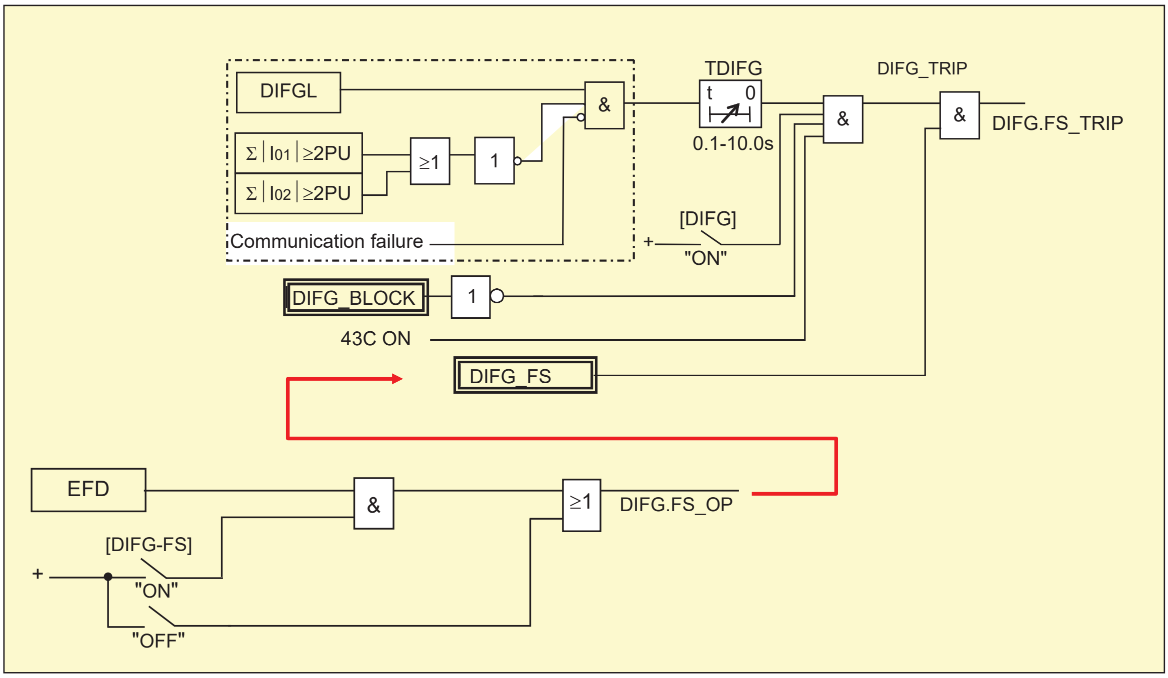
2. Scheme Logics of Current Differential Protection

< fault detect (check relay) function for current differential protection >



2. Scheme Logics of Current Differential Protection

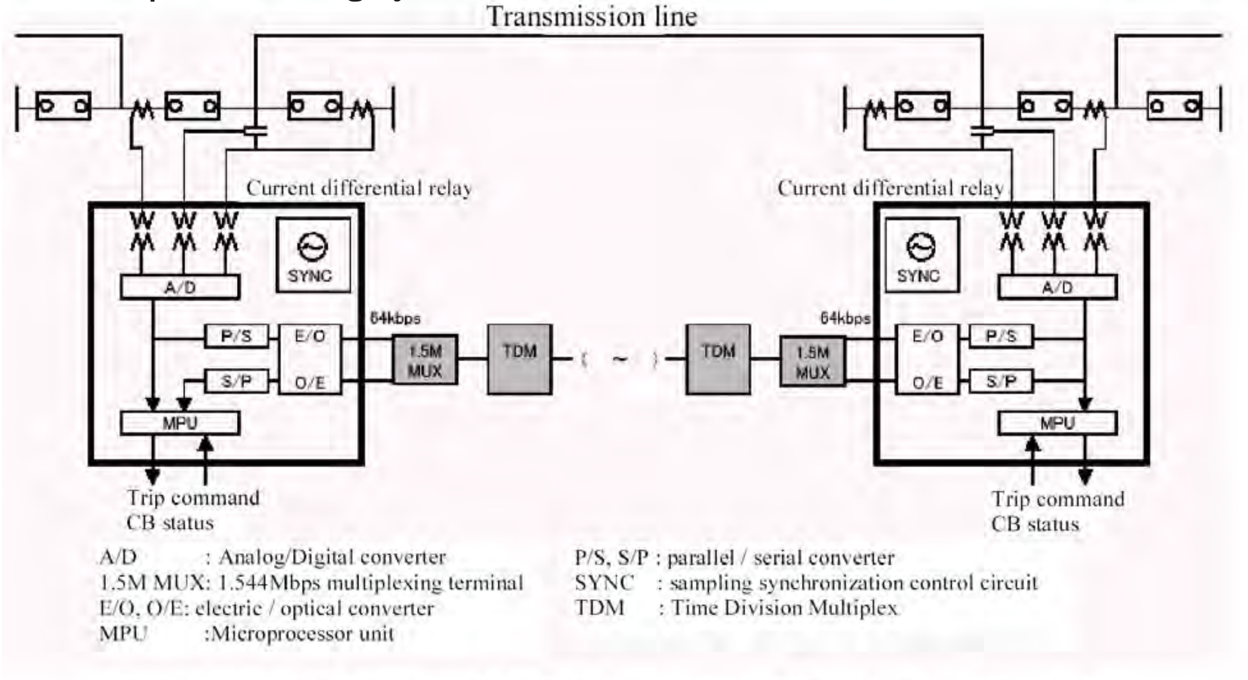
Zero-phase current differential protection scheme logic



3. Communication Systems

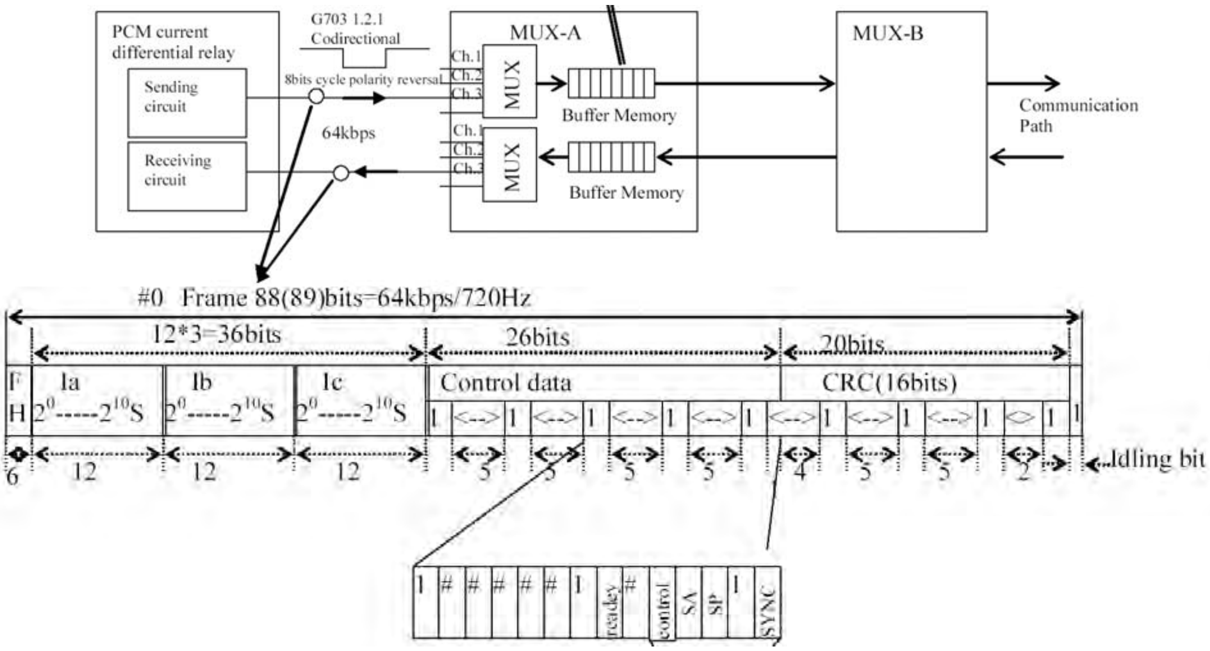
Communication Systems for Current Differential Protection

An example of existing systems



Configuration of the digital-type current differential relaying system

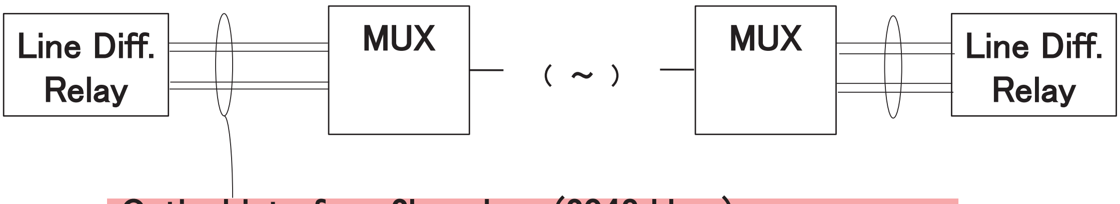
Transmission data format (example for 60Hz systems)



・fundamental wave 60Hz、Sampling frequency 720Hz

Recent standard of IEEE C37.94

Securing clock recovery, jitter tolerance, physical connection, and spuriousness are specified by the international standard.



Optical interface 2km class (2048 kbps)

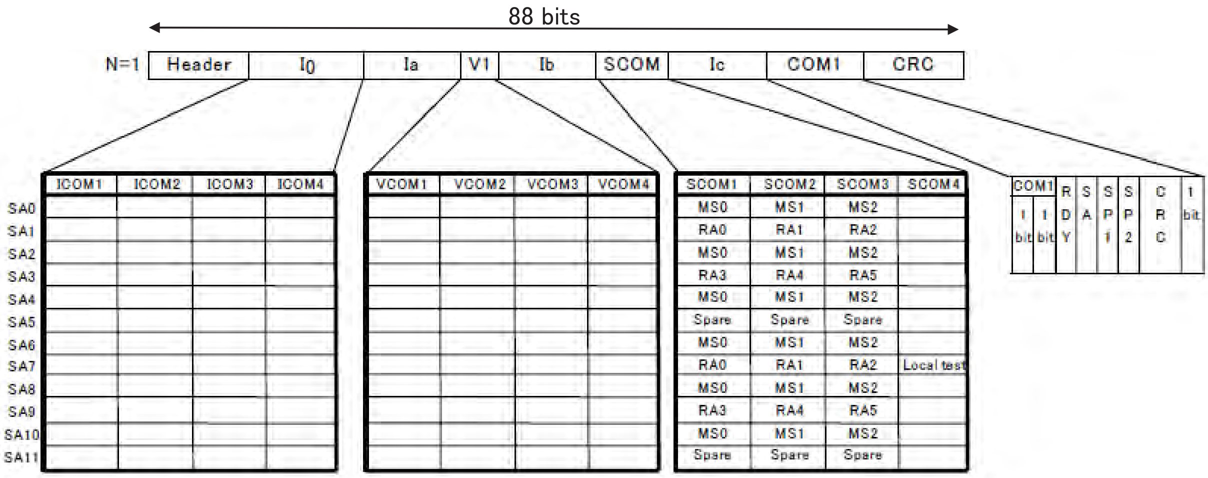
Graded–Index 50/125 or 60/125 micro m

Connector: ST type

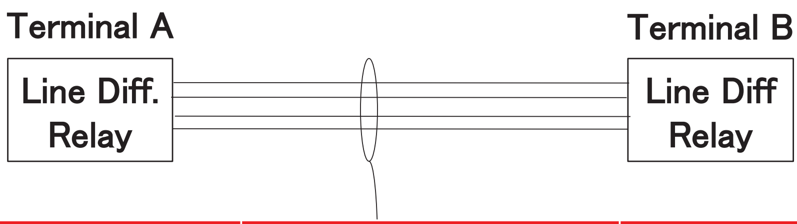
Wave length: 820 nm

Transmission data format (example 2)

IEEE C37.94 frame format



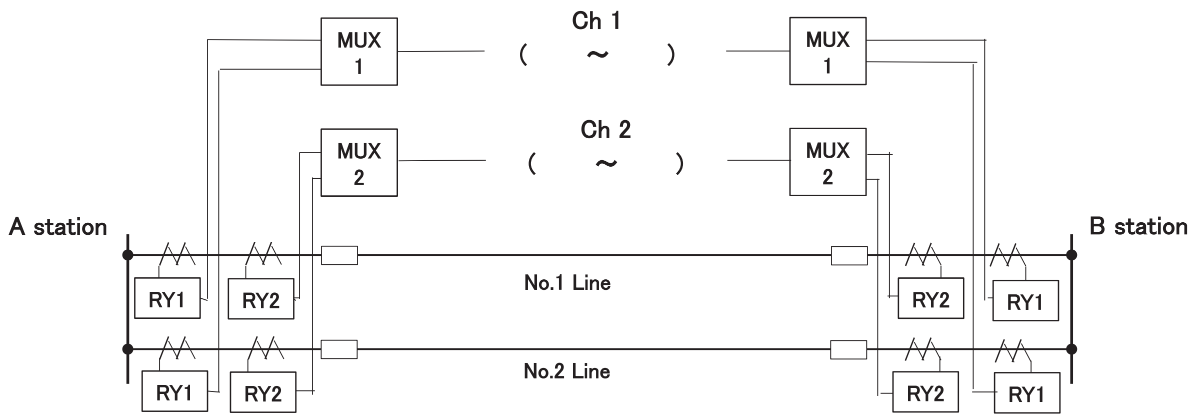
Direct fibre communication



Length	30km class	80km class
Type of fibre	Single mode 10/125 µm	DSF 8/125µm
Connector type	Duplex LC	Duplex LC
Wave length	1310nm	1550nm

19

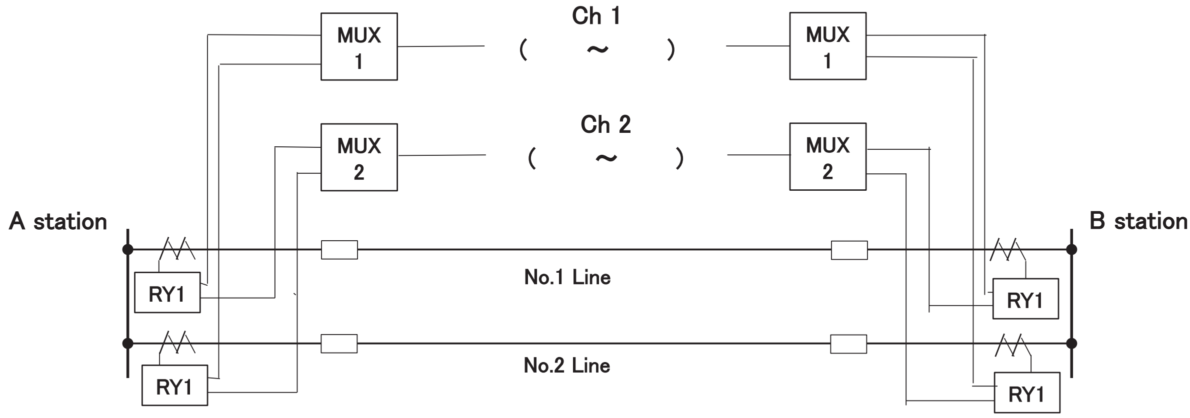
Dual Relay systems and
Dual Data Transmission system



Relay 1 and Relay 2 have the separate communication route.

3. Communication Systems (redundant configuration (2))

Single Relay system and
Dual Data Transmission system



Relay 1 has two communication control parts.

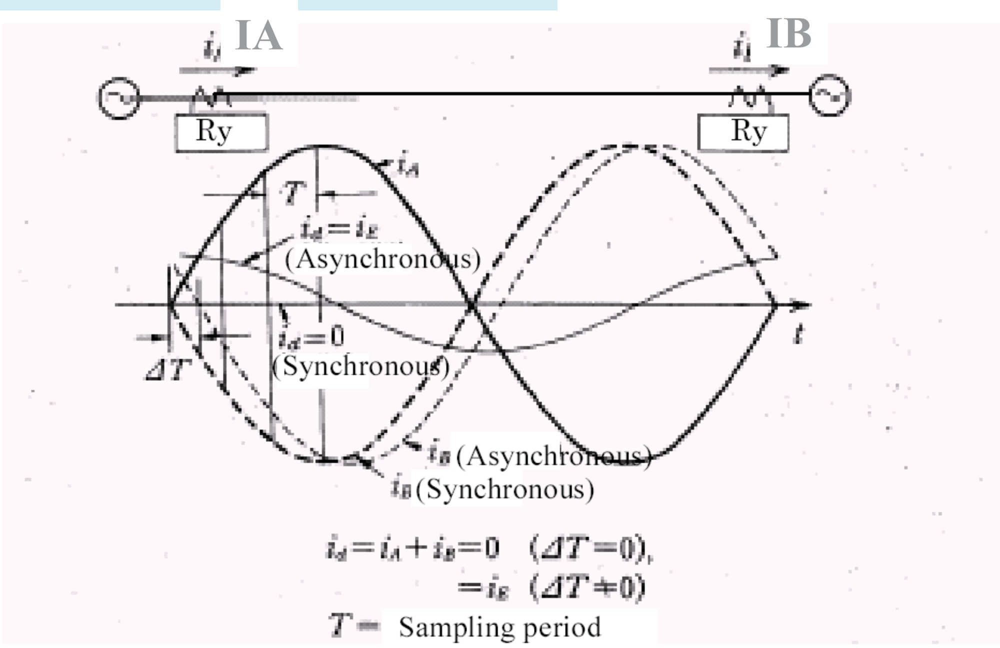
These communication routes are separate paths.

4. Synchronized Sampling

Synchronized Sampling of Current Differential Protection

4. Synchronized Sampling

Data Sampling Synchronism between the both terminals



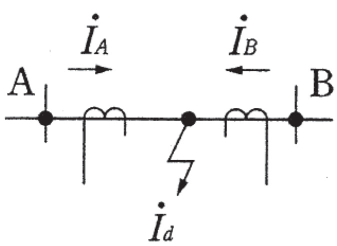
]

Sampling synchronization is necessary.
An error current i_E will be generated if there is a lag (ΔT) in the sampling timing.

4. Synchronized Sampling

The instantaneous values of current from each terminal need to be obtained at the same time, and synchronization control is required to match the acquisition timing (sampling timing).

Data Sampling

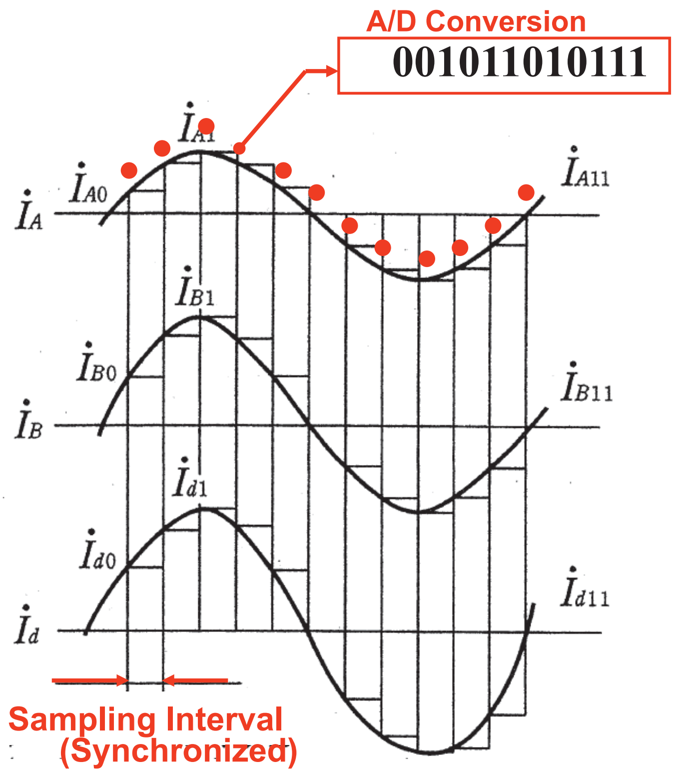


$$\dot{I}_{d0} = \dot{I}_{A0} + \dot{I}_{B0}$$

$$\dot{I}_{d1} = \dot{I}_{A1} + \dot{I}_{B1}$$

$$\vdots$$

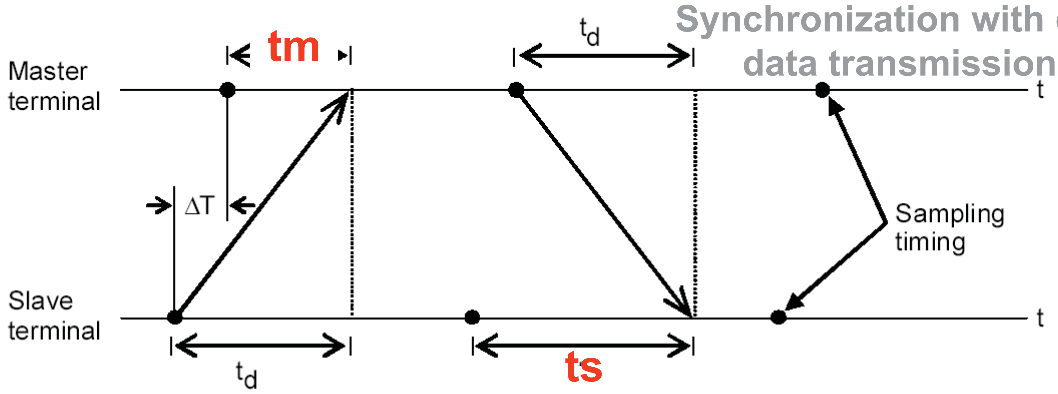
$$\dot{I}_{d11} = \dot{I}_{A11} + \dot{I}_{B11}$$



4. Synchronized Sampling (Control theory)

Synchronization control is performed on the assumption that the upstream and downstream (transmit and receive) transmission paths are identical

Synchronization with dedicated data transmission route



$t_d = \Delta T + t_m$ $t_d + \Delta T = t_s$

$\Delta T = \frac{t_s - t_m}{2}$

(a)

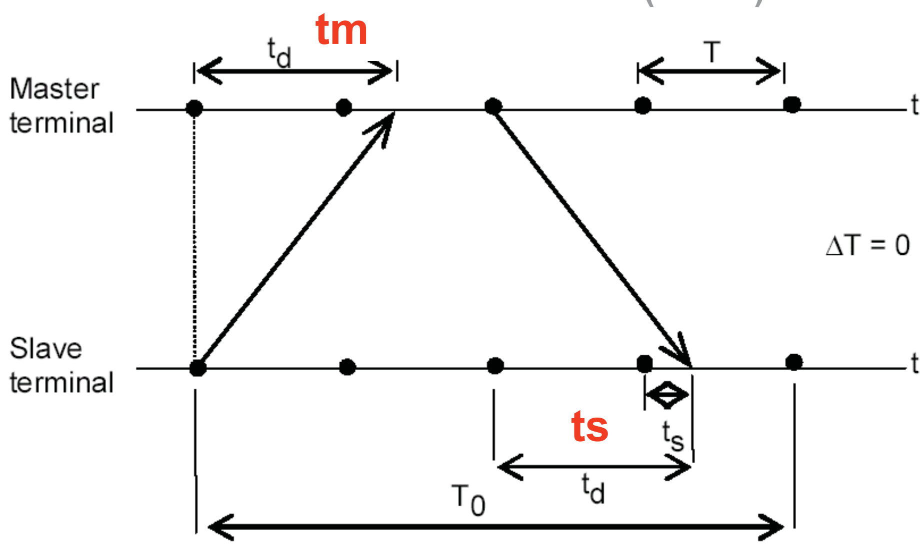
(1) Send tm and ts each other

(2) Control at Slave terminal to be tm=ts

At both master and slave stations control is exercised such that the time differences tm and ts between the time at which the sampling synchronization flag was received from the remote station and the timing of the sample taken at the local station are transmitted alternately to bring about the state ΔT=0 at the slave station side.

4. Synchronized Sampling (Control theory)

Synchronized Condition (tm=ts)



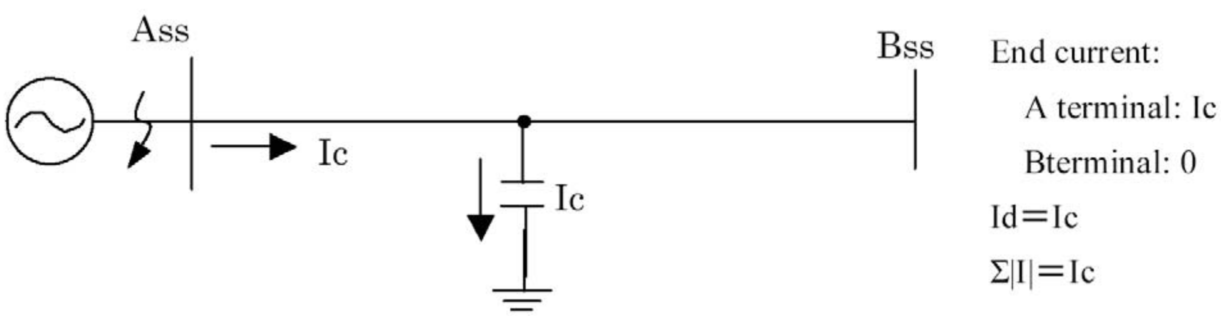
$t_d = (\frac{T_0}{2} - T) + t_s$

(b)

Charging Current Compensation of Current Differential Protection

Line Charging Current

Line charging current "Ic" appears differential current "Id".



Charging current will flow in the protected section of long-distance overhead transmission lines and underground cables and can lead to the incorrect operation of the protection if the value exceeds the detection sensitivity level.

5. Charging Current Compensation

$$\begin{bmatrix} i_{ca} \\ i_{cb} \\ i_{cc} \end{bmatrix} = \begin{bmatrix} C_{aa} & -C_{ab} & -C_{ac} \\ -C_{ba} & C_{bb} & -C_{ba} \\ -C_{ca} & -C_{cb} & C_{cc} \end{bmatrix} \cdot \frac{d}{dt} \begin{bmatrix} V_a \\ V_b \\ V_c \end{bmatrix}$$

C_{ae}, C_{be}, C_{ce} : Earth capacity

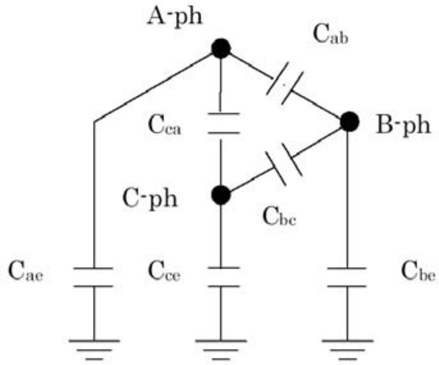
C_{ab}, C_{bc}, C_{ca} : Line capacity

i_{ca}, i_{cb}, i_{cc} : Charge current (each phase)

$C_{aa} = C_{ae} + C_{ab} + C_{ac}$

$C_{bb} = C_{be} + C_{bc} + C_{ba}$

$C_{cc} = C_{ce} + C_{ca} + C_{cb}$



Example

Phase-earth (μF/km)	Phase-phase (μF/km)
0.01222	-0.00147

(275kV transmission line measurement capacity)

Charging capacitance of transmission line

It is normally adequate for practical applications to regard the diagonal element as being the same for each phase, with the off-diagonal element set to zero, as long as the line is 200 km or shorter in length.

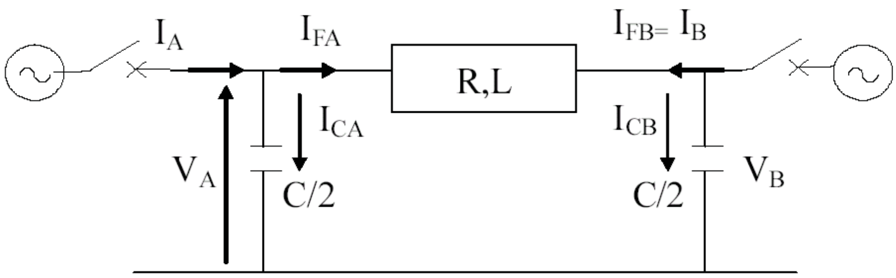
5. Charging Current Compensation (Divisional Compensation)

Compensation of the charging currents of all sections are equally divided at each terminal,

Transmission Data

terminal A: $I_A - \frac{C}{2}\frac{dV_A}{dt}$

Terminal B: $I_B - \frac{C}{2}\frac{dV_B}{dt}$



RL: Line impedance (whole length)

C: Line charging capacity (whole length)

Relationship between charging current and current of each terminal:

Equivalent compensation for all terminals

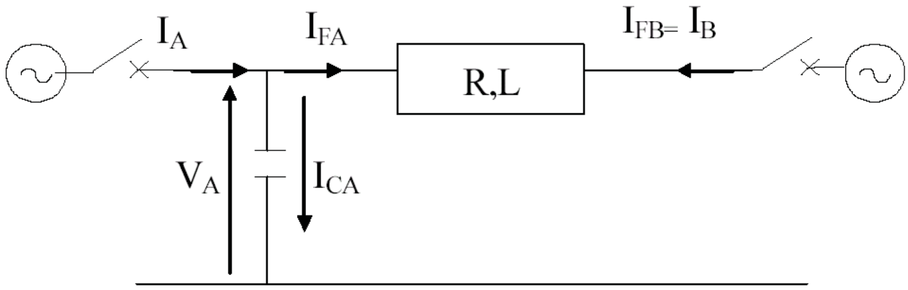
5. Charging Current Compensation (Lump-sum Compensation)

100% compensation is implemented at the local terminal

Compensation at one-terminal

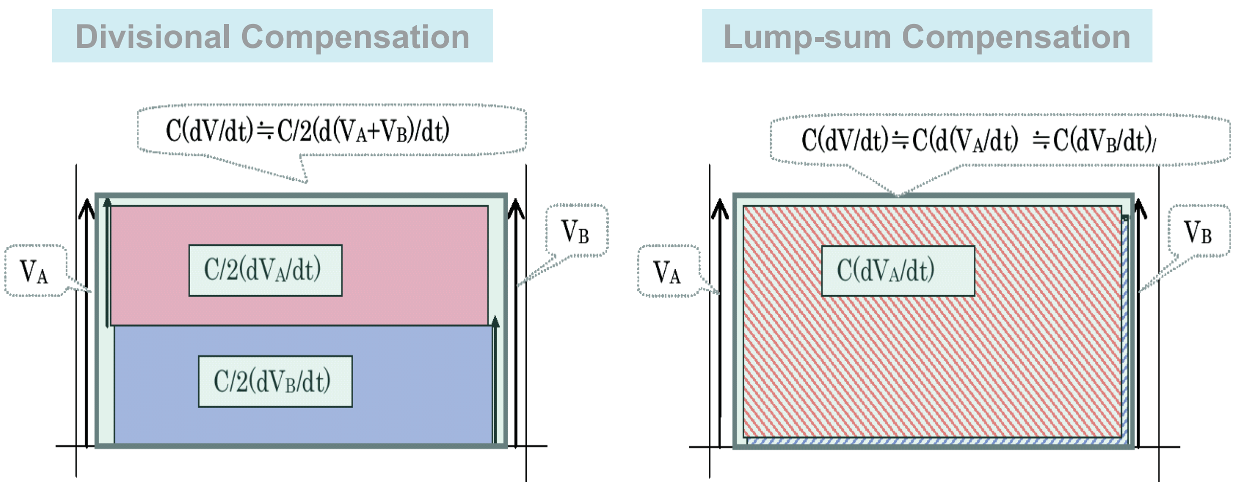
Terminal A: $\left|I_{FA} + I_{FB}\right| = \left|I_A - C\dfrac{dV_A}{dt} + I_B\right|$

Terminal B: $\left|I_{FA} + I_{FB}\right| = \left|I_A + I_B - C\dfrac{dV_B}{dt}\right|$



Relationship between charging current and current of each terminal:
Compensation for all sections in local terminal

5. Charging Current Compensation (normal condition)



(a) Compensation quantity of the terminals

(b) Each compensation for charging current of the terminals

Charging current and compensation current under normal condition

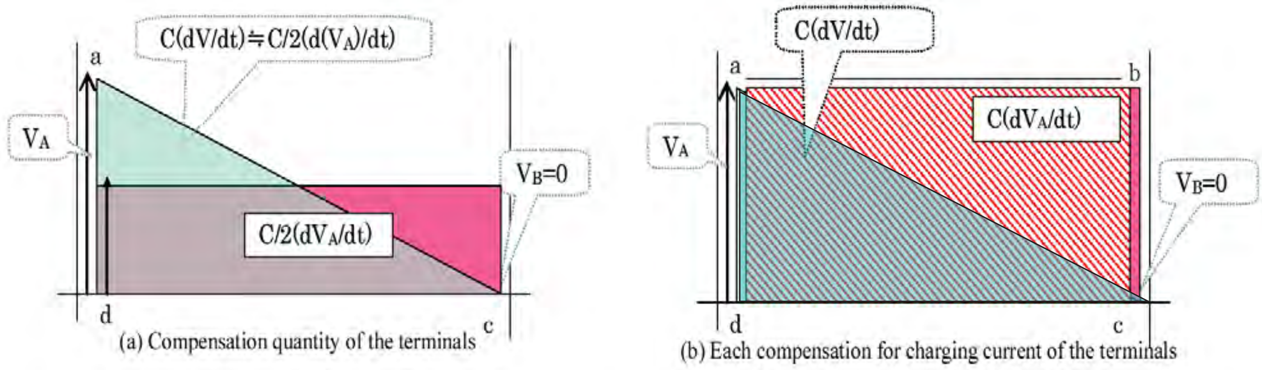
There is little compensation error in both methods under normal conditions.

5. Charging Current Compensation (close-up fault at B)

A close-up fault has occurred external to terminal B, and hence VB is zero.
The area of triangle 'a-c-d' is equivalent to the total charging current.

Divisional Compensation

Lump-sum Compensation



Charging current and compensation current under external fault in B terminal

(a) Divisional: the compensation quantity (rectangle) based on the voltage VA/2 at terminal A is equivalent to the approximate area of the triangle, and little compensation error.

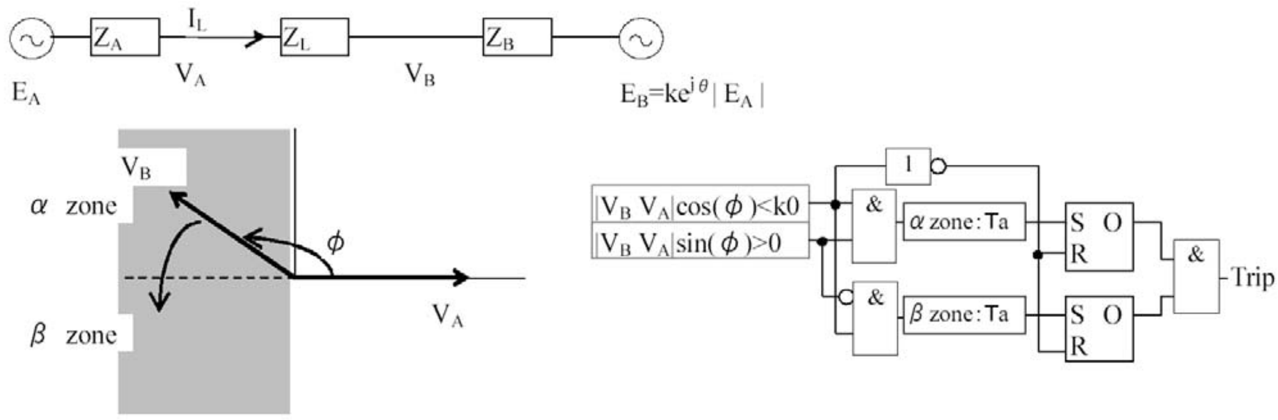
(b) Lump-sum: under compensation at B terminal, overcompensation at A terminal

6. Out-of-Step Protection (Voltage phase comparison)

Out-of-Step Protection with voltage phase comparison

6. Out-of-Step Protection (Voltage phase comparison)

Out-of-step Detection: voltage phase comparison



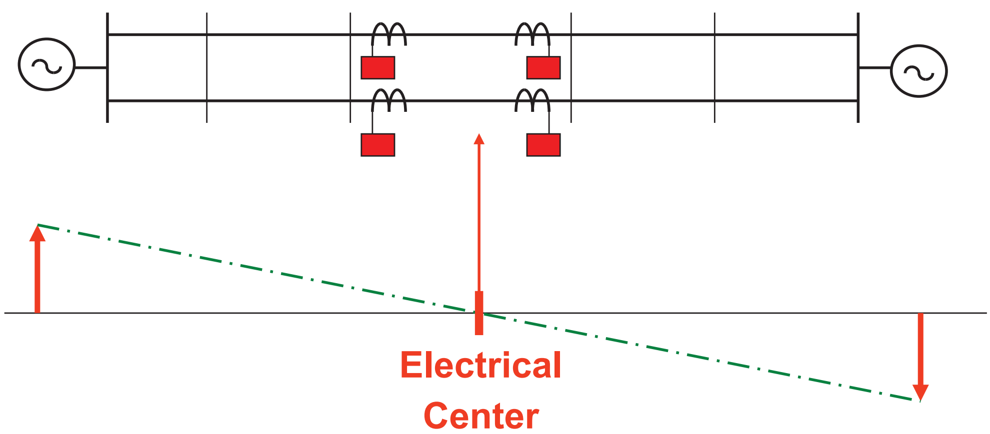
Out-of-step detection relay using positive-phase

The out-of-step protection function is realized by comparing the phase angle of the positive-sequence voltage received from the remote terminal with that of the local voltage, confirming that the phase angle difference passes through 180 degrees.

35

6. Out-of-Step Protection (Voltage phase comparison)

to separate the power system at the Electrical Center for a Out-of-step



The best separation point is the "electrical center" of the out-of-step. Voltage phase comparison will operate only when the "electrical center" is located in the protected area of line differential relay.

36

Current Differential Protection

Auto-Reclosing Function

Outline of Auto-reclosing

<TRANSIENT FAULT>

Majority of faults on overhead line ➡ Lightning(Transient Fault)

Permit re-energization after short time interruption

This processes are performed automatically

➡ *Auto-reclosing*

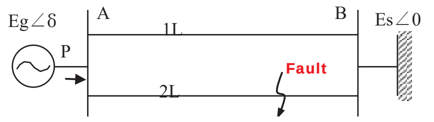
<PERMANENT FAULT>

Faults on cable circuits ➡ Insulation Failure (Permanent Fault)

Auto-reclosing is not performed on cable circuits, and also transformers, generators and busbars to prevent from the extension of system damage.

7. Auto-reclosing function (purpose)

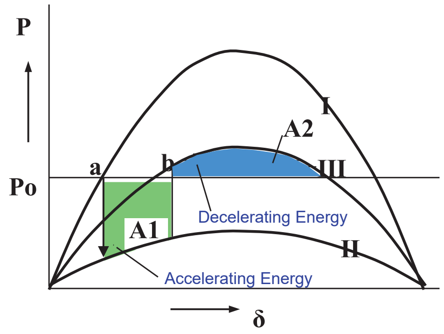
(1) Improvement in Transient Stability



P= Eg × Es × sinδ/ X

P : Power from A to B
δ: Phase angle between A and B
X : Reactance between A and B

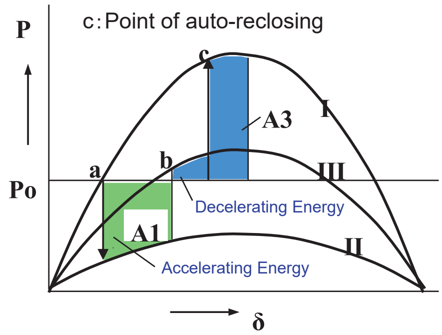
Ⅰ : Double circuit in operation
Ⅱ : During fault
Ⅲ : Single circuit in operation
a : Normal operating point
b : Point at which the CB trips
c : Point of auto-reclosing



SINGLE LINE OPERATION

Accelerating Energy(A1) > Decelerating Energy(A2)

➡ **UNSTABLE**



PARALLEL LINE OPERATION(After reclosed)

Accelerating Energy(A1) = Decelerating Energy(A3)

➡ **STABLE**

7. Auto-reclosing function

(2) Reduction in power outage period

- Fast auto-reclosing enables re-transmission of power within 0.5 to 1 sec or so
- Transient stability is improved

➡ **Failure of the entire system can be prevented.**

(3) System restoration time and operator workload

- Complicated operations and checks are required for system restoration. It will take a long time to restore the system.
- The workload for operators will increase.

➡ **Execute quickly, Reduce workload, minimize human errors**

Classification for dead time

Classification	Dead time	Description
High-speed Auto-reclosing	0.35s to 1s	To auto-reclose with consideration given to de-ionization time in the case of interconnection
Medium-speed Auto-reclosing	A few seconds to 25s	To auto-reclose with consideration given to turbine generator axis torsion; attenuation of conductor vibration due to damage induced by wind and snow; to maintain an interconnection in the event of an unsuccessful high-speed auto-reclosing operation to perform automatic recovery
Low-speed auto-reclosing	A few second to 70s	To auto-reclose in order to achieve recovery of a power network automatically and quickly

Example of High-speed Autoreclosing Dead time (in Japan):

- 500kV system : approx. 1.0s
- 187 – 275kV system : approx. 0.5 – 0.8s

7. Auto-reclosing function (classification)

Number of disconnected phases

Classification		Auto-reclosing	Description
Single phase Auto-reclosing		High-speed	To auto-reclose only the faulted phase (single phase) for the case of a single phase trip for a single phase-earth fault
Three phase auto-reclosing	Interconnection to an adjacent line	High-speed Medium-speed Low-speed	To auto-reclose three phase for the case when a three phase trip is issued for every fault, used for the condition when interconnected to an adjacent line
Three phase auto-reclosing	Synchronism check	High-speed Medium-speed Low-speed	To auto-reclose three phase when a three phase trip is issued for every fault, used for the condition of synchronism check depending on the leading and following terminal i.e. dead line charge and check sync
Multi-phase Auto-reclosing		High-speed	To auto-reclose on the condition that a total of at least two different phases or three phases are healthy in two lines of a parallel line
Preference trip/reclosing on double circuit lines (not multi-phase auto-reclosing)		High-speed	When two differing fault types occur simultaneously in a double circuit line configuration e.g. a single phase-to-earth fault on one line and a phase-to-phase fault on the second line preference will be given to the phase-to-phase fault because it is more severe in terms of network stability. A three phase trip is issued separately for each fault the most severe fault taking priority.

7. Auto-reclosing function (1-phase ARC)

(1) Single-phase auto-reclosing

Performance

-Reclosing is preformed, if single-phase fault occurs

-Final trip is performed, if multi-phase fault occurs

Case	Fault phase						Tripping and relosing	
	#1 line			#2 line			#1 line	#2 line
	A	B	C	A	B	C		
1	X						1φT→ARC	
2	X	X					3φFT	
3	X	X	X				3φFT	

7. Auto-reclosing function (3-phase ARC)

(2) Three-phase auto-reclosing

Performance

-Reclosing is always preformed, if any fault occurs

Case	Fault phase						Tripping and relosing	
	#1 line			#2 line			#1 line	#2 line
	A	B	C	A	B	C		
1	X						3φT→ARC	
2	X	X					3φT→ARC	
3	X	X	X				3φT→ARC	

(1)&(2) Combination of Single-phase and Three-phase auto-reclosing

Performance

-Reclosing is preformed, if any fault occurs

- Single-phase AR is performed, if single-phase fault occurs
- Three-phase AR is performed, if multi-phase fault occurs

Case	Fault phase						Tripping and relosing	
	#1 line			#2 line			#1 line	#2 line
	A	B	C	A	B	C		
1	X						1φT→ARC	
2	X	X					3φT→ARC	
3	X	X	X				3φT→ARC	

(3) Multiple-phase auto-reclosing (MPAR)

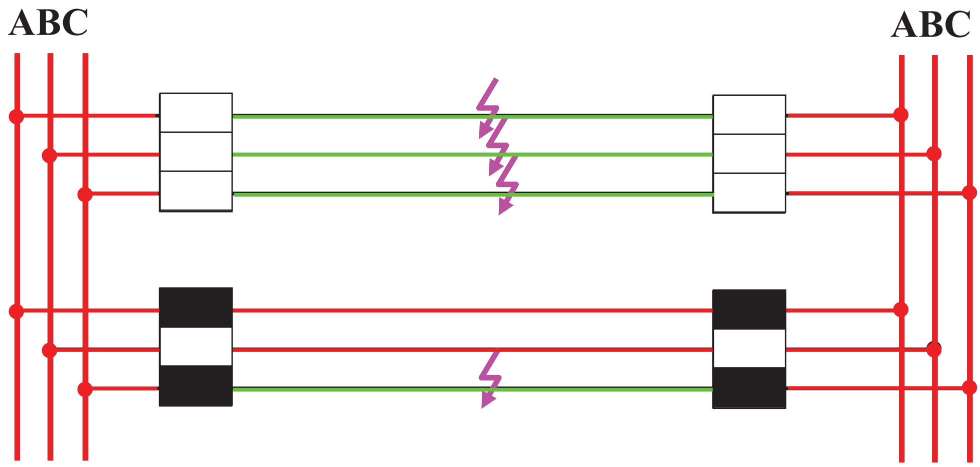
Performance

-Reclosing is preformed according to the fault condition in double-circuit line

- MPAR is to be performed, if two or more healthy phase remain in double-circuit line
- Final trip is to be performed, if above condition is not satisfied.

7. Auto-reclosing function (Multi-phase ARC)

(3) Multiple-phase auto-reclosing



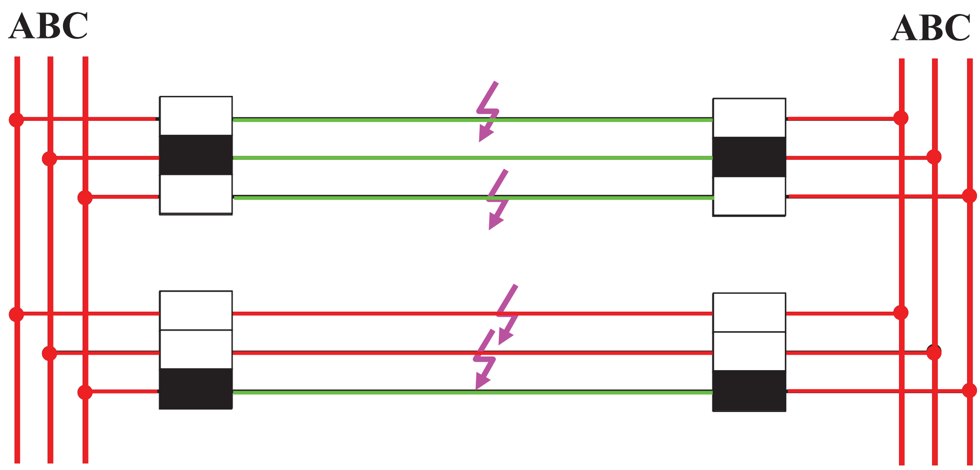
Two-different phase remain

□Open ■Close

MPAR

7. Auto-reclosing function (Multi-phase ARC)

(3) Multiple-phase auto-reclosing



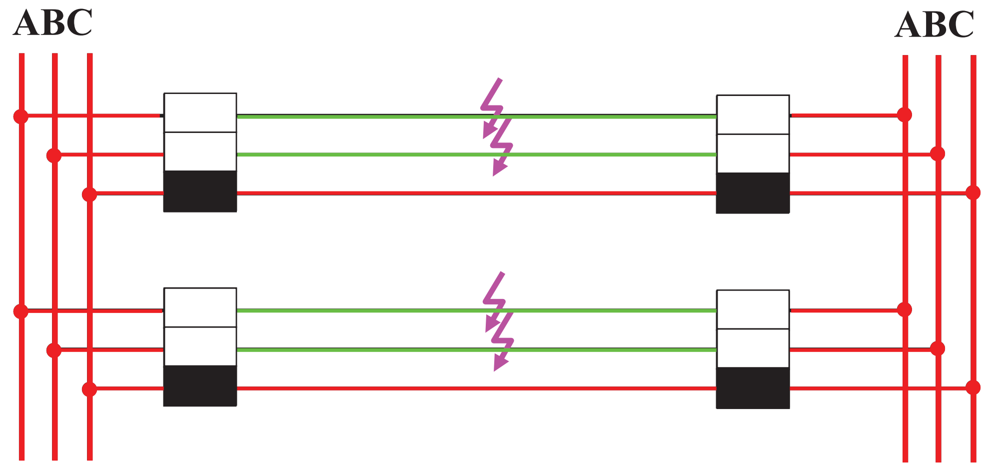
Two-different phase remain

□Open ■Close

MPAR

7. Auto-reclosing function (Multi-phase ARC)

(3) Multiple-phase auto-reclosing



Two-different phase don't remain

□Open ■Close

FT(Final Trip)

7. Auto-reclosing function (Multi-phase ARC)

(3) Multiple-phase auto-reclosing

Case	Fault phase						Tripping and reclosing	
	#1 line			#2 line			#1 line	#2 line
	A	B	C	A	B	C		
1	X			--	--	--	1φT→ARC	--
2	X	X		--	--	--	3φFT	--
3	X	X	X	--	--	--	3φFT	--
4	X						1φT→ARC	
5	X			X			1φT→ARC	1φT→ARC
6	X	X					2φT→ARC	
7	X				X		1φT→ARC	1φT→ARC
8	X	X		X			2φT→ARC	1φT→ARC
9	X	X		X	X		3φFT	3φFT
10	X	X	X				3φT→ARC	
11	X	X				X	2φT→ARC	1φT→ARC
12	X	X			X	X	2φT→ARC	2φT→ARC
13	X	X	X	X			3φT→ARC	1φT→ARC
14	X	X	X	X	X		3φFT	3φFT
15	X	X	X	X	X	X	3φFT	3φFT

7. Auto-reclosing function (High-speed ARC)

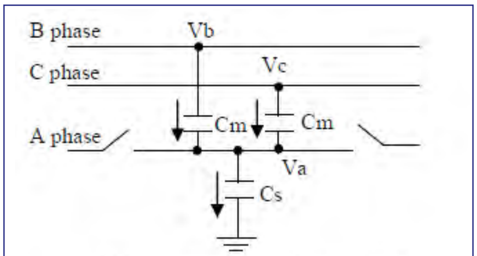
Classification according to dead time

(1) High-speed auto-reclosing

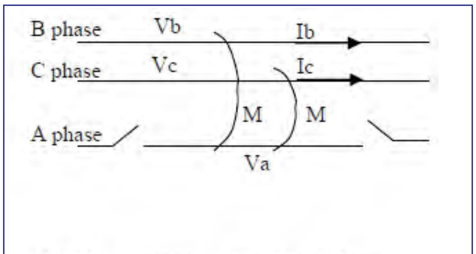
- The dead time is mainly determined by **the de-ionization time**

The time taken for the secondary arc to disappear

- **Secondary arc current**



(a) Electrostatic coupling voltage
(a-phase disconnection)



(b) Electromagnetic coupling voltage
(a-phase disconnection)

The dielectric recovery time and de-ionization time

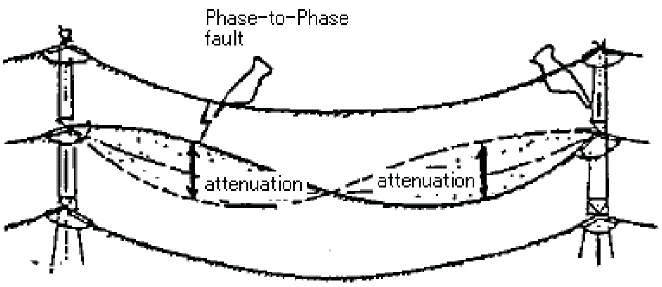
➡ **Longer as fault current increases, In proportion to system voltage**

7. Auto-reclosing function (Medium-speed ARC)

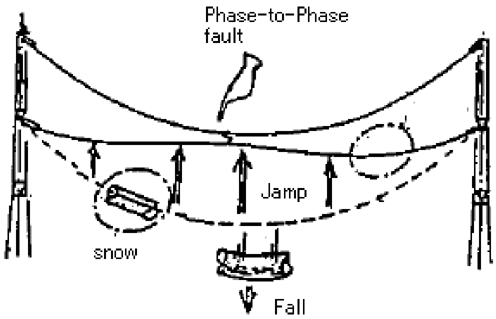
Classification according to dead time

(2) Medium-speed auto-reclosing

- The dead time is considered by:
  - Attenuation of turbine generator shaft vibration,
  - Attenuation of conductor vibration ("Galloping" and "Sleet jump") etc.



"Galloping"



"Sleet jump"

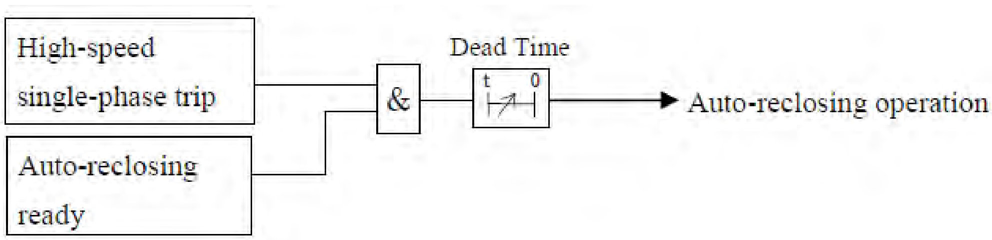
Classification according to dead time

(3) Low-speed auto-reclosing

- The dead time is considered to be more like an automatic recovery method
  - In the event of unsuccessful high-speed auto-reclosing

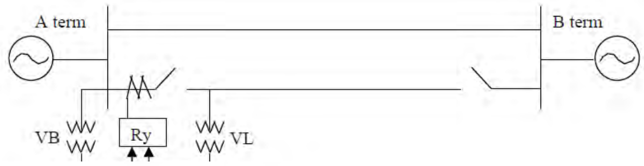
(1) Single-phase auto-reclosing

- **Only one out of three phases is opened**
- **Other two phases maintain the interconnection between both terminals**
- **No special interconnection checks are required**

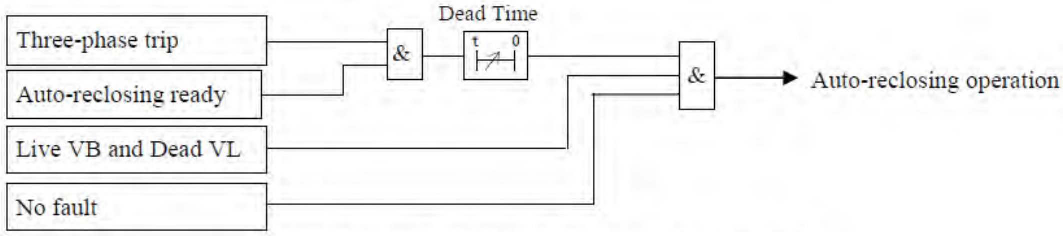


7. Auto-reclosing function (Requirement)

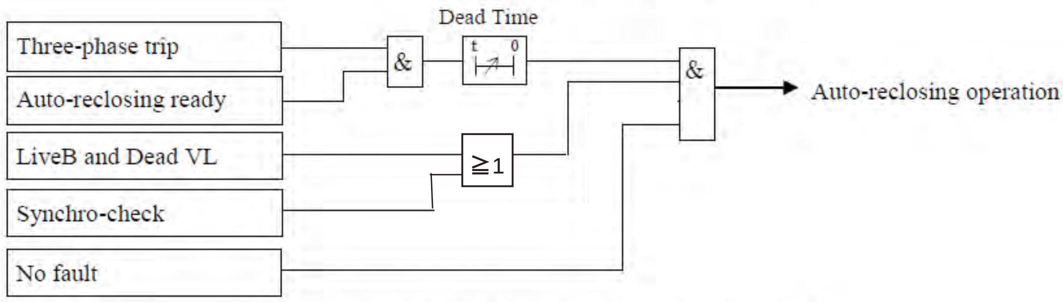
(2) Three-phase auto-reclosing



- **Synchronism-check**



Auto-reclosing condition for leading terminal

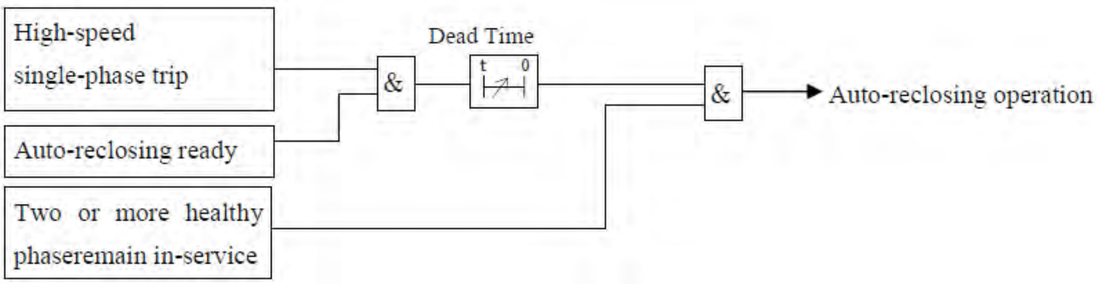


Auto-reclosing condition for follower terminal

7. Auto-reclosing function (Requirement)

(3) Multiple-phase auto-reclosing

- **High speed auto-reclosing after first confirming of different phases in double circuit line**
- **Interconnection of the form of two phases or three phases**



8. Application examples of Japan to long distance line

Line name	Line length	Voltage	In service from	User name	Remarks
Nishi-Gumma-kansen	137.7 km	500kV	1992 ~	TEPCO	1000kV design
Minami-Niigata-kansen	110.8 km	500kV	1993 ~	ditto	ditto
Higashi-Gumma-kansen	44.4 km	500kV	1999 ~	ditto	ditto
Minami-Iwaki-kansen	195.4 km	500kV	1999 ~	ditto	ditto
Dai Kurobe-kansen	245.16 km	275 kV	1988～2011(*1) 2011～ (*2)	KEPCO	1:FM (Analog) 2: Numerical

Note: TEPCO : Tokyo Electric Power Company /TEPCO-Power Grid Inc.

KEPCO: Kansai Electric Power Company /Kansai Transmission and Distribution Inc.

FM: Current differential relay based on Frequency modulation, static type relay

END