Lao People's Democratic Republic
Ministry of Energy and Mines
Electricite Du Laos

Data Collection Survey On Improvement Of Power System Operation In Laos

Final Report

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Japan International Cooperation Agency (JICA)

Tokyo Electric Power Services Co., Ltd. (TEPSCO)
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Abbreviation

aFRR	automatic frequency restoration reserve
AGC	Automatic Generation Control
ASEAN	Association of South-East Asian Nations
BOT	Build-Operate-Transfer
BNCC	Backup National Control Center
DEM	Department of Energy Management
DERM	Department of Enterprise Registration and Management
DX	Digital Transformation
EDC	Economic Dispatch Control
EDL	ELECTRICITE DU LAOS
EDL-Gen	EDL-Generation Public Company
EDL-T	Electricite du Laos Transmission Company Ltd.
EGAT	Electricity Generating Authority of Thailand
EMS	Energy Management System
ERAL	Electricity Regulatory Authority of Laos
EGAT	Electricy Generation Authority of Thailaind
FM	Financial Management
FMS	Financial Management System
FTC	flat tie line control
GCRP	Grid Code Review Panel
GMC	Grid Code Management Committee
ICT	Information and Communication Technology
IEC	International Electrotechnical Commission
IP	Internet Protocol
IPP	Independent Power Producer
ISO	the International Organization for Standardization
ITU	International Telecommunication Union
JICA	Japan International Corporation Agency
LCU	Local Control Unit
LFC	Load Frequency Control
MEM	Ministry of Energy and Mines
NCC	National Control Center
PAS	high-level application software
PPA	Power Purchase Agreement
RCC	Regional Control Center
RTU	Remote Terminal Unit
SAP	Structural adjustment programs
SCADA	Supervisory Control and Data Acquisition
TBC	Tie line load frequency Bias Control
TCP	Transmission Control Protocol
TM	Telemetary

Table

Figure

Chapter 1 Survery Summary

1.1 Survery Background

Lao PDR is abundant with hydropower resources that can contribute to low-carbonization, and hydropower accounts for most of the country's power supply. In recent years, the development of hydropower plants has been further promoted, resulting in rapid increase in surplus power, especially during the rainy season. In order to make effective use of these resources, In addition to the current exchange of power to other countries using power lines exclusively for export, synchronization will be achieved by interconnecting power systems with alternating current (AC) using international interconnection lines in order to exchange power with neighboring countries through interconnection lines. The policy aim is to expand the interconnected system.

However, at present, although synchronous interconnection is being carried out only with Thailand, the Laos domestic power system does not reliably perform supply and demand adjustment to match demand and supply from time to time, and supply and demand operation (frequency adjustment) .There are various issues in system operation, including the fact of relying on the Thailand. If supply and demand adjustment in the domestic power system remains at the current level, it will not be possible to expand the synchronous interconnection system, and the goal of increasing the amount of power exchange will not be achieved. Therefore, in the future, in order to expand the AC and synchronous interconnection systems with neighboring countries and increase the amount of interchange of hydropower sources, autonomous and stable system operation is a prerequisite, especially supply and demand operation, which is the key. Improving the quality of (frequency adjustment) is a major challenge. In order to solve this problem, it is extremely important to improve grid operation capabilities, including the development of NCC systems.

EDL's NCC system, which was introduced in 2013, has been unable to capture information on newly constructed power plants and substations due to the expansion of the grid in recent years. It is not possible to monitor the grid status online, which is the basis for making appropriate judgments, and this is causing problems in grid operation.

It is assumed that communication equipment is in place in many locations, but it is presumed that there are issues with setting up data connections between the NCC central system and the information exchange systems within the power generation and substation sites.

1.2 Strategy of Survey

1.2.1 Purpose of Survey

This study will analyze the current status and issues of grid operation operations and feed-in systems in Laos, especially the requirements of the operation operations and feed-in systems required of NCCs, and examine the future feed-in system configuration and the roadmap for improving grid operations related to NCCs. The objective is to analyze the content, effectiveness, necessity, and appropriateness of individual projects that be formed in the future, and calculate the optimal business content and scale of the projects.

1.2.2 Policy of Implementation of Survey

(1) Survey Period

This study will be conducted from November 2023 to the end of February 2024.

(2) Practical Survey

In this study, two field surveys are planned to be conducted. The first field study will start with an understanding of the current status and issues of domestic grid operation in Japan, and will include the future vision of the operational tasks required of NCCs and the requirements for power supply systems, a study of the possibility of utilizing existing RTUs at each site, an understanding of policies and plans for improving grid operation in Japan, and a study of the configuration of power supply systems and a road map for strengthening grid operation capacity for NCCs. The second field study will be a roadmap and final report. The main activities of the second field study are expected to be the discussions with the relevant authorities on the roadmap and the Final Report (draft).

(3) Individual projects expected to be formed (draft)

The candidate project for the grant assistance project is assumed to be the one to improve the operation of the country's domestic supply system by upgrading the NCC and other power feeder systems. Based on the contents of the roadmap for the configuration of the NCC and other feed-in systems and enhancement of grid operation capacity, or alternatives considered in this study, the specific details (including component outline, estimated cost, schedule, and establishment of operational effectiveness indicators) will be discussed.

For the candidate projects envisaged, it shall be confirmed that the projects do not fall under the large-scale power transmission and distribution sector listed in the JICA Guidelines for Environmental and Social Considerations (promulgated in January 2022, hereinafter referred to as "JICA Environmental Guidelines"), and that the undesirable effects on the environment are small.

(4) Utilization of existing materials and review of existing projects

In addition to JICA, other donors have been implementing studies and projects in the power sector in this country. Therefore, when collecting and confirming information on the current status and issues of the domestic supply system operation, policies and plans for improving the country's system operation, research reports on related projects conducted in the past by JICA and publications published by other donors will be used. as much as possible, paying attention to efficiency and promptness, and at the same time avoiding duplication of research. If sufficient information cannot be obtained from existing materials, information will be collected through interviews with relevant Lao government agencies, including the Lao Electric Power Corporation, the Ministry of Energy and Mining, etc., and field surveys.

(5) Conducting Surveys at Operating NCC, Substations, and Power Plants

In order to investigate the current situation at NCC, substations, and power plants that are in operation, the study team will work closely with EDL and make sufficient adjustments to ensure a smooth investigation without disrupting normal operations.

(6) Operation and Maintenance Capacity

After the candidate project is implemented, the operation and maintenance of facilities and equipment, as well as the preparation of personnel systems, etc., will be carried out by the Lao PDR Electric Power Company, but this study will confirm the organizational structure and staff training system related to system operation work. As a result, if it is determined that technical support for improving system operation operations is necessary and appropriate, support options such as technical cooperation and soft components will be considered.

(7) Contribution to Climate Change Countermeasures

In recent years, there has been an international call for a shift to renewable energy and energy conservation/low carbonization as a measure against climate change. Climate change countermeasures will be considered in all candidate projects considered in this study.

(8) Examining the Possibility of Utilizing Digital Technology

In confirming the needs for cooperation in the electric power sector, the study team will confirm the possibility of utilizing Japan's DX technology and its significance.

(9) Confirmation of Significance of Project Implementation

The development effects of implementing the candidate projects envisaged in this study will be examined quantitatively and qualitatively.

1.2.3 Matters to Require Attention

It has been assumed that many substation equipment and communication equipment use international standards as standards and protocols. However, the detailed settings and specifications of the equipment have not been clearly confirmed, and it is not known whether the communication equipment and RTU can be used without modification when the NCC system is updated. For example, even if it is compliant with international standards, there are not rules for how to create all RTU data, so there is a possibility that the supplier manufacturer has created its own specifications, and there is a possibility that the specifications are made by the supplier, and there is a possibility that they are in accordance with the rules in which parts. It is assumed that there is a possibility that these specifications cannot be clarified by information from EDLs (e.g., instruction manuals and other documents provided by the suppliers). As a result, there is a high possibility that some RTU equipment will become unusable when connected to new equipment.

For this reason, EDL plans to upgrade its NCC system to a new manufacturer's product. Possible upgrade methods when there are budget constraints are: (1) selecting and connecting power generation and substation sites that can reliably connect data from the NCC central system; and (2) for the data connection between the NCC central system and the information exchange system at the power generation and substation sites, being handled by EDL, which has received training from the manufacturer.

1.3 Status of Support from JICA and Other Donors

1.3.1 JICA

As of February 2024, the JICA power sector cooperation projects in the Lao are shown in Figure 1-1. The power policy advisor aims to strengthen MEM's power policy capabilities, improve system operation to improve power quality by developing grid codes and strengthening operational systems, and improve management of electric power utilities by strengthening EDL's organizational management structure and capabilities. . Furthermore, the purpose of formulating an integrated energy master plan for a carbon-neutral society is to formulate a long-term energy transition master plan to realize a carbon-neutral society

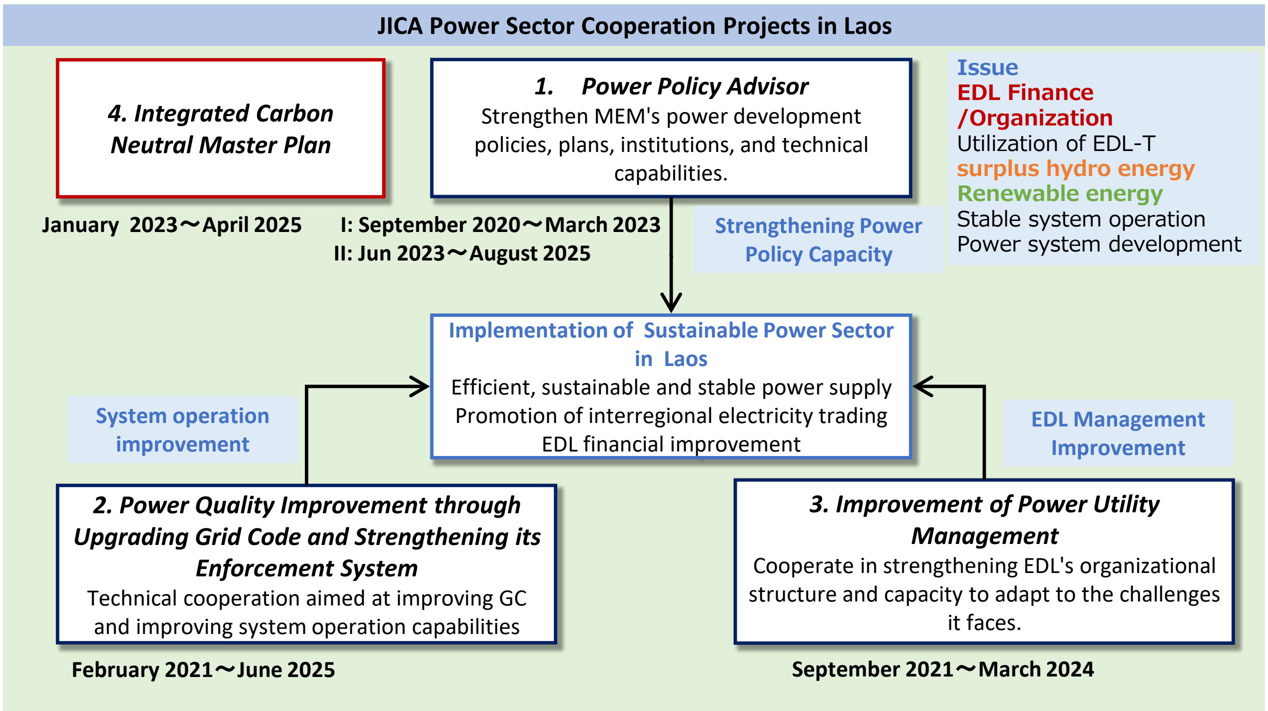


Figure 1-1 JICA Power Sector Cooperation Projects in Laos (Source: the study team)

1.3.2 Ministry of Foreign Affairs and Trade of New Zealand

New Zealand's Ministry of Foreign Affairs and Trade has been supporting EDL's system operations and planning since 2021. The project consists of three phases: Phase 1 is from 2021 to 2022 to understand the current situation and formulate a support plan, and Phase 2 is from 2023 to 2024 to provide training on PyPSA and PowerFactory and to model EDL systems. Phase 3 is scheduled for 2025-2026 and is planned to provide more advanced training than Phase 2 for NCC operators and system planners.

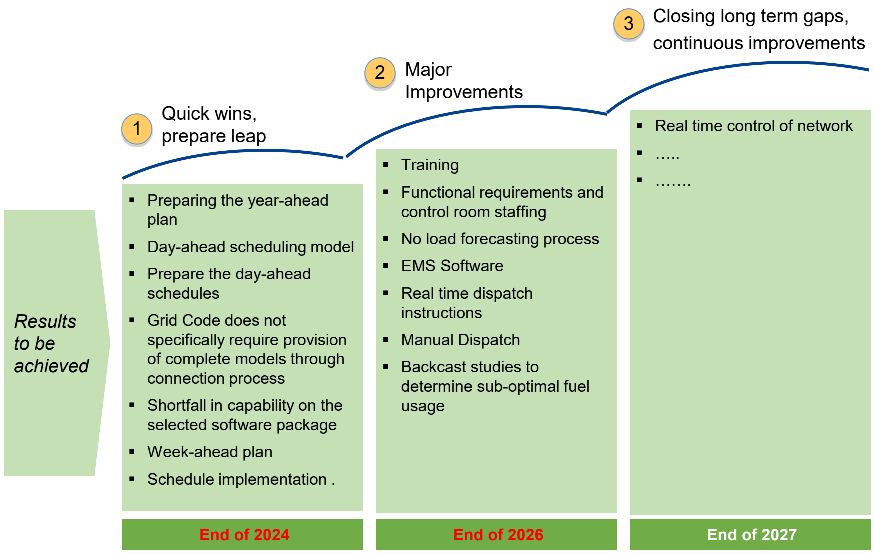


Figure 1-2 Overview of the technical Assistance on System Operation and Planning

1.3.3 World Bank

The World Bank implemented the Lao PDR Power Grid Improvement Project(P149599)[1] from September 2015 to March 2020 to improve the reliability and efficiency of the power distribution system. (See Table 1-1) The pilot project was conducted in Xaythany, Vientiane District, and smart meters, power distribution automation systems, etc. were installed.

Table 1-1 Components The Lao PDR Power Grid Improvement Project (P149599)[2]

Component	Description
omponent 1: Smart metering, distribution improvement, and distribution losses reduction (Approved: IDA US$19.0 million; Actual completion: IDA US$21.43 million).	This component introduced advanced metering infrastructure (AMI) technology and digital meters for residential and nonresidential customers in the project area. In addition, it strengthened the power distribution infrastructure and distribution automation to help improve reliability of power supply and reduce losses in selected parts of the distribution network. This component included rehabilitation of power distribution lines, upgrading of conductors, increasing of transformer capacity, placement of capacitors for reactive power and voltage control, and installation of load break switches and reclosers and so on.
Component 2: Electric utility information system (Approved: IDA US$6.0 million; Actual completion: IDA US$6.64 million).	This component improved EDL's utility information system by (a) supply and installation of communication hardware and software links to support advanced metering and distribution automation, (b) extension of GIS to support power distribution O&M, and (c) supply and installation of an updated corporate FMIS.
Component 3: Institutional capacity building and project implementation support (Approved: IDA US$5.0 million; Actual at completion: IDA US$1.32 million).	This component included (a) power system software, distribution equipment, testers, and other instruments; (b) consultancy for the electric utility information system; (c) support to measure distribution system performance indicators; and (d) project implementation support (including training in World Bank procurement procedures and so on) and incremental operating costs. This component enhanced EDL's institutional capacity to use new technologies to address distribution losses and improve power grid efficiency. Although only US$1.32 million was spent under Component 3, the total expenditure on institutional capacity building and project implementation support was in fact slightly over US$5 million.
Component 4: Contingent emergency response (Total approved: US$0; Actual at completion: US$0)	The objective of the contingency emergency response component with a provisional zero allocation was to allow for the reallocation of financing in accordance with the IDA Immediate Response Mechanism to provide a rapid response to disaster or emergency events, as needed. This component would have financed expenditures on a positive list of goods and/or specific works and services required for emergency recovery. This contingency component was not used as no relevant disaster or emergency events actually occurred.

[1] https://projects.worldbank.org/en/projects-operations/project-detail/P149599
[2] https://documents1.worldbank.org/curated/en/726761635537794917/pdf/Lao-Peoples-Democratic-Republic-Power-Grid-Improvement-Project.pdf

Currently, the Power Distribution Improvement Project (P178477)[3] that started in 2023 is being implemented (see Table 1-2) and is scheduled to be implemented until August 2028. This project involves reducing technical losses in the distribution system, implementing EDL's financial system, and providing related technical support.

Table 1-2 Components of Power Distribution Improvement Project (P178477)[4]

Component	Description
Component 1: Substation Investments and Grid Monitoring Systems (US$46 million IDA).	The sub-component will support the replacement or installation of transformers in targeted substations that have low performance and high technical losses due to the age of transformers and/or inadequate distribution capacity, or design discordance. The replacement with/installation of new transformers will enable EDL to improve the efficiency and the capacity of its distribution grid systems supplied by those substations. The sub-component will also support the installation of system monitoring and protection relays, procuring design and planning software and portable analyzers, alongside providing technical project implementation support, and EDL staff training for the use of the planning software and portable analyzers.
Component 2: Financial Management System (FMS) and SAP1 Implementation (US$5 million IDA).	This component will support consulting and non-consulting services, technical assistance and capacity building required for the strengthening of FMS at EDL corporate level and for completing the effective functioning, integration, and adoption of the SAP. This component also includes also FM and Procurement implementation support at the project-level, as well as supporting annual external independent audits of financial reports both at the project level and at for EDL as a corporate entity.
Component 3: Contingent Emergency Response (US$0 million IDA)	This component will provide immediate response to an eligible crisis or emergency, as needed.

[3] https://projects.worldbank.org/en/projects-operations/project-detail/P178477
[4] https://documents1.worldbank.org/curated/en/099095503162319718/pdf/P178477020d41807087b204ff78e5bd5eb.pdf

Chapter 2 Current Status and Issues on Power System Operation

2.1 Current Status of Power Plants and Power System

2.1.1 Current Status of Power Plant

Power plants in Laos are divided into those for export and those for domestic supply. Export-only power plants are sold to neighboring countries by IPPs (Independent Power Producers) under BOT (build-operate-transfer) contracts. It is directly connected to the grid through a dedicated power transmission line and is operated according to the power supply instructions of the relevant power company. According to the contract, the plant will be returned to the Lao government after approximately 25 to 30 years of operation. Also, at this time, it will be overhauled and returned. Power plants for domestic supply are projects runned by EDL (Electricite Du Laos), EDL-Gen (EDL-Generation Public Company), or IPP, sell power to EDL, the domestic power transmission and distribution company in Laos, and are operated under EDL's power supply instructions. Table 2-1 shows the power generation capacity and amount of power generated by power plants operating in Laos in 2021.

Table 2-1 Power generation equipment capacity and amount of power generated by power plants operating in Laos in 2021

	For export (Y2021)			For domestic supply(Y2021)		
Type	Installed Capacity (MW)	Generated Power (GWh)	Occupancy rate (GWh)	Installed Capacity (MW)	Generated Power (GWh)	Occupancy rate (GWh)
Hydro	4,933	24,192	56%	3,992	8,848	25%
Thermal	1,803	11,222	71%	75	660	100%
Solar / Bio	-	-	-	168	116	8%
Total	6,736	35,414	60%	4,235	9,624	26%

(source: Electricity Statistics, 2021, DEPP)

2.1.2 Current status of domestic grid

The domestic power supply system in Laos consists of 230kV and 115kV transmission systems, and 33, 22, and 11kV distribution systems. The planning and maintenance of 230kV transmission lines and 230kV substations has been transferred to EDL-T (EDL Transmission Company Ltd.), and with some exceptions, the transmission and distribution systems below 115kV are owned and maintained by EDL. However, EDL NCC is consistently responsible for system operation.

Furthermore, due to geographical constraints and other reasons, some domestic power transmission and distribution systems near borders with neighboring countries are connected to the power transmission and distribution systems of neighboring countries and receive electricity cross-border from the neighboring countries. Conversely, there are cases where power is transmitted cross-border from the Laos system to neighboring countries. At that time, the power transmission and distribution systems in areas where cross-border power transmission and reception is carried out with China, Cambodia, and Myanmar, which are not synchronously interconnected, are operated separately from the main system.

Figure 2-1 shows an overview of Laos' power transmission system and an image of system division.

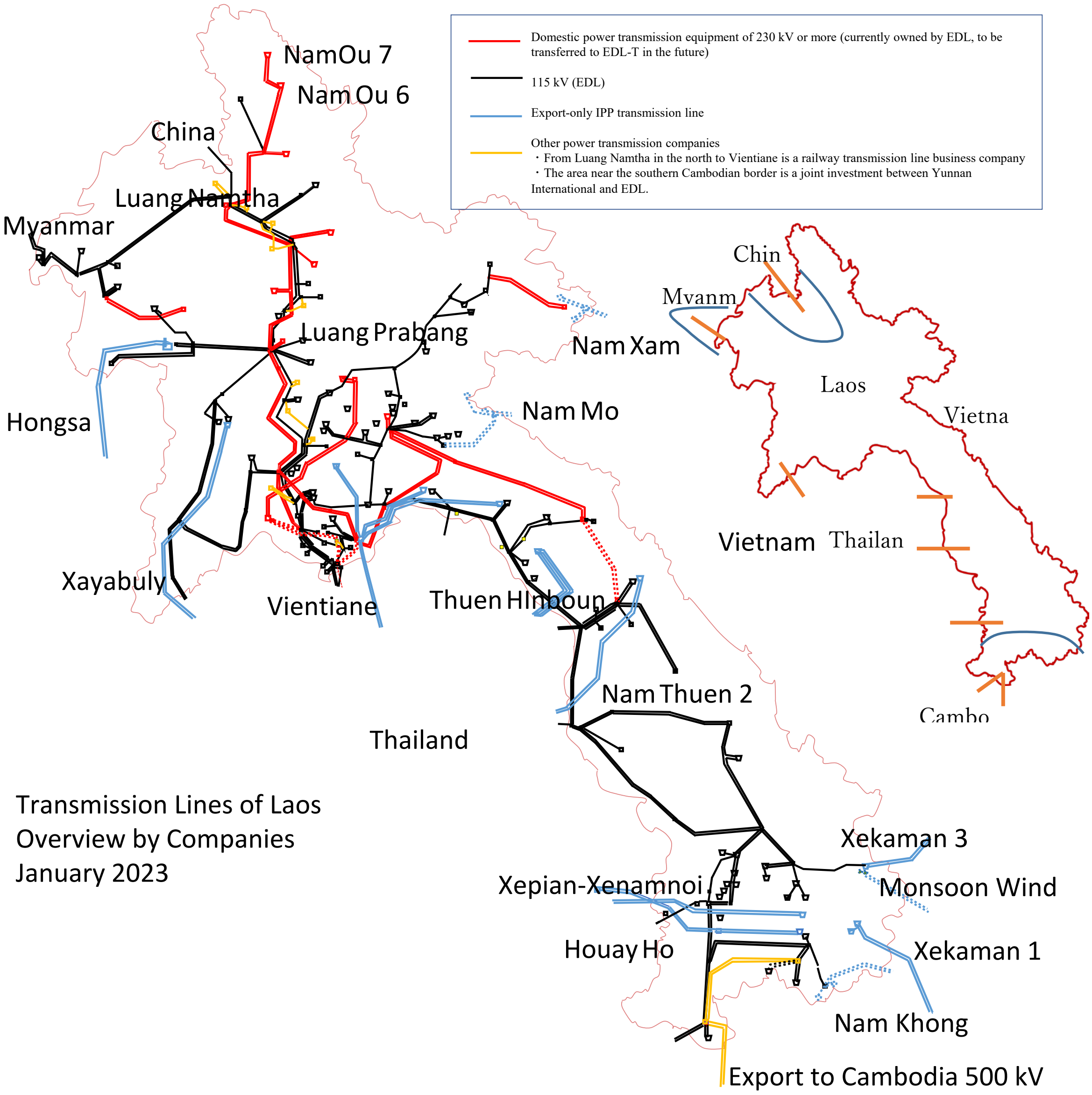


Figure 2-1 Overview of power transmission facilities in Laos

Table 2-2 shows the actual length of power outage in the power transmission system. Black-out refers to a power outage in the entire system, and partial outage refers to a power outage in more than one area.

Table 2-2 Record of power transmission system outage time

Transmission line / transformer / feeder		Year 2022			Year 2023		
		Number (times)	Outage time (minutes)	Average Outage time (minutes)	Number (times)	Outage time (minutes)	Average Outage time (minutes)
Tripped without outage	230kV	60	1,207	20.1	43	504	11.7
	115kV	218	7,478	34.3	130	4,805	37.0
	Tr230kV	19	1,754	92.3	5	3,451	690.2
	Tr115kV	35	3,983	113.8	10	764	76.4
	Total	332	14,422	43.4	188	9,524	50.7
Tripped with forced outage	230kV	67	1,140	17.0	66	2,330	35.3
	115kV	19	444	23.4	1	5	5.0
	Tr230kV	0	0	-	5	625	125.0
	Tr115kV	97	5,321	54.9	121	3,494	28.9
	Total	183	6,905	37.7	193	6,454	33.4
Tripped with partial outage	115kV	29	510	17.6	38	440	11.6
	230kV	11	203	18.5	2	22	11.6
	Total	40	713	17.8	40	462	27.7
Tripped with black-out		0	0	-	3	83	27.7
outage transmission system		556	22,122	39.8	424	16,523	39.0
outage on distribution system	22kV	9,019	231,254	25.6	8,789	190,558	21.7
	34.5 kV	4,563	150,532	33.0	521	7,834	15.0
	Total	13,582	381,786	28.1	9,310	198,392	21.3

(Source: Created by the study team based on the material provided by EDL)

2.1.3 Status of electricity export system

The power system for domestic supply in Laos is connected to Thailand, China, Myanmar, and Cambodia from the EDL system. There are 6 interconnection points with Thailand at 115 kV, and a total of 9 lines have been installed. It is interconnected with China via a single 115 kV line, and initially received power from China, but in recent years has been exporting surplus water from the rainy season to China. To Cambodia, power is exported from the Dongsahong power plant through a 230 kV transmission line directly connected to Cambodia, and at 115 kV to Khampongsalao. In December 2022, a 500 kV designed transmission line will be completed from Ban Hat in Champasak province to M. Phuvong, and the domestic portion of Nam Kong 1 and Xepian-Xenamnoy will both be exported to Cambodia. Exports to Myanmar have started using two 115 kV circuits that will be completed in 2022.

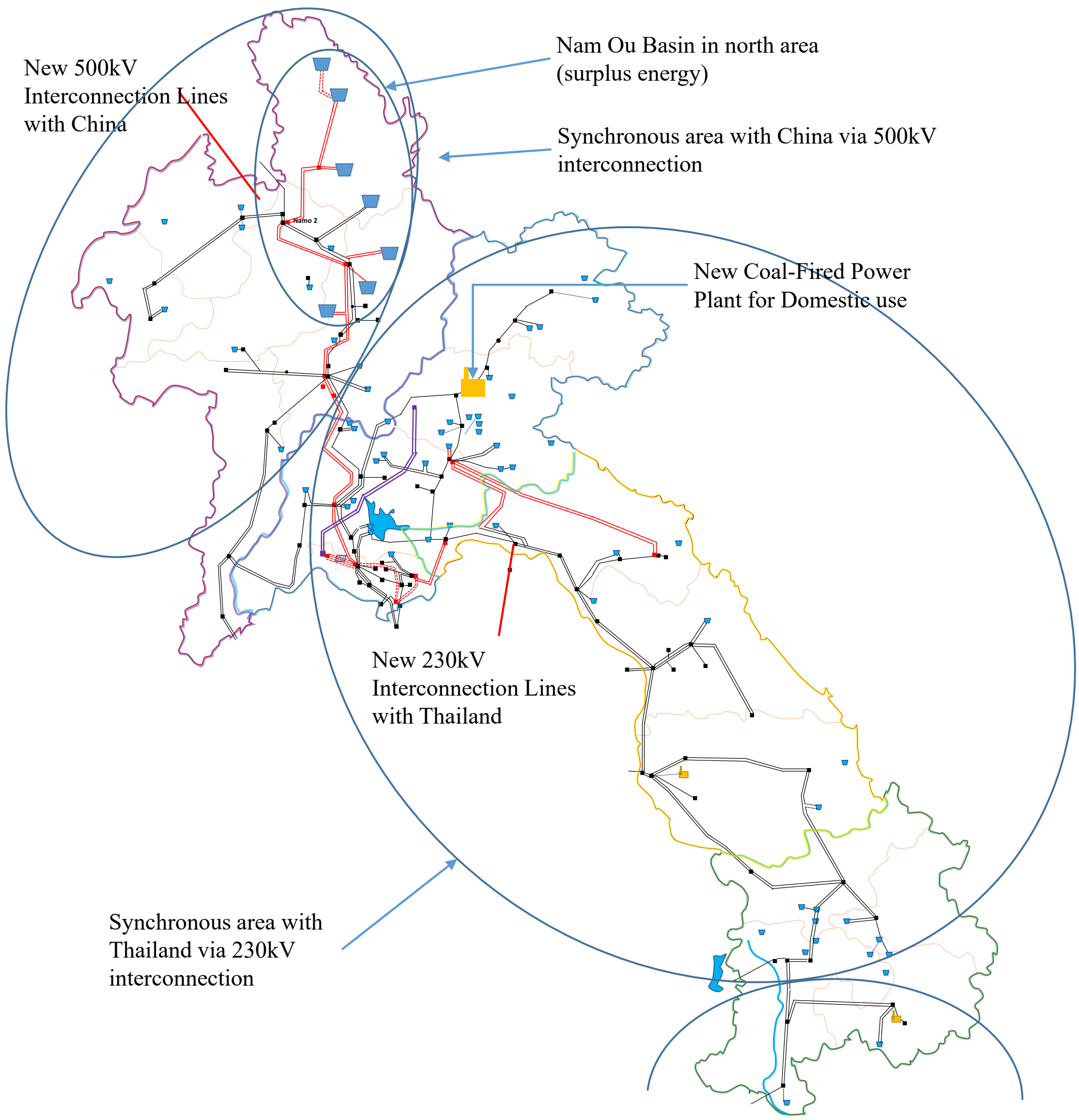
In recent years, exports to Malaysia via Thailand have begun, albeit in small quantities, and in 2021, exports to Singapore via Thailand and Malaysia have also begun.

2.1.4 Current status of power supply system development plans

From February to March 2023, regarding plans for the domestic grid in Laos, there are several moves related to strengthening the domestic grid , such as "Starting construction of domestic coal-fired power plant " , "Construction of China-Laos 500 kV interconnection line decided (PPA under discussion, construction by

EDL-T)) ", Agreement in principle with EGAT for the construction of a new 230 kV interconnection line between Laos and Thailand", etc. (See Figure 2-2)

China-Laos 500 kV interconnection line will adjust the seasonal imbalance of supply and demand through accommodation with China, while exporting significant surplus power to China, especially in the northern region centered on Nam Ou, Laos-Thailand 230.The main purpose of the new kV interconnection line is to adjust the seasonal imbalance of supply and demand around Vientiane and to export surplus electricity to Thailand. In both cases, it is possible to utilize the amount of electricity that can be generated by hydroelectric power, and is expected to have an effect on improving EDL's finances. The domestic coal-fired power plant will be constructed as a base supply capacity to meet the expected future large-scale demand such as silicon mining and ammonia manufacturing plants, as well as other increases in domestic demand in Laos.



(Source: Created by the survey team based on information provided by MEM and EDL)
Figure 2-2 Latest trends regarding domestic grid planning in Laos

2.2 Current status and issues of grid operation and power supply systems

2.2.1 Organization and regulation of system operation

(1) Regulation

In recent years, in addition to EDL and IPP, many stakeholders such as EDL-T and EDL-GEN have entered the power system in Laos. Appropriate regulation and supervision by the Ministry of Energy and Mines (MEM) is necessary from the perspective of ensuring fairness and ensuring the stable supply and quality of power in the system operation operations of the National Control Center (NCC). It is pior to the 2012 version of the Lao Electricity Law, there were no clear provisions regarding the entity responsible for regulating and supervising the electric power business, but the current 2017 version generally stipulates as follows.

□ Articles (Articles 37 to 41) regarding licensing requirements for general electric utilities have been added, and the licensing authority is MEM.

□ The following three-level organizations have the responsibility and authority for orders and supervision related to the electricity business in general (Articles 103 and 104, Paragraph 4).

・MEM Headquarters
・MEM's Provincial, Capital City Divisions
・MEM district offices (District, Municipality and city Offices)

However, the functions for regulating and supervising grid connection, grid usage, grid operation, etc. in MEM are currently distributed and overlapped among multiple departments, so it is necessary to reconfigure a unified regulatory and supervisory organization. is desired.

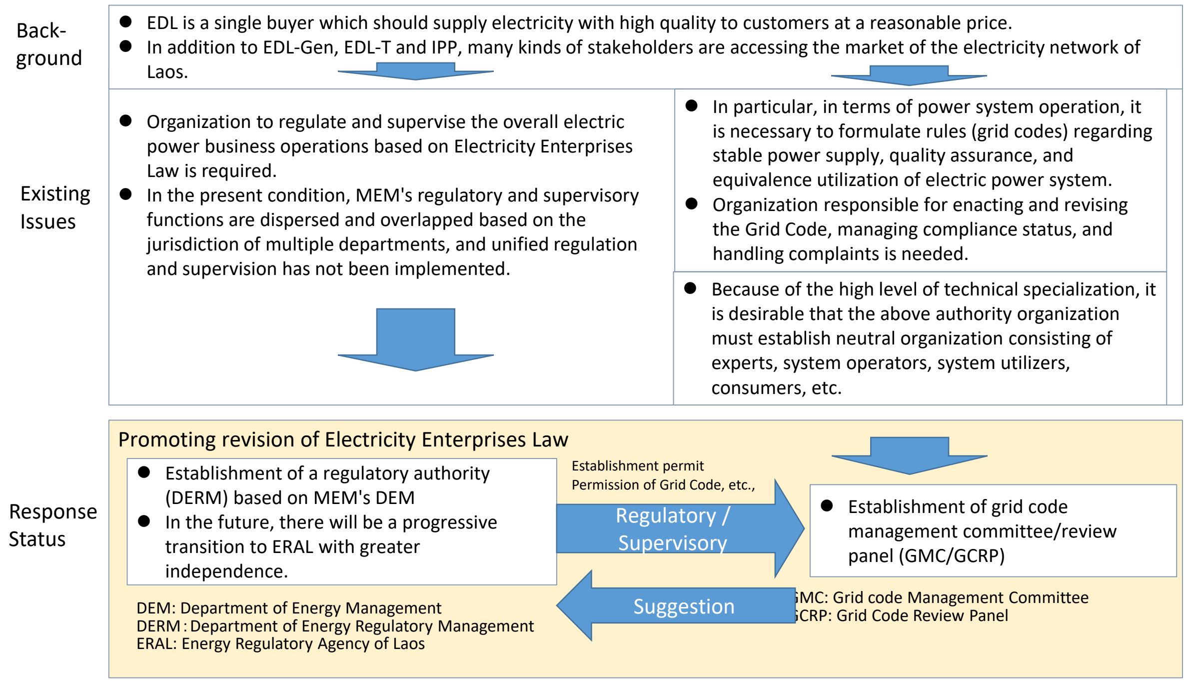
In addition, in order to carry out regulation and supervision, since specialized knowledge of power system technology is often required, a specialized neutral organization to conduct neutral and fair business operations related to grid connection, grid usage, and grid operation, coordinate stakeholders, and provide advice to regulatory and supervisory authorities, must be composed of electricity-related experts, system operators, system users, consumers, etc. and It is conceivable to establish a mechanism for indirect regulation and supervision as described below.

- Regulatory and supervisory authorities should have the right to license and approve the establishment of the above-mentioned neutral organization.
- Requiring the same neutral organization to establish and submit common rules (articles of incorporation and grid code) related to business operations, and giving regulatory and supervisory authorities the right to approve and approve these documents.
- The regulatory/supervisory authority should have the authority to issue orders for business improvement to the neutral organization, if necessary.

We are currently in the process of amending the Electricity Business Act to incorporate the above policy.

- Establish a new organization (Department of Enterprise Registration and Management, DERM) with the current MEM's DEM (Department of Energy Management) as the central regulatory and supervisory authority.
- In the future, a more independent regulatory body (Electricity Returatory Authority of Laos, ERAL) will be established and regulatory and supervisory functions will be progressively transferred.
- Establish a Grid Code Management Committee/Grid Code Review Panel (GMC/GCRP) as a neutral organization.

etc. are being considered.



(Source: Created by the study team based on the research conducted in the "Project to improve power quality by improving grid code and strengthening operation system in Lao PDR")

Figure 2-3 Current issues and consideration of countermeasures regarding regulation and supervision of power system-related operations in Lao PDR

(2) Organizational structure for system operation

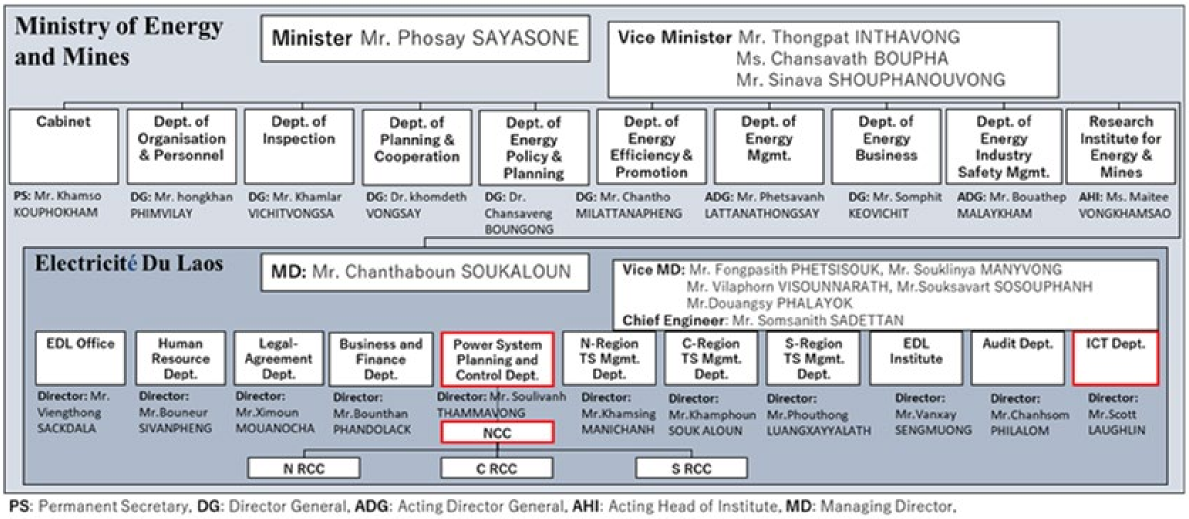
EDL's power transmission system monitoring system is managed by the National Control Center (NCC) and Regional Control Center (RCC) under the Power System Planning & Control Department at the head office. is organized. The general division of duties is as follows.

□ NCC: Supply and demand monitoring, generator paralleling/decoupling operation, power supply transmission line operation, international interconnection line operation, 230kV and 115kV transmission system operation

- RCC: Operation support for 115kV power transmission system based on NCC directives
- The RCC is divided into the following three organizations and monitors the grid by region.

- ➢ North RCC (@Luang Prabang): Northern province of Laos (Phongsaly, Luang Namtha, Bokeo, Oudomxai, Luang Prabang, Huaphanh, Xayabuly, Xieng Khuang,)
- ➢ Central RCC (@Vientiane Capital): Central province of Laos including Vientiane Capital Region (Vientiane Capital, Vientiane, Xaysomboun, Bolikhamxai)
- ➢ South RCC (@Champasak): Central and southern provinces of Laos (Khammouan, Savannakhet, Saravan, Sekong, Champasak, Attapeu)

- A backup center (BNCC) in case of NCC disaster is also set up in Hin Heup.
- EDL ICT Department maintains and manages the monitoring and control systems of NCC, BNCC, and RCC.



(Source: Created by the survey team)

Figure 2-4 Power sector organization chart in Lao PDR

NCC personnel composition (24 people in total)

- Managers 2
- 4-shift 4-operator 16
- System Analysis 3
- System Maintenance 3

RCC personnel composition (information on operator composition only)

- N RCC: 3-shift 2-operator 6
- C RCC: 4-shift 2-operator 8
- S RCC: 4-shift 2-operator 8

2.2.2 Current status and challenges of power supply systems

(1) Current status of power supply system

(a) Functions of the NCC system

A list of current NCC system functions is shown below.

SCADA
- Electric Quantity
- Station List
- Total Load
- Load Balance
- Transformer Status
- CB Bus-Bar Status
- National Power Grid
- State Grid Data
- Whole Network Diagram
- Historian

AGC
- Schedule
- Parameter
- Alarm
- Statistic
- Measure
- Record

Network Applications
- State Estimation
- Dispatcher Power Flow
- SA – Security Analysis
- SCD – Security Constrain Dispatch
- Load and Gen Forecast

System
- Editor Maintenance
- Data Examining
- System Configuration
- System Supervision
- Retrieving and Counting
- Database Maintenance
- Communication Supervision
- System Application

(Source: Created by the survey team)
Figure 2-5 List of NCC system functions

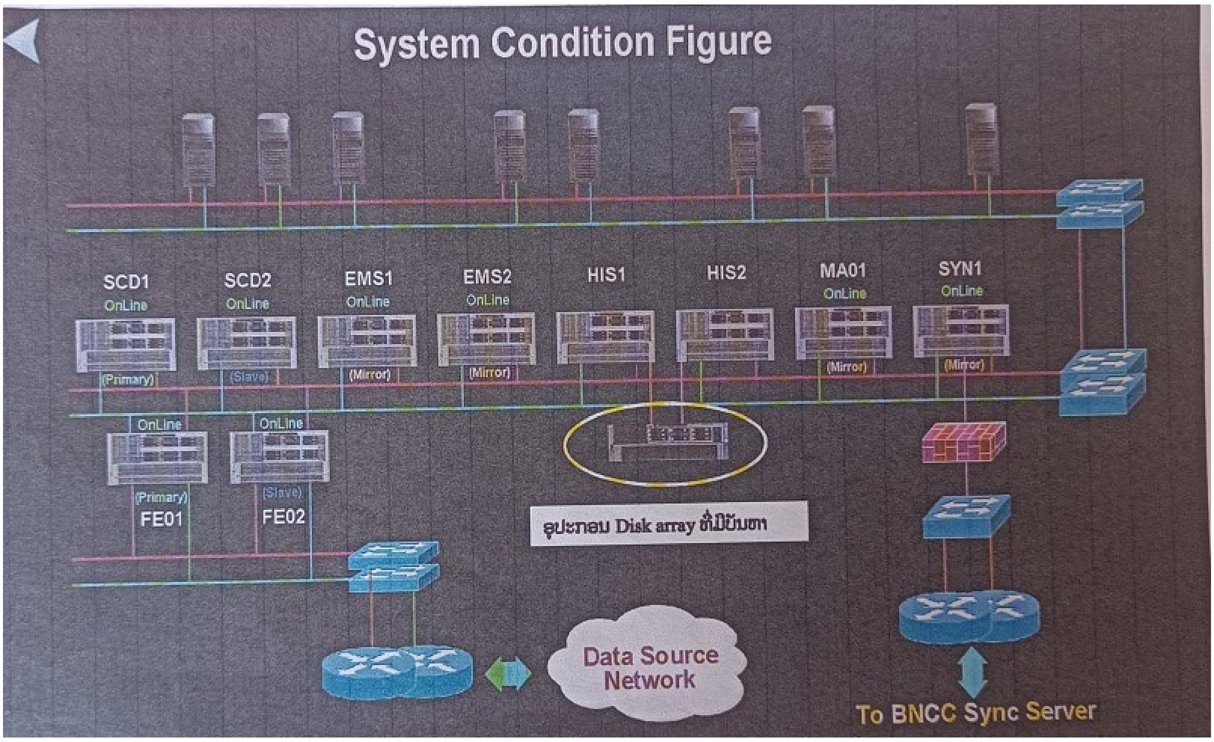
It has three types of functions.

A) Operation of power transmission and substation equipment (corresponding to so-called SCADA)
B) Power plat operations (corresponding to so-called EMS)
C) Maintenance of power supply system

Although it does not have advanced functions, it does have the necessary functions such as EMS and AGC (Automatic Generation Control) for on-duty operators to carry out their normal operations. However, these functions cannot be utilized because data collection from power plants and substations is incomplete.

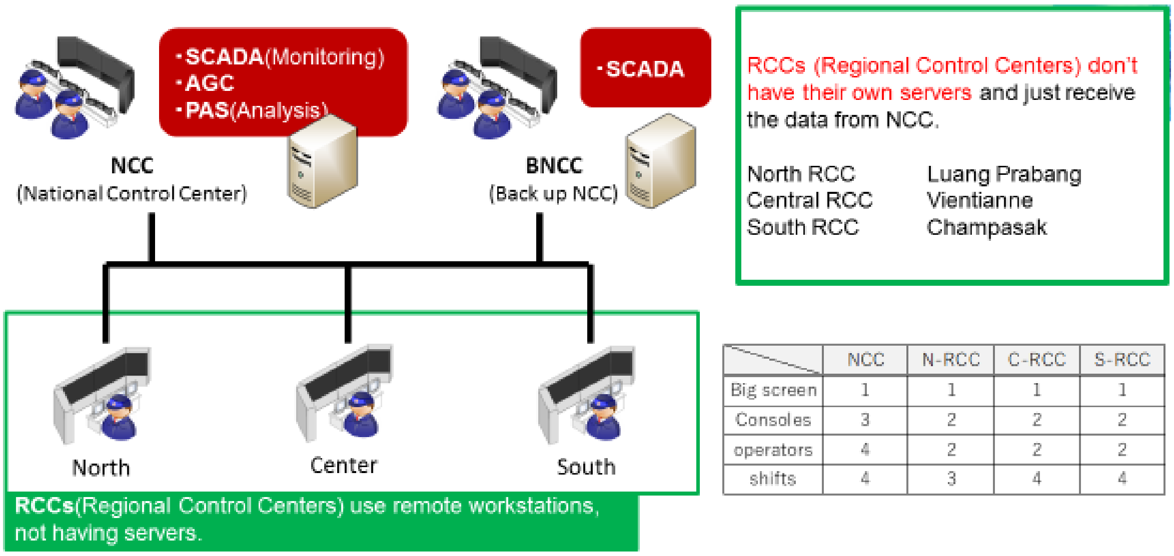
(b) NCC system configuration

The system configuration diagram of the NCC system is shown below. The existing NCC system was installed in 2010 and has been in operation for over 13 years. The SCADA server (SCDx), EMS (EMSx), historian server (HISx), and front-end server (FEx) are configured in two lines, and the maintenance server and synchronization server are configured in one line.



(Source: Received from EDL)
Figure 2-6 NCC system configuration diagram

Furthermore, a BNCC (Backup NCC) has been installed at HinHeup to ensure that the monitoring and control functions are not lost even if the NCC system goes down. Additionally, Regional Control Centers (RCCs) have been established for system operation operations at regional bases. The outline structure of NCC, BNCC, and RCC is shown below. BNCC has a SCADA server installed, so even if the system installed at NCC goes down, the NCC system can maintain SCADA functionality. (AGC and PAS (high-level application software) functions will be lost.) Only a workstation will be installed on the RCC, and information on power plants and substations can be monitored by acquiring NCC and BNCC data. A shematic diagram of the NCC system, BNCC system, and RCC system is as below.



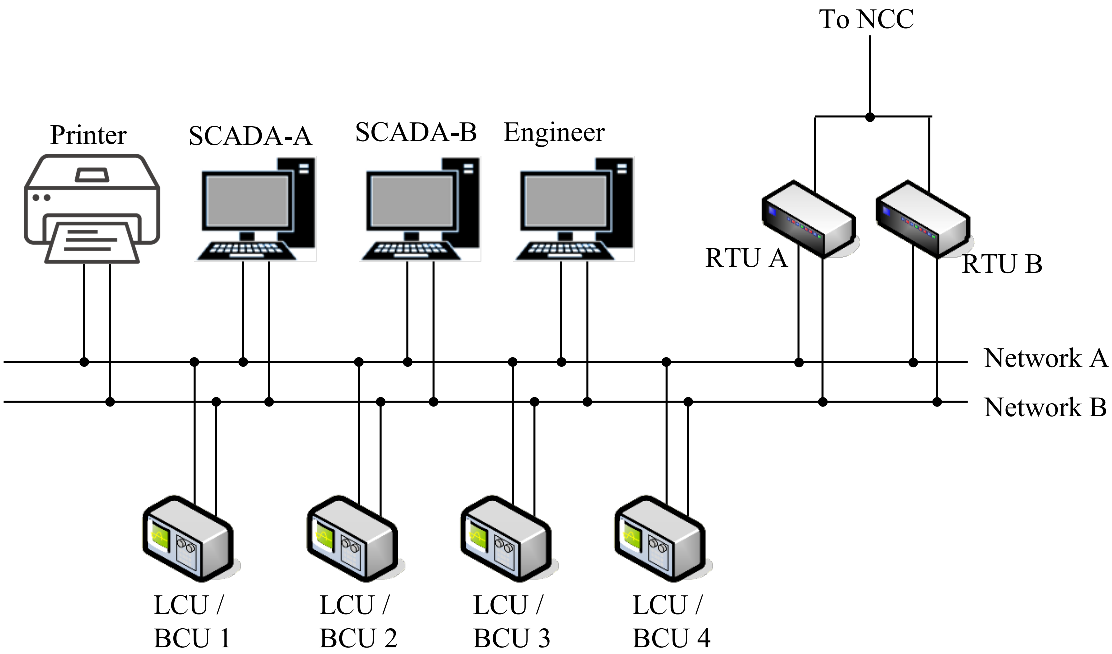
	NCC	N-RCC	C-RCC	S-RCC
Big screen	1	1	1	1
Consoles	3	2	2	2
operators	4	2	2	2
shifts	4	3	4	4

(Source: Created by the survey team)

Figure 2-7 Schematic system configuration of NCC, BNCC, and RCC

(c) Power generation/substation system

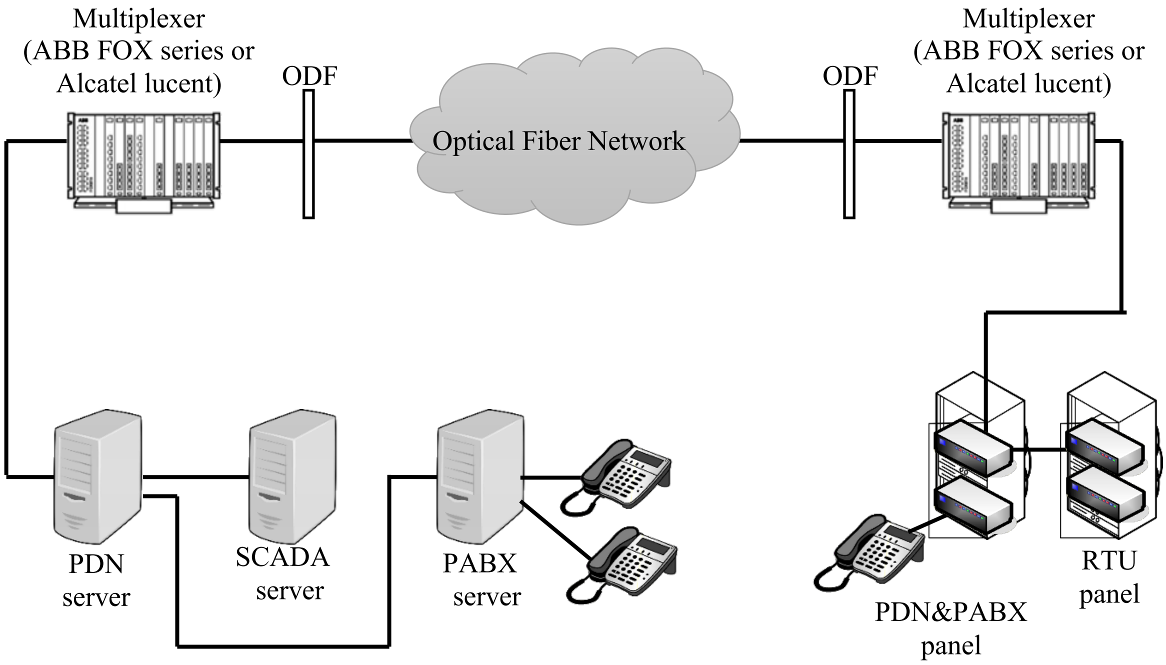
Figure 2-8 shows the standard system configuration of a power plant. The system includes an RTU (Remote Terminal Unit) that aggregates measurement information from the power plant, transmits control signals from the NCC to the LCU (Local Control Unit), a LCU, and a terminal that monitors and controls the power equipment within the power plant. It consists of SCADA, printers, etc., and the RTU, SCADA, and network within the premises are divided into two systems. In the case of a substation, the LCU becomes the BCU (Bay Control Unit), which acquires measurement information for power transmission lines and transformer bays and controls switches.



(Source: Prepared by the survey team from EDL materials)
Figure 2-8 Standard system for power generation and substatio.

(d) Communication equipment

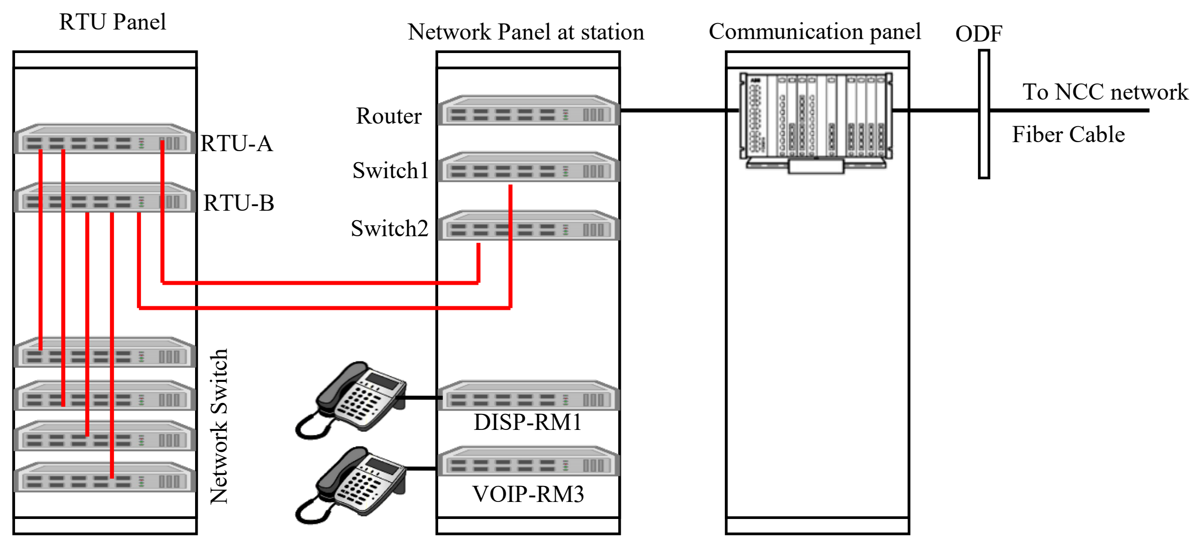
Optical fiber has been installed between EDL's NCC, power plants, and substations. Normally, optical fiber for power communication is divided into two routes, but the current EDL optical fiber network does not have a complete two-route configuration. The optical transmission equipment includes a mixture of Alcatel Communication Network's 1660 series and Hitachi Energy's FOX series. These optical fiber communication systems accommodate telephone lines (EDL dedicated lines), protection lines (relays, etc.), and control lines. Note that (IEC60870-5-104) is used as the communication protocol between the NCC and the power generation/substation. IEC104 is a standard that defines transport, network, data link, and physical layers that are not specified in IEC101 (IEC60870-5-101), and is extended to operate on TCP/IP networks. Note that the application layer of IEC104 is the same as IEC101. Attachment-1 shows EDL's communication equipment as of December 2023.



(Source: Prepared by the survey team from EDL materials)

Figure 2-9 Communication equipment between NCC system and power generation/substation

The standard communication equipment for power generation and substations is shown below.



(Source: Prepared by the survey team from EDL materials)

Figure 2-10 Standard communication equipment for power generation and substations

(e) Security measures

Laos was lagging behind in responding to cybersecurity issues among ASEAN countries, but in 2016, with the support of neighboring ASEAN countries and the International Telecommunication Union (ITU), the Ministry of Posts, Telecommunications The Lao Computer Emergency Response Center (commonly known as LaoCERT) was established under the Lao Computer Emergency Response Center (LaoCERT).

LaoCERT is a technical unit with a status equivalent to a department within the Ministry of Posts and Telecommunications, and plays the role of the main department for preventing and resolving computer system emergencies within the Ministry. Table 2-3 shows the laws and regulations related to cybersecurity in Lao PDR. All laws fall under the jurisdiction of the Department of Cyber Security, Ministry of Technology and Communications.

Table 2-3 laws and regulations related to Cybersecurity in Laos

Laws	Outline
Law on Prevention and Combating Cyber Crime	A law that stipulates the principles, rules, and means for taking effective measures to prevent, reduce, and eliminate cybercrime for the purposes of security, peacekeeping, and maintaining social order. The content mainly focuses on the country's responsibilities and roles. It includes the establishment of an emergency response organization called Lao CERT by the state.
Law on Electronic Data Protection	A law that stipulates principles, rules, and methods regarding the operation, monitoring, and activities of electronic data protection for the purpose of protecting the rights and interests of the country, corporations, individuals, etc., and developing the country economically and socially. Mainly content related to the country's responsibilities, roles, policies, and jurisdiction.

EDL stipulates security policies. (The details were not provided) EDL internally conducts audits in accordance with international standards (such as ISO/IEC 27000 seriers). The network used by the NCC system is a private network with no connection to external networks. Entry/exit control to the NCC control room and NCC system server room is performed using fingerprints, PIN numbers, and card authentication.

(a) NCC control room

(b) NCC system server room

Figure 2-11 Entry/exit control

(2) Power supply system issues

(a) Unable to connect new power station/substation to NCC system

The problem with the current NCC system is that it is not possible to change network information settings. In other words, even if new power generation and substations are added, new monitoring and control information cannot be added. EDL contacted NARI Technology Co., Ltd., the manufacturer of the current NCC system, to request assistance, but the maintenance period has expired and even the manufacturer is unable to perform maintenance.

Table 2-4 shows the number and percentage of locations that can be monitored.

Table 2-4 Current information acquisition status of the NCC system

	In operation	In operation (Inc. on standby)
Total number of monitoring points	102	145
Current locations that can be monitored	80	80
Percentage of monitoring points	78.4 %	55.2 %

(Source: Created by the survey team)

The causes of current inability to obtain information in the NCC system include problems on the NCC side and the site side, and about half of the cases are due to problems on the NCC side. If the NCC system is updated this time, the problems on the NCC side will be resolved and they will be able to be monitored. According to EDL, the site-side issues can be addressed within EDL's budget. Additionally, due to problems with the NCC system, new power generation and substations that will be built in the future will not be able to connect to the NCC, and are expected to remain on standby for connection.

(b) Current status of NCC system failures

Information on recent NCC system failures is shown in Table 2-5.

Table 2-5 Information regarding current NCC system failures

year	failures	Period of failure	Location of failure
2020	1	2 years	Recording HardDisk down
2021	2	48h、4h	NCC system down (including backup) Both of system 1 and 2 were down
2022	3	1h、3h、48h	GPS down Hard disk down Both of system 1 and 2 were down
2023	3	0.5h、0.33h、0.17h	Server down HardDisk down System Error (False positive)

2.2.3 Current status and issues of gird operation work

(1) Supply and demand operation plan

Demand forecasting is performed using linear forecasting based on (1) yesterday's demand data, (2) demand data from one week ago, and (3) demand data from two weeks ago. Data such as weather, temperature, and humidity are not recorded and are not used for demand forecasting. Although hourly demand data from 24 locations for the past two years is saved, data from more than two years ago is not saved.

Supply and demand operation plans are made based on water level and demand forecast information. Yearly, monthly, weekly, and up to the previous day, day shift workers are in charge. NCC operators are in charge of responding on the day. The rainy season is four months from July to October, and the dry season is eight months from November to July. Adjustments are being made so that the water level will be at its lowest level at the end of June.

For annual power generation plans, power plants submit monthly power generation plans for the following year to NCC by October 25th. NCC will confirm the power generation plan and respond to the power plant with approval of the plan at the end of December. For monthly power generation plans, power plants submit hourly power generation plans to the NCC by the 25th of each month, and approval is sent back to the power plant by the 30th of each month. For weekly power generation plans, power plants submit hourly power generation plans by noon every Thursday, and NCC responds to the power plants by 4:00 p.m. that day. For day-ahead plans, the power plant submits an hourly plan by noon every month and replies to the power plant by 4:00 p.m. on the same day. If the demand forecast is incorrect, or if the forecast for the amount of inflow to the regulating pond is incorrect, the power generation plan based on the previous day's forecast will be changed on the same day.

There are 10 interconnection lines of 100MW, and the plan is for imports and exports to be 0MWh throughout the year.

In terms of merit order, priority is given to Take or Pay IPPs. Next, priority is given to small hydropower and run-of-river hydropower that cannot be adjusted with EDL-Gen, followed by small hydropower and run-of-river hydropower that cannot be adjusted with IPP.

(2) Functions of the NCC system and its usage status

Figure 2-12 shows the current NCC system functions and their usage status. Currently, the functions used by shift workers are limited to SCADA functions. In some locations (e.g. HinHeup substation), control functions can be performed, and the switching operations of substation breakers have been tested (actual switch operation), but operations are carried out through field work. Due to safety concerns such as concerns about incorrect operation, remote control using the NCC system (such as turning on and off circuit breakers) is not implemented.

AGC has no applicable generators as there is no control arrangement from NCC in the PPA.

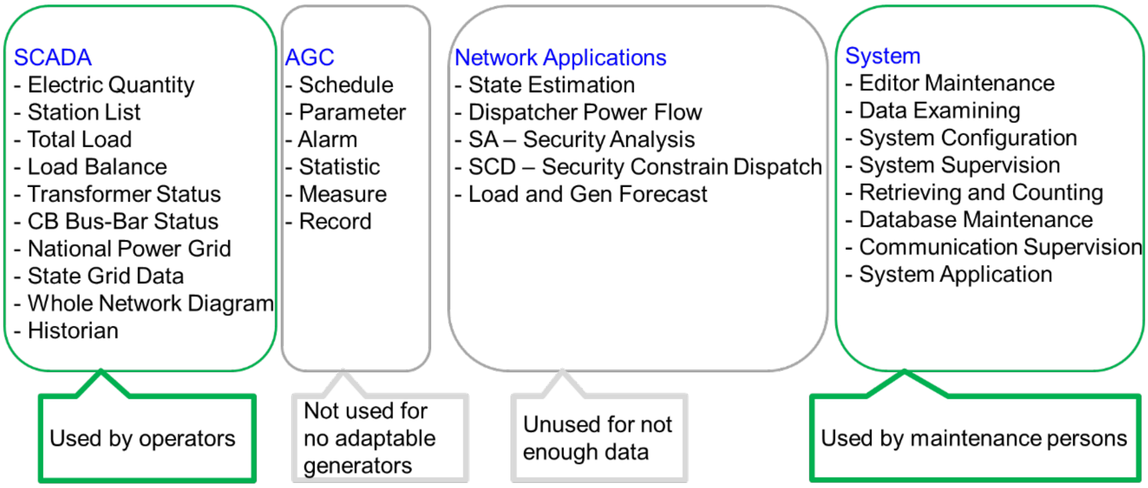
Network Applications cannot be used because the information obtained is insufficient.

The maintenance function (System in the diagram above) is used by day shift maintenance staff. In general systems, this is a function that is often executed on a control console that has entered maintenance mode. Although information cannot be linked to the newly installed and expanded equipment at all, it is possible to draw the newly installed substation on the system.

Please note that there is no training or testing system for the environment, and training in the system is not possible. Grid simulation is possible if the analysis function (PAS) can be used, but due to a malfunction in the NCC system, the current grid information cannot be input, so the following tools are used as an alternative to PAS for analysis of grid operation. .

- Power flow calculation Power World
- Stability calculation Digsilent Power Factory

*The generator data used for stability calculations does not contain actual data and uses standard parameters.



(Source: Prepared by the survey team)

Figure 2-12 Usage status of NCC system functions

(3) Issues in system operation

This section describes some of the issues in system operation, with a particular focus on issues related to supply and demand operation planning.

- There is a discrepancy between planned and actual values in the supply and demand operation planning. This is seen as the biggest challenge. It is a common practice in the work flow that the day shift workers prepare the annual, monthly, weekly and annual to the previous day's planning stages of the supply and demand operation plan, and the shift operators is in charge of the day's operations, but the accuracy of the figures for each task, especially during the planning stage, needs to be improved. There are issues in terms of both accumulating actual data and improving the accuracy of planned values based on analysis. The quality of work needs to be improved, including for power producers and all other parties involved in grid operations.

- The next issue continues to be the fact that no reserve is secured at all. Specifically, the following issues exist: the required amount of regulating power secured is not being checked; decisions on which generators to use as regulating power based on priorities, mainly from a cost perspective, are not being made appropriately; and regulating power is not being paid for appropriately. In practice, the hydropower generators are operated to be used as regulating power when necessary, based on the experience of the shift operators, so although there are (hydropower) generators that can be used as regulating power, it is necessary to ensure that the necessary regulating power is available on the day, to make decisions based on priority, and to pay compensation and bear costs that are commensurate with this. We believe that they're necessary.

- Detailed weather data (weather, temperature, humidity, etc.) is not used for electricity demand forecast and water output assumptions. Real-time demand is also inaccurate due to missing information.

- Most of the supply capacity is hydropower, with a large share of small-capacity run-of-river hydropower and IPPs with take-or-pay contracts, and there is a lack of flexibility in output adjustment.
- Due to the above situation, there is a issue of not being able to properly manage interconnectors power flow with neighbouring Thailand. The situation is particularly acute during the rainy and dry seasons when power flow is needed, but it is easy for power flow to exceed planned values, resulting in a situation where the thermal capacity of the transmission line is close to its capacity, and the operation relies on ad hoc responses by shift operators.

(4) Current status of IPP operation

In this study, interviews were conducted with IPPs Nam Theun 2 Power Plant and Theun Himboun Power Plant. The results of the hearing are listed below.

(a) Nam Theun 2

Operation started in 2010. It owns 40% EDF, 35% EGCO, and 25% Lao Holding State Enterprise (LHSE). There are 4 x 251.3MW generators for export and 2 x 37.5MW generators for domestic supply. Electricity for export will be sent to Thailand via a 500kV transmission line. Domestic power is transmitted via 115kV transmission lines. The contracted power generation amount to EGAT is 5,636GWh, and the contracted power generation amount to EDL is 500GWh. (However, the actual power generation results are 95% for EGAT and 5% for EDL) Net Head is officially 348m. Both export and domestic use are take-of-pay contracts, with EGAT accounting for 97% of the total revenue. The reservoir will be shared for export and domestic use, and the amount of water used in each will be divided proportionally based on the amount of power generated as determined by the PPA.

Regarding the power generation plan for EGAT, Nam Theun 2 will submit the unit utilization rate to EGAT, and EGAT will decide whether to dispatch or not. The generator unit for export is equipped with AGC and controlled by EGAT. Nam Theun 2 can technically be controlled from the NCC and has the equipment to implement AGC, it is currently not controlled from the NCC. However, detailed study is required separately, and additional equipment may be required. There is no mention of AGC in the current PPA with EDL. In order to carry out AGC, it is necessary to review the PPA. The generator for domestic use is a Pelton turbine, and the adjustment range is 1MW to 37.5MW (maximum).

(b) Theun Himboun

THPC is a 60% owned company by EDL-Gen and has a 60MW generator for domestic supply. The dam is being built separately for export purposes. Because the NamThuen 2 dam was built upstream, there was not enough water during the dry season, and Domestic reservoirs do not release water during the rainy season, but instead release water during the dry season to generate electricity and supply hydropower for generators used to export located downstream. The BOT period ends in 2036.

2.2.4 Current status and challenges of wide-area operations with neighboring countries

(1) Supply and demand operation plan formulation phase

According to interviews with NCC staff, the supply and demand operation plan, including electricity import and export with Thailand's EGAT, has been formulated as an annual plan, monthly plan, weekly plan, and day-ahead plan, as shown in Figure 2-13, and is close to the actual supply and demand plan. As the situation progresses, demand forecasts and power generation plans are reviewed with the latest information, and normal procedures are used to improve supply and demand balance plans.

However, because no analysis has been conducted of the causes of discrepancies between the estimated and actual power demand, it is assumed that the accuracy of domestic power demand forecasts is not very high.

Therefore, at the planning stage, it is only necessary to roughly confirm whether it is possible to secure the supply capacity to meet the expected domestic demand in Laos, and it is considered difficult to systematically estimate the import and export of electricity with Thailand's EGAT.

The current method is to accumulate the hourly power generation plans aggregated by the deadline for the hourly power demand assumed at the time of each plan formulation, and apply the subtracted amount as an error term as the amount of electricity export/import. In terms of actual results, as shown in the graph in Figure 2-14, during the rainy and dry seasons, the tide flows towards exports and imports, reaching the operating limits of interconnectors, respectively. It's not like I'm controlling it.

In terms of actual results, as shown in the graph in Figure 2-14, during the rainy and dry seasons, although the electric power flows towards the diection of exports and imports until reaching maximum operating limits of interconnection lines, it is not controlled according to target plan.

Therefore, from the perspective of Economic Dispath Control (EDC) and Load Frequency Control (LFC), the planned power flow (control target value) of interconnectors is currently equivalent to being treated as ±0 MW.

【Issues of Developing plan of Power Supply and Demands】

- The export/import amount to Thailand via the interconnection line is targeted at ±0MW, and planned electricity exports have not been implemented.
- Electricity demand is estimated using past historical values, but comparative analysis with actual results is not conducted.

Current Conditions (Plannig on the day-ahead, weekly, monthly, annually)

		Annually	Monthly	Weekly	Day-ahead
Demand Forecast		Impemented	Implemented	Implemented	Implemented
Generation Planning	Received	by October	by 25th of M-1	by AM, Thursday	
	Decided & Notified	by November (the end of Y-1 at the latest)	by the end of M-1	by evening, Thursday	by 16:00,D-1 (24:00,D-1 at the latest)
	Time Slot	every 1 hour	every 1 hour	every 1 hour	every 1 hour
Import/Export	Target	±0MW	±0MW	±0MW	±0MW

(Source: Created by the survey team)

Figure 2-13 Current status of supply and demand planning work at NCC

(2) Real-time supply and demand operation phase

According to interviews with NCC staff, interconnector power flows in real time tend to fluctuate greatly due to the following events.

- The output of domestic power plants deviates from the plan. (Changes in power generation plans occur frequently, especially during the rainy season)
- Domestic electricity demand deviates significantly from expectations
-

Currently, there is no automatic generation control (AGC) function in place to adjust the power flow of the interconnector between Laos and Thailand, so the power demand and generated power vary from moment to moment. The operation is such that the difference between the two and the same is eliminated by the power being brought in and taken out via the international interconnection line.

In addition, the thermal capacity of each interconnection line is small at around 100 MW, and power flow adjustment is complicated because it is connected to the EGAT system at multiple points, and when the power flow reaches the thermal capacity limit, it is necessary to respond by cutting off power generation and shedding the load.

As mentioned above, even if the amount of electricity exported and imported to Thai EGAT is planned, it is not possible to adjust the power flow according to the plan, so for Thai EGAT, Laos' electricity is not expected in terms of supply capacity (kW value). This will not lead to a reduction in the amount of new power source development. Currently, the system only makes ex-post monetary payments based on the net amount of electricity exported and imported (kWh) measured at the end of each month and year.

[Issues in real time operation]

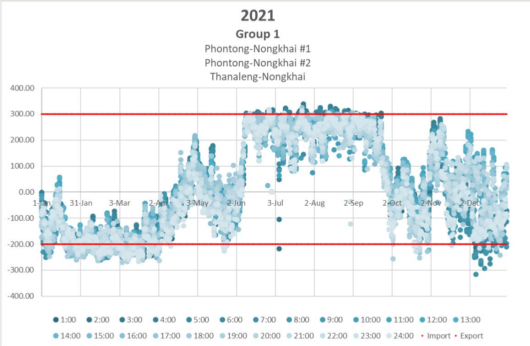
- Power flow of interconnection lines is prone to significant fluctuations due to the following events:
  - Power plants do not produce power output as planning. (especially during the rainy season)
  - Domestic electricity demand deviates significantly from forecasted values.
- Power flow control is complicated because the thermal capacity per int'l line is very low (around 100 MW) and connection with the EGAT is meshed configuration.
- Therefore, power flow of the interconnection lines easily can reach the thermal capacity limit, and load shedding or gen. shedding scheme is frequently implemented.

Current Operation

- Frequency (Pri. Sec. Control) --- Maintained by EGAT
- Balance (Third. Control) --- The generator output is adjusted in the following order of priority:

1. Internattional line capacity constraints;
2. Water level constraints; then
3. Compensation for demand estimation error.

- Electricity imports during the dry season is compensated with electricity exports during the rainy season to avoid excess imports during the year. Therefore, during the peak of the rainy and dry seasons, the power flow of interconnections lines tends to reach their operational capacity limits.



Annual Power Flow on NongKhai Int'l Line in 2021

(Source: Created by the survey team)

Figure 2-14 Current status of real-time supply and demand operation operations at NCC

Chapter 3 Study of the roadmap for improving the power supply system and grid operation

3.1 Roadmap for improving power supply operation

3.1.1 General remarks

As mentioned in 2.2.4(2), the fact that the EGAT in Thailand, which is expected to become the future power hub of the Indochina region, does not expect power imported from Laos as supply capacity (kW value) does not contribute to a reduction in fossil fuel power generation facilities in the entire Indochina region, through the effective use of hydropower (renewable energy), which exists in abundance in Laos. It does not contribute to a reduction in the overall fossil fuel power supply.Furthermore, it will also not contribute to enhancement of the national interest of Lao PDR, such as increasing EDL's revenues.

In the case of synchronous interconnection by AC transmission lines (HVAC), such as between Thailand and Lao PDR girds, it is essential to develop Automatic Generation Control (AGC) by the NCC system (SCADA/EMS) to control the power flow on the international connection lines. However, although functions are implemented in the current NCC System, data setting has not yet been carried out, and support by the system manufacturer is not expected. In addition, it is necessary to check in cooperation with the generation companies whether each generator can respond to AGC.

Therefore, JICA Study Team propose to replace the NCC system of the NCC and eventually develop AGC functions to support the realisation of independent supply and demand balance control (LFC: load frequency control) in Laos, including control of the amount of electricity imported and exported from international connection lines.

3.1.2 Stage-by-stage realisation of supply-demand balance control of the Lao electricity system

In order to realise independent supply-demand balance control (LFC: load frequency control) from Thailand in the future, it is necessary to develop various conditions in addition to the replacement of the NCC system. Therfore, the JICA Study Team propose that the LFC be achieved in the following three stages:

Stage 1: Constant control of import and export energy by offline instruction (manual-FTC, Flat Tie line flow Control)

This stage is to gradually improve the accuracy of the supply-demand adjustment currently implemented by the NCC, using the period until the replacement of the NCC system is completed.

Currently, in relation to Thailand, there is no import/export plan for electricity, and the difference between the domestic supply and demand balance is merely transferred to unplanned inflow and outflow through the international connection lines. As mentioned in 2.2.4(2) and 3.1.1, under these conditions, Thailand cannot expect Lao power supply as supply capacity (especially MW value), and it is also difficult to make effective use of hydropower resources in the entire Indochina region to achieve a low-carbon society.

In order for electricity exports from Laos to be recognized as a supply source, it is necessary to estimate demand and supply capacity from the supply-demand operation planning stage, and how much electricity can be exported or needs to be imported at any given time, including the risk of upswings or downswings, and present this information to Thailand as an electricity import and export plan. In addition, the plan must be implemented in the real-time stage.

Therefore, this stage is positioned as a stage to formulate the electricity import/export plan and to verify the causes of errors in the actual supply and demand in order to further improve the accuracy of the plan. This stage will improve the quality of the supply-demand planning work so that electricity, which has been treated by Thailand as a "fluctuation," will be recognized as a "plan," even if only gradually.

In other words, based on the electricity import and export plan with Thailand, the generator output is adjusted manually (offline instructions by telephone, etc.) so that the net amount of electricity energy to be exported and imported over a certain period matches the planned amount of electricity energy. The period of power accumulation is progressively shortened from annual, to seasonal, to monthly, to weekly, as far as the speed of manual instruction work can keep up.

<u>Stage 2:</u> Constant control of electricity import and export using the NCC system(automatic-FTC)

This stage is envisaged to start from the time when the replacement of the NCC system and the AGC function have been developed.

In other words, the supply-demand balance adjustment of the amount of exported and imported electricity energy with Thailand in a shorter span of time will be achieved by automatic control by the NCC system, based on the same concept as Stage 1. The period of accumulation of electricity energy will be progressively shortened from daily to hourly to 30 minutes.

<u>Stage 3:</u> Minimization Control of Gap between electricity supply and demand in Laos using the NCC system (TBC)

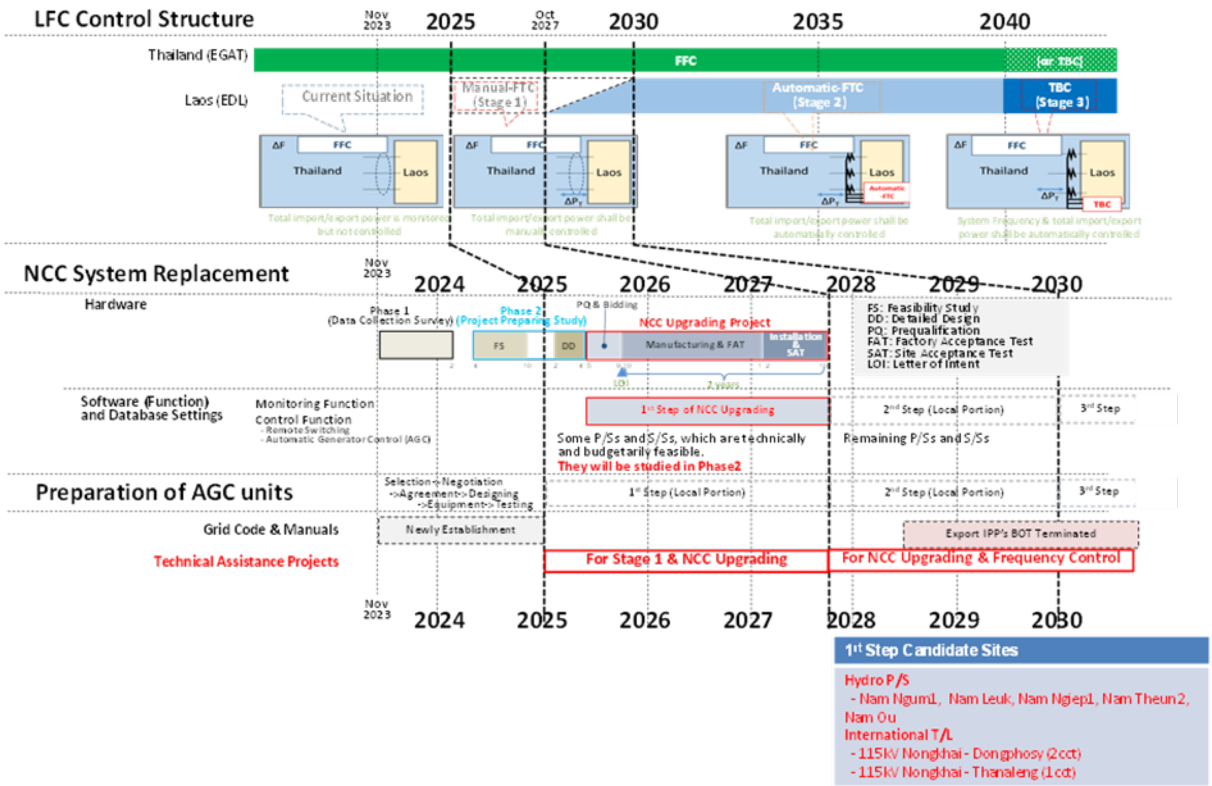
This stage is the final form of load frequency control (LFC), which is assumed to start after automatic-FTC in Stage 2 has been established to some extent.

In other words, the so-called “Tie-line power flow frequency Biased Control (TBC)”, which is also used by many TSOs in Japan, is to be applied to Laos, where the deviation of frequency from the nomnal value (50Hz) and the deviation of the power flow on the international connection lines (tie-lines) from the planned net import and export value are detected and the generator output is automatically controlled by the NCC system to minimize the two deviations simultaneously.

The Project for “Power Quality Improvement through Upgrading Grid Code and Strengthening Its Enforcement System” in Lao PDR, which is currently being implemented with funds from JICA, is developing the grid code and operational manuals, and plans to incorporate the contents of the above stage in the formulation of supply and demand operation plans and frequency management.

In developing the grid code and operational manuals, the EDL's Power System Planning and Control Dept. and NCC staff are working in close communication to improve their literacy in supply and demand balance planning and frequency management work.

At the same time, JICA Study Team would like to propose technical assistance projects of capacity building for revision of grid codes and manuals, lectures and training, if necessary, before each stage is started.



(Source: Prepared by the JICA Study Team)

Figure 3-1 Roadmap for realising supply-demand balance control in the Lao power system

3.1.3 Functions of the NCC system required to achieve load frequency control

(1) Required functions

Among the functions of the NCC system, the following are the minimum requirements that need to be in place to achieve load frequency control (TBC, which is the ultimate goal in the roadmap).

<u>Function 1:</u> Development of supply-demand balance and grid status monitoring functions

A function to collect and distribute grid information (binary and TM (Telemetory) information) via SCADA.

Note that, as a minimum, the development of monitoring functions for the following facilities is required to realise load frequency control (LFC), and to the development of these functions should be prioritized:

- Active power output of generators that will be candidates for future AGC (Currently, AGC is not implemented, so the candidate units need to be determined. The candidate power plants, at this moment, are Nam Ngum1, Nam Ngiep1, Nam Theun2(d), Nam Leuk and Nam Ou, and the current system is unable to obtain information on the active power of Nam Ou 2, 5 and 6 G, Nam Ngum1 6, 7 and 8 G and Nam Ngiep1).
- Active power flow (kW, kWh) of the international connection lines with EGAT in Thailand (The information can be obtained in the current NCC SDACA/EMS.)
- Availability of the generators subject to AGC on the day and total amount of auto-Frequency Restoration Reserves (aFRR, Secondary Control Reserves) (This information is not acquired in the current NCC system.)
- Grid frequency (information is also available in the current NCC system.)

Function 2: Development of supply and demand control functions

A function to remotely control the output of generators, mainly from the NCC system.

In order to realise load frequency control (LFC), the following control functions need to be developed as a minimum, and therefore should be developed as a priority:

- A function to calculate the area control error (ACE) and the total amount of generator outputs required to be controlled to minimize the ACE from the active power flow and system frequency of the international connection line obtained in function 1.
- A function to distribute the above total required amount of generator outputs to each generator unit subject to AGC and to transmit dispatch control signals.
  (The AGC function programme is implemented in the current NCC system, but control cannot be implemented as no data is input).

Function 3: Development of grid control functions

Function to realise the remote switching operation of circuit breakers at the generator and substation from the NCC system.

Although this function is not directly necessary for the realisation of load frequency control (LFC) in normal conditions, the following functions should be developed in order to avoid the collapse of the power grid in emergency situations when stabilisation by load frequency control cannot keep up due to significant frequency fluctuations.

However, of the following functions, the automatic control function should be realised by frequency protection relays and other stabilising systems.

- Automatic/Manual Generator Shedding (AGS/MGS)
- Automatic/Manual Load Shedding (ALS/MLS)
- Automatic/manual international connection line shedding

(Current NCC system has the capability for remote control of circuit breakers, but are not used for reasons of personal and equipment safety).

(2) Functional development schedule

In developing the schedule, JICA Study Team proposes to divide it into the following three steps, taking into account when the installation of the new NCC system will be completed and when a certain quantity of AGC-capable generators will be available to implement full-scale automatic-FTC (Stage 2).:

1st Step: from 2025 to 1st half of 2027

This step corresponds to the installation period of the new NCC system.

Basically, the policy is that, in conjunction with this installation work, the monitoring and control functions to be equipped in the NCC system will be developed as far as possible within the budgetary and other various limitations in the project.

2nd Step: from 2nd half of 2027 to 2030

This step corresponds to the period after the completion of the installation of the NCC system, when secondary control will start sequentially from the generators for which the AGC-related information and communication connection has been implemented, but before full-scale automatic-FTC (Stage 2) can start due to insufficient amount of generator reserves for full-scale AGC.

Basically, it is envisaged as a period when the rest of the monitoring and control functions not realised in the 1st Step will be realised as local potions.

3rd Step: from 2030

This step corresponds to the period after the full-scale start of automatic-FTC (Stage 2).

Basically, this period is envisaged as the time when the monitoring and control functions of the newly secured generators subject to AGC are developed as a local potion in order to complete the realisation of automatic-FTC (Stage 2) and TBC (Stage 3).

Based on the above mentioned steps and each basic cncept, Table 3-1 shows the current proposal for the minimum requirement of grid facilities to be monitored and controlled in order to realise load frequency control (LFC).

Table 3-1 Roadmap for functional development of the NCC system

(Source: Prepared by the JICA Study Team)

	1st Step (2025 – 2027.10)	2nd Step (2027.10 – 2030)	3rd Step (2030 -)
Monitoring Function	**Hydro P/Ss** **(at least one of following P/Ss)** - Nam Ngum1 (1G-6G) - Nam Leuk, Nam Ngiep1 - Nam Theun2 (d), Nam Ou **International T/Ls** - 115kV Nongkhai – Dongphosy (2cct) - 115kV Nongkhai – Thanaleng (1cct)	**Hydro P/Ss (BOT Retire P/Ss)** - Houay Ho (see below) **International T/Ls** - remaining lines (see below) **Availability of Secondary Control Reserves (aFRR)**	**Hydro P/Ss (BOT Retire P/Ss)** - Nam Theun2 (e) - Theun Himbon - Nam Ngum2 (see below) **Grid Frequency**
Control Function (AGC)	**Hydro P/Ss** **(at least one of following P/Ss)** - Nam Ngum1(1G-6G) - Nam Leuk, Nam Ngiep1 - Nam Theun2 (d), Nam Ou	**Hydro P/Ss (BOT Retire P/Ss)** - Houay Ho (see below)	**Hydro P/Ss (BOT Retire P/Ss)** - Nam Theun2 (e) - Theun Himbon - Nam Ngum2 (see below)

International T/Ls

115kV Nongkhai – Dongphosy (2cct)
115kV Nongkhai – Thanaleng (1cct)
115kV Nakhonphanom – Thakhek (2cct)
115kV Mukdahan – Pakbo (1cct)
115kV Beungkhan – Paksan (1cct)
115kV Sirindhorn – Bangyo (2cct)
115kV Thali – Keanthao (1cct)

BOT Retire P/Ss

Name of P/S	Year of Retire	Rated Capacity	Location	Voltage Level of Transmission Line
Houay Ho	2029	150MW	Attapeu, Southern Area	230kV
Nam Theun2 (e)	2035	1000MW	Khammouan, Central2 Area	500kV
Theun Himbon	2039	440MW	Khammouan, Central2 Area	230kV
Nam Ngum2	2040	615MW	Xaysomboun, Northern Area	230kV

・These units are used for not only LFC (secondary control) but also GF (primary control).
・Convert 500kV and 230kV export-only transmission lines to int'l connection lines.
・The connection point during normal operation will be consolidated into one as much as possible.
・The existing 115kV int'l connection lines are used as reserves and are normally kept open.

- **The monitoring and control functions of the generators that are candidates for AGC** are developed in the 1st step at the power plants built with Japanese financial assistance (Nam Ngum1, Nam Leuk, Nam Ngiep1), the power plants that have been negotiated for AGC operation in the past (Nam Theun2(d)) and Nam Ou, which was requested as an additional candidate by the EDL during the second visit. In the 2nd step and after, the development of monitoring and control functions will be proceeded for IPPs with expiring BOT contracts for export-only-to-Thailand that are already implementing AGC in accordance with the Thai Grid Code.

- **The monitoring function of the international connection lines** will be developed at the latest by the completion of the 2nd Step, when full-scale automatic-FTC will be started.

- **The development of the frequency monitoring function** is set to be realised by the 3rd Step in the table, because it is necessary by the start of TBC (Stage 3) at the latest, but needless to say it is a basic monitoring information that should be realised as early as possible.

- In addition to the usage of the BOT-retire IPPs as the AGC in the EDL gird, it would be effective **to continue to utilise the export-dedicated transmission lines that have been directly connected to the grid of EGAT in Thailand as international connection lines between Laos and Thailand**.

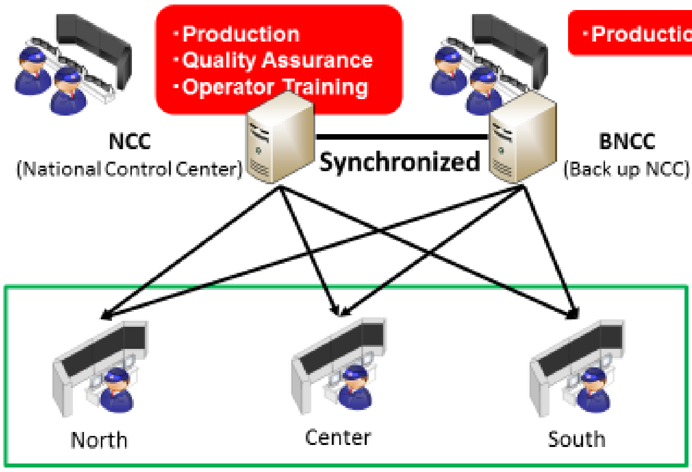
3.2 Draft proposal for the NCC system update

3.2.1 Draft proposal for the NCC system configuration

The draft proposal of the NCC system update is described based on the current equipment and operational status and the roadmap of our suggestion.

(1) Configuration

The proposed configuration of the updated NCC system is shown below.



	NCC	N-RCC	C-RCC	S-RCC	Total
Big screen	1	1	1	1	4
Consoles	5	2	2	2	11

(Source: Prepared by the JICA Study Team)

Figure 3-2 Proposed configuration of the updated NCC system

Currently, the monitoring function is inadequate due to the limited number of locations where information can be acquired. Therefore, after the replacement of the NCC system, the first priority must be placed on improving the soundness of the monitoring function by steadily reducing the number of points where information cannot be acquired.

Next, following the improvement of monitoring functions, it will be necessary to make available functions to support power grid operation, such as EMS (Energy Management System, which is function related to generator operation, including automatic control) and state estimation.

The configuration of new NCC system is considered to be based on the current system configuration, which corresponds to a general standard.

- NCC and BNCC has own servers each other, while three RCCs do not have servers and will be linked to the NCC and BNCC servers via workstations.
- Each system has a duplicated configuration to ensure that it remains functional in the event of the failure of one component.
- NCC has servers realising the three modes (environment) as Normal, Test/Maintenance and Training. BNCC has servers realising the Normal mode (environment).

- The number of screens and consoles is shown in the table of the figure.
  The number of consoles in the NCCs is currently three, but will be increased to five in view of the increasing workload trend.

•

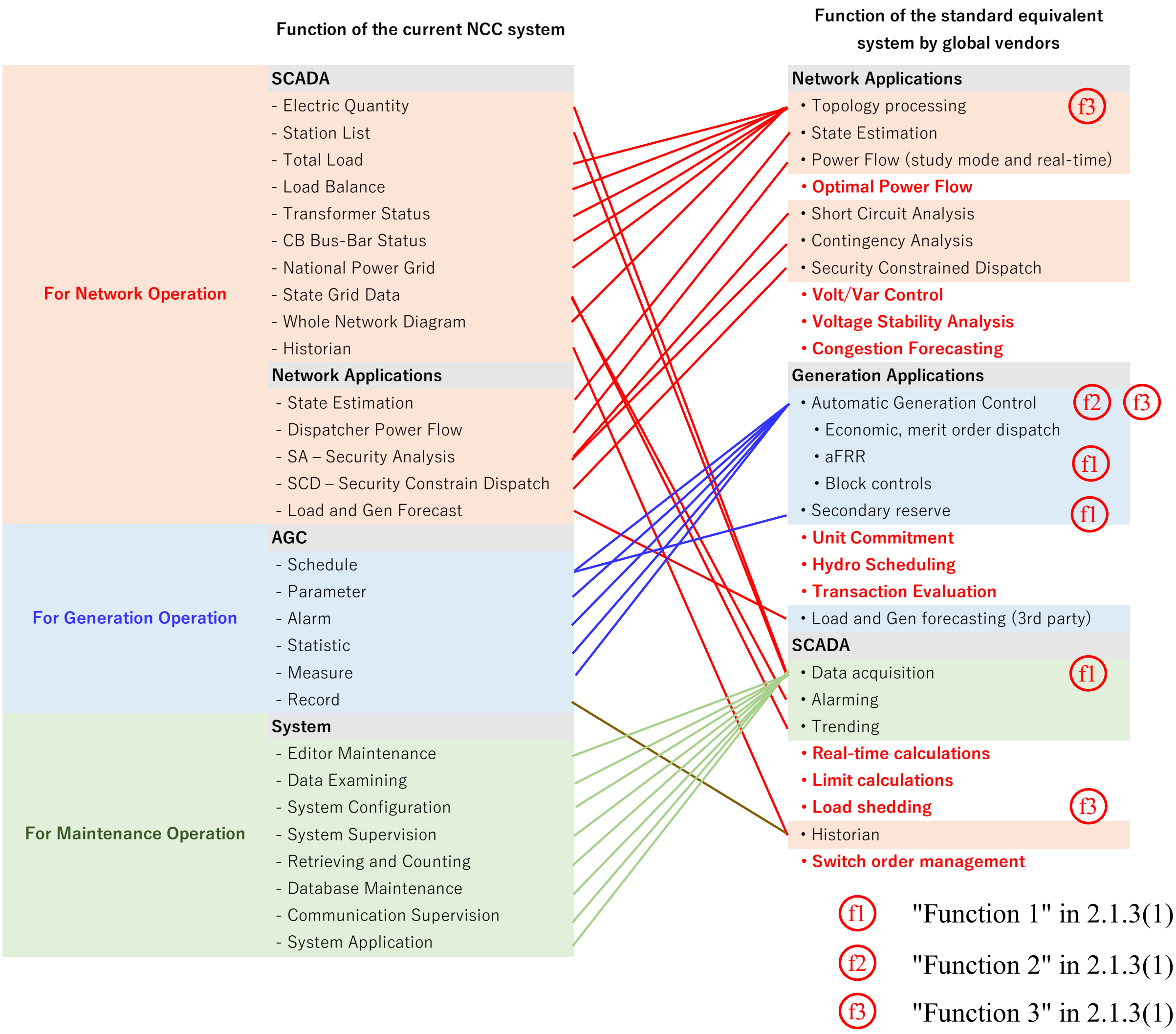
(2) Function

(a) Comparison of the functionality of the current NCC system and standard products.

A comparison of functionality between the current NCC system and foreign vendors' standard products is presented below. To show the broadly classified, the following three colour-coded categories are used.

- SCADA function including state estimation Red
- EMS function Blue
- Maintenance function Green

It can be seen that the foreign vendors' products related to SCADA/EMS contains the standard functionality of the current NCC system, plus possesses many additional functions shown in bold red.



Note: f1 to f3 are the minimum functions required to achieve load frequency control; they are not the minimum functions required to implement an NCC system.

(Source: Prepared by the JICA Study Team)

Figure 3-3 Comparison of functions of the current NCC system and foreign vendors' standard products

(b) Functions required for the updated NCC system.

The functionality of the updated NCC system is under consideration in the following directions

- ➢ The functions of the current NCC system, such as SCADA (including state estimation), EMS, etc., will be maintained.
- ➢ Some additional functions will be selected and implemented, but the specific selection will be decided in consultation with EDL, taking into account budget constraints, etc.

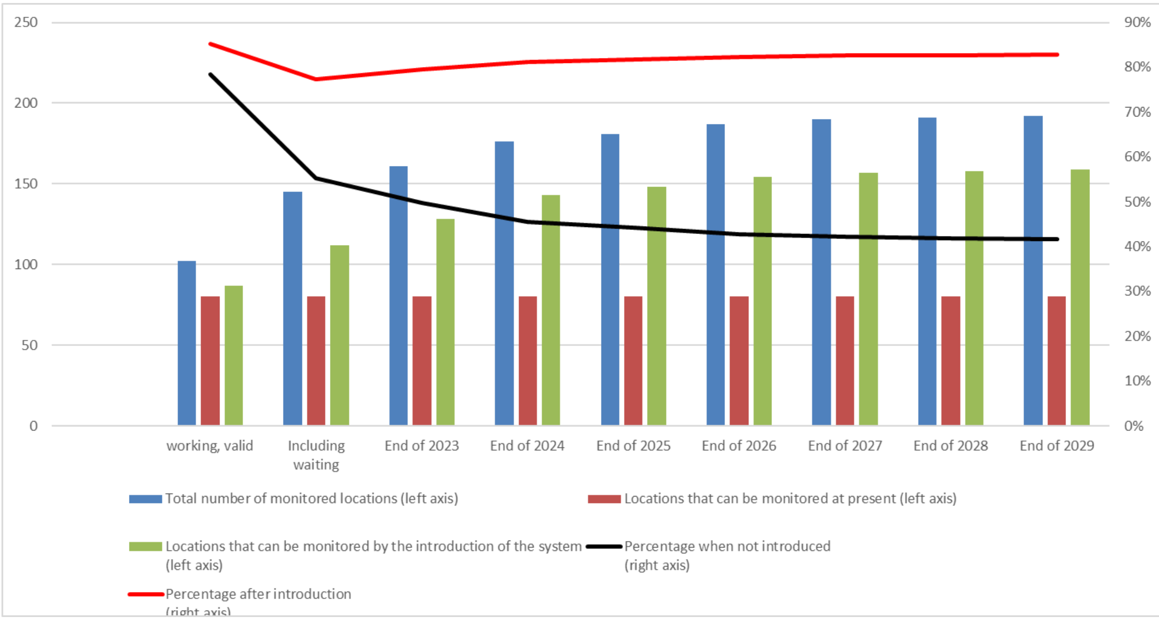
(c) Assumed number and percentage of sites that can be monitored.

The assumed number and percentage of sites that will be able to be monitored as a result of the updated NCC system are shown below.

Table 3-2 Assumed number and percentage of sites that can be monitored

(Source: Prepared by the JICA Study Team)

	At present		In the future						
	working, valid	Including waiting	End of 2023	End of 2024	End of 2025	End of 2026	End of 2027	End of 2028	End of 2029
Total number of monitored locations (left axis)	102	145	161	176	181	187	190	191	192
Locations that can be monitored at present (left axis)	80	80	80	80	80	80	80	80	80
Locations that can be monitored by the introduction of the system (left axis)	87	112	128	143	148	154	157	158	159
Percentage when not introduced (right axis)	78.4%	55.2%	49.7%	45.5%	44.2%	42.8%	42.1%	41.9%	41.7%
Percentage after introduction (right axis)	85.3%	77.2%	79.5%	81.3%	81.8%	82.4%	82.6%	82.7%	82.8%



(Source: Prepared by the JICA Study Team)

Figure 3-4 Assumed number and percentage of sites that can be monitored

Figure 3-4 shows the number of locations that can be monitored after the NCC system is updated and the problem is resolved. The following three types of locations that can be monitored by updating the NCC system are included:

(1) Locations that were once monitored by the current NCC system, but can no longer be monitored due to problems with the NCC system.

(2) Newly installed power plants and substations that have already commenced operation but are on standby for monitoring because the NCC system is unable to acquire information due to constraint of the number of positions.

(3) Power plants and substations that will be put into operation between now and the time when the NCC system replacement is completed, and that will be on standby for monitoring in the future.

The above locations (1) to (3) are assumed to be in compliance with IEC60870-5-104, and all of them will be able to be connected and monitored when the NCC system is replaced. Although there are some negative views on whether all of the above locations will actually be able to be connected and monitored, JICA Study Team assumes that all of them will be able to be monitored at this time, based on the views of manufacturers with extensive experience in the field.

JICA Study Team also assumed that the monitoring of sites that currently cannot be monitored due to problems on the site side will not be improved even after the NCC system is updated. This assumption is the reason why the percentage of sites that can be monitored after the renewal of the NCC system has not reached 100%.

(d) Information on the current NCC system failures.

The following is the current NCC system's track record for failures:

Table 3-3 Track Record for the current NCC system failures

Year	Times	Duration	Equipment
2020	1	17,520 (2 years)	Recording HD down
2021	2	48h、4h	NCC system down (including backup) Servers 1 and 2 down
2022	3	1h、3h、48h	GPS down HD down Servers 1 and 2 down
2023	3	0.5h、0.33h、0.17h	Servers down HD down System error (error misdetection)

3.2.2 Suggestions for improvements of information security

The current status of information security related to the introduction of the NCC system is as described in Chapter 2 (2.2.2 (1) (e)), but there are many issues that need to be addressed and improved in the future.

EDL has two networks, one for office processing and the other for control, and the NCC system is one of the systems connected to the control network, which requires higher security. The "General items for the EDL for the information security”, below pertains to both the office processing system and the control system network, while the "Contents on the NCC system update” pertains to the control system network.

The terms "information security" and "information system," which are also used in the title of this item, are used as terms that cover both the office processing system and the control system network. The NCC system is connected to the control system network using dedicated facilities owned by EDL, and it is recognized that certain measures for reduction of cyber security risk have been taken based on the management and operation of the system. On the other hand, it is considered necessary to develop security policies, guidelines, and systems as a corporate entity.

- General items for the EDL for the information security
  - EDL's policy development
    - Developing an information systems strategy
    - Establishing an information security management system
    - Management policies, rules and manuals about information and system security and information handling
    - Development of BCP plans (business continuity plans)
    - Development of contingency plans (Contingency Plan)
  - EDL's organisational structure
    - Involvement of management, clarification of responsibilities
    - Securing relevant organisations and personnel
    - Preparing emergency response team available 24 hours a day
    - Establishing IT governance
    - Setting up an incident response organisation
    - Establishment of the Cyber Security Task Force

- Contents on the NCC system update
  - Deploy security products that comply with international standards. Examples of standards are given below.
    - ISO/IEC27000 series (in particular, ISO/IEC27001): a set of information security standards
    - IEC62443: standard covering industrial automation and control equipment and development processes
    - IEC62351: standard developed to process the security of the TC 57 series of protocols, including authentication of data transmission by digital signature, anti-eavesdropping and intrusion detection.
  - Appropriate maintenance agreements with manufacturers
    When the NCC system update, warranty and maintenance service will be contracted. At that time, it is important to include the appropriate contents such as the manufacturer's maintenance system, expected response time and response details in case of problems, software updates, anti-virus content and updates, and cyber security measures, and to confirm the details. Specifically, it is recommended to conclude a Service Level Agreement (SLA) that describes the content, including the quality levels mentioned above.

- Development of incident response plans
  It is also necessary to prepare for incident response plan related to the NCC system although it is an element of the BCP and contingency plan. Specifically, this includes criteria related to the switchover of control rights to the BNCC in the event of loss of NCC functionality, as well as plans for periodic training exercises.
- Update, maintenance etc.
  From the perspective of maintaining the quality of the NCC system, it is also considered a necessary response to regularly check updated and additional functions, availability, operability and maintainability.
- Trainings
  Ongoing regular (and, in some cases, unannounsed) trainings to ensure that NCC operators, the EDL's cyber security team and relevant staff on the front line of incident response are able to respond effectively and quickly, in accordance with advance plans and written countermeasures.
- Education and enlightenment
  Ongoing employee education and enlightenment including access control, response to malware detection, etc. with new information and countermeasures added as appropriate.
- Support for future external network connections
  At present, facilities are built on dedicated networks that are completely cut off from external networks, but it is assumed that in the future, when the use of advanced functions based on a variety of information becomes a priority (e.g. obtaining detailed weather information for renewable energy output forecasts, or automating the work of promptly reporting information on grid accidents and power outages to the relevant ministries and agencies and publicising such information to the general public), it will become necessary to connect to external networks via firewalls.
  At such a stage, while convenience will improve, cyber security risks will increase, and it will be necessary in the future to develop standards, criteria and specifications for equipment that take such aspects into account.

3.2.3 Study of the possibilities of using digital technologies

The updating of NCC systems is also considered to be an opportunity for the future use of digital technology, but there is a significant gap with the current situation before reaching the level of so-called DX operations, which requires steady steps to be taken. This section describes the sequence and methods of these steps and includes examples of utilisation that are candidates for future application.

- ■ Step1 Improving the quality of work by introducing software into the supply and demand operational planning work of EDL NCC day shift workers
  - Assumed year The year 2024 to 2027
  - Implementation

Among the grid operation tasks in the NCC, a particularly important task is to maintain the balance between supply and demand of electricity and to maintain frequency quality. Therefore, as the first task to be addressed, the improvement of supply and demand operation planning work is envisaged and described.

Currently, data management and analysis of demand assumptions and generation plans is carried out using spreadsheet software, and is based on simple addition and subtraction, with NCC staff manually inputting information and numerical data obtained from power station and substation staff. Therefore, in order to improve the quality of supply and demand operational planning, it is desirable to introduce software for supply and demand analysis. In addition, as it is desirable to use highly reliable information and numerical data to be input into this software, it may be effective to centralise the database and create an environment where relevant parties can access it to input and amend information and numerical data.

Furthermore, the format of this information and database and the supply-demand analysis software should be developed with a view to compatibility with the software and other functions to be implemented in the new NCC system to be introduced in step 2.

- Step2 On-line information gathering to be obtained from power stations and substations.
  - Assumed year The year 2027 to 2030
  - Implementaion

    The NCC system upgrade, currently envisaged for the second half of 2027, will significantly increase the amount of information obtained from power stations and substations. The current assumption is that the ratio will increase from 42% to 83% shown at Table 3-2, with the aim of achieving 100% by continuing EDL's own efforts. This increased ratio will enable state estimation and an accurate picture of the operational status of the power grid at each time of day (e.g. every minute). This enables appropriate and rapid simulation (grid analysis) of grid issues and facilitates the consideration of reasonable countermeasures. For example, by using accurate data to simulate and study countermeasures for grid issues such as overloads, voltage drops and stability, cases where excessive operational limits have been set to be on the safe side (e.g. cases where generators have been tripped or output limits have been imposed beyond the required amount to maintain stability) can be relaxed.

    Furthermore, the demand and generation data currently collected by EDLs and NCCs is likely to be unreliable, as a low proportion of the data is automatically collected by SCADA and other means, and most of it is based on telephone interviews.

    The updated NCC system will enable highly accurate demand forecasting through the automatic collection of data. In addition, by ensuring appropriate reserve and regulating capacity and improving conditions to cope with supply and demand fluctuations, it will be possible to adjust the imbalance between electricity supply and demand in Laos, including planning errors in power exchange via international connection lines, to within the expected level, even if only roughly.

Although equipping the NCC system with functions such as demand forecasting and solar output forecasting is considered effective for the stable supply of electricity in Laos in the future, the first priority is to acquire and maintain data on the ground, including the acquisition and accumulation of real-time demand and weather data, and statistical analysis of the correlation between electricity demand and other factors.

- Step3 Introduction of necessary equipment at power stations and substations to be controlled online
  - Assumed year The year 2030 to 2035
  - Implementation

    The next step, after the NCC system has been able to acquire sufficient information and make appropriate decisions in step 2, is to prepare facilities that can respond to controls and instructions from the NCC. For example, gradually increasing the number of AGC-compliant generators from 2027 is one such measure, but there is also a need to increase the number of generators that can respond to economic dispatch control (EDC), and to install reactive-power-regulating equipment such as power capacitors, shunt reactors and SVCs at substations for voltage adjustment in the power system. The installation of control signal receiving terminal facilities necessary for remote control of these equipment, etc., is also effective. As the equipment needs to be developed in a rational manner, taking into account the characteristics of the power system as a whole, the soundness of information acquisition in the power grid in Step 2 needs to be addressed continuously after 2030, depending on changes in the power grid.

- Step4 Initial stages of digital data utilisation
  - Assumed year The year 2035 to 2037
  - Implementation

    The steps 2 and 3 will enable effective control based on studies from system analysis (simulation) in many operations. As a current proposal, the following digital data utilisation case study could be introduced.
    - Online optimal control of voltage and reactive power as an additional function to the NCC system
    - Electricity demand forecasting and renewable energy output forecasting and automatic supply-demand control using the results
    - Automatic restoration of the power system (or support functions) in the event of an accident using AI
    - Automating of information transmission (public relations response, response to government agency reports) in the event of an accident

- Step5 Significant improvement in operational quality through DX
  - Assumed year The year 2037 to 2040
  - Implementation

    Based on the verification of the effects of the introduction of the above-mentioned digital data use cases, and based on the introduction of further improvement measures, a company-wide effort will be made to promote a significant reduction in manpower and higher efficiency that will transform the existing organisation, personnel and work methods.

3.3 Technical Support to build capacity of realisation of the roadmap for improving dispatch operations

In the 2nd and 3rd Step of the functional equipment schedule shown in 3.1.3(2), the following technical support can be considered in realising the remaining part of the monitoring and control functions as local potions not realised in the 1st Step:

1) Technical support for evaluation of generator governor-free operation and AGC testing.

2) Technical support for capacity building of grid operation for NCC staffs and shift operators

3) Technical support for RTU and NCC maintenance and management staffs to improve their operational capacity.

Possible outcomes of the technical assistance include;

Outcome 1: The NCC system database can be updated in advance of the COD of new power stations and substations to keep the monitoring and control functions up-to-date.

Outcome 2: Demand and supply balance planning and real-time power flow control of international connection lines to the planned values are achieved.

Outcome 3: Testing for AGC implementation can be carried out.

3.4 Alternatives in the event of difficulties in realising NCC system replacement

If NCC system replacement is difficult to realise, the following alternative support measures can be considered:

(1) Installation of reactive power control equipment to improve the voltage control reserve capacity of the power grid

(Summary)

The Lao EDL power grid basically lacks reactive power control equipment in the direction of voltage reduction specially, and the voltage tends to remain higher than the upper limit of voltage rise; nominal voltage +5%. Therefore, even during the heavy power flow period in the rainy season, there are some areas where generators are operated under zero or leading state of their power factors in order to eliminate the reactive power surplus in the power system.

Currently, as a measure to prevent voltage rises and avoid leading-power-factor operation of generators, one of the two circuits transmission lines is de-energized even during the rainy season (heavy power flow period) to increase reactive power consumption and lower the voltage, but there are concerns that this may reduce the reliability of the electricity supply.

It is therefore appropriate to install equipment for voltage and reactive power regulation, such as shunt reactors, SVCs and synchronous capacitors, on the bus bars of substations to improve the system voltage regulation capability.

(Draft operational effectiveness indicators)

- Reduction in the number of hours or frequency of annual deviations of the bus bar voltages from nominal voltage ± 5% of the 115 kV power system
- Reduction in the annual duration of leading-power-factor operation of generators

(2) Replacement of 115 kV transmission line protection relay equipment from distance relay system to current differential relay system

(Summary)

The main protection relay system for transmission lines in the Lao EDL is mostly a distance relay system for 115 kV transmission lines, although the current differential system is used for 230 kV and above transmission lines. (The current Lao Grid Code also stipulates the adoption of the distance relay system as standard.)

The distance relay system requires careful coordination between relay devices in terms of the set point values for the range (reach) at which the relay device detects the fault location and the timing (timer) at which the faulty transmission line is to be tripped. If these set point values are not co-ordinated properly, relays that should not operate will open the circuit breaker, that causes unnecessary extending of the outage area.

In recent years, there have been cases, mainly in the Vientiane Capital region, where new substations have been built at the middle point of transmission lines to catch up with electricity demand increase, in which case the reach and timer setpoint values of distance relays need to be reviewed, but this tends to be neglected.

In addition, the distances between substations are becoming closer and the lengths of transmission lines tend to be shorter, and in such cases it is generally more difficult to co-ordinate setpoints between distance relays.

Therefore, it is proposed to replace the distance relay type protection equipment of the 115 kV transmission line in Vientiane Capital region with a current differential relay type at an early stage.

(Draft operational effectiveness indicator)

Reduction in the number of annual power outages

Chapter 4 Recommendation of priority implementation projects

4.1 Overview of NCC system upgrading project

Based on the results of the survey, priority implementation projects will be proposed in the next section. Please note that this priority implementation project is carried out by the study team from a technical perspective, and does not imply a proposal for cooperation or a promise of implementation by the Japanese government or JICA.

4.1.1 Draft of Grant aid Project

The current EDL’s NCC system that has been investigated has aging equipment and a noticeable lack of performance, so it is necessary to upgrade the NCC system as soon as possible. EDL's ICT Department has stated that the communication servers are too old and could fail and stop working.

Given this situation, the NCC system will be considered to upgrade as soon as possible. Since there are many connections and some sites have problems on the power plant/substation side, connections to power plants and substations will be prioritized and dealt with.

Data connections will be possible for existing RTUs that cannot connect to data by updating the NCC and repairing the RTUs using EDL. For the future, we will design an NCC system with system capacity that considers the increase in substations and power plants due to demand growth. Regarding connection settings for new power plants and substations built in the future, EDL will perform additional settings for the NCC system. It is also necessary to consider whether manufacturer training (additional setting work for newly constructed power generation and substations) is necessary so that EDL personnel can perform the connection work.

4.1.2 Draft equipment specifications for updating the NCC System

In order to understand the scale of the NCC system upgrading project, the basic specifications for NCC system upgrading equipment will be established.

Equipment specifications will be examined taking into consideration the current NCC equipment specifications and the functions required to realize the roadmap. Additionally, future plans up to 2040 will be considered in determining the system connectable capacity.

(a) Functions of NCC system

The functions of the existing NCC power supply system are as follows. The existing system uses only the SCADA function, but it also has a function that allows LFC operation as a grid operation system, but data settings have not yet been implemented. The NCC upgrading system will also have functions that enable LFC implementation. Since these functions will be operated and maintained by EDL staff, manufacturer training will be included in the scope.

The EDL System Planning and Operations Director requested that VRE output prediction application functionality be added as there are plans to connect many PVs to the grid after 2025.

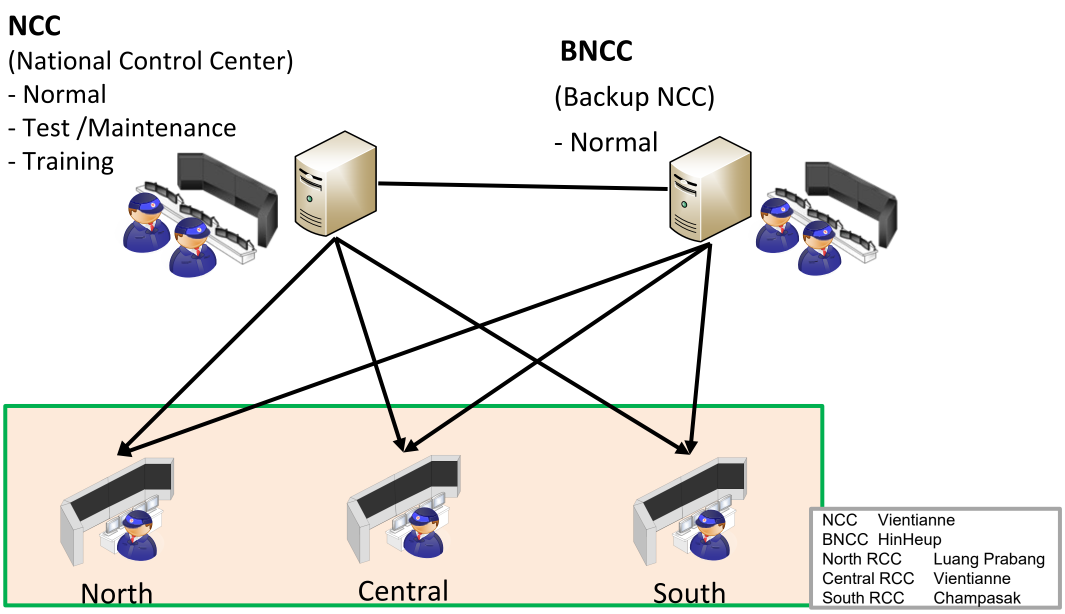
Table 4-1 List of NCC upgrading system functions

Item	SCADA	AGC	Network Application	System
Function	- Electric Quantity - Station List - Total Load - Load Balance - Transformer Status - CB Bus-Bar Status - National Power Grid - State Grid Data -Whole Network Diagram - Historian	- Schedule - Parameter - Alarm - Statistic - Measure - Record	- State Estimation - Dispatcher Power Flow - SA: Security Analysis -SCD: Security Constrain Dispatch - Load and Gen Forecast - Variable Renewable Energy Outputs Forecast	-Editor Maintenance - Data Examining -System Configuration -System Supervision -Retrieving and Counting -Database Maintenance -Communication Supervision -System Application

(Source: JICA study team)

(b) Layers and environments

The specifications of the NCC power supply system are as follows. The main system has three layers: Normal, Test/Maintenance, and Training. The backup power supply station has a Normal layer.
One large monitor will be installed at each power supply station. The NCC will have five workstations, and each RCC will have two workstations.
Although the EDL System Planning and Operation Bureau commented that installing BNCC is a low priority, the study team recommends that BNCC is necessary to ensure redundancy and maintain the reliability of the NCC system.



(Source: Prepared by the JICA Study Team)

Figure 4-1 Configuration diagram of the entire NCC system (Source: the study team)

(c) Warranty period and maintenance contract

The project includes a sufficient warranty period and maintenance contract to ensure that EDL can continue to use the system throughout its technical life.

(d) Location of NCC system server

The NCC main system server will be installed in the server room on the 9th floor of the EDL headquarters.

(e) Other incidental equipment

The scope of the project includes the following components necessary to maintain the functionality of the NCC system.

・UPS (including battery)
・Air conditioning equipment
・Additional communication interface required for NCC system update
*EDL will be responsible for laying power lines within the building premises.

4.1.3 Security measures when using existing RTU

The existing RTUs comply with international standards, and the communication lines are dedicated. However, existing RTUs may not comply with the latest international security standards because they had been installed before setting the standards. Early replacement is recommended for RTUs that do not comply with the latest international standards.

4.1.4 Evaluation of environmental and social considerations

The NCC power supply system renewal project, a candidate project for grant aid, is related to the power transmission, transformation, and distribution sectors listed in JICA's environmental and social consideration guidelines (version January 2022). Because the project's construction work is within the EDL headquarters, it is considered a project that corresponds to a "cooperative project that is expected to have minimal or almost no undesirable impact on the environment or society." Therefore, it corresponds to a "Category C" project in JICA's environmental and social consideration guidelines.

4.1.5 Priority order of substation/power plant connection confirmation

Prioritizing the confirmation of connections and control functions is to connect the points necessary for TBC control, which is positioned as the goal of the Road Map, such as power plants connected to the domestic grid necessary for AGC and international interconnection lines with EGAT. Priority will be given to substations. Next, if there are no problems with the communication equipment on the power plant/substation side and the NCC side is ready, connections will be made in sequence at the points that can be connected.

Specifically, based on the intentions of the EDL System Planning and Operation Bureau, we are considering connecting the following power generation and substations with top priority. Many of these priority connection candidate sites use equipment manufactured by NARI Technology Co., Ltd. for their RTUs, etc.

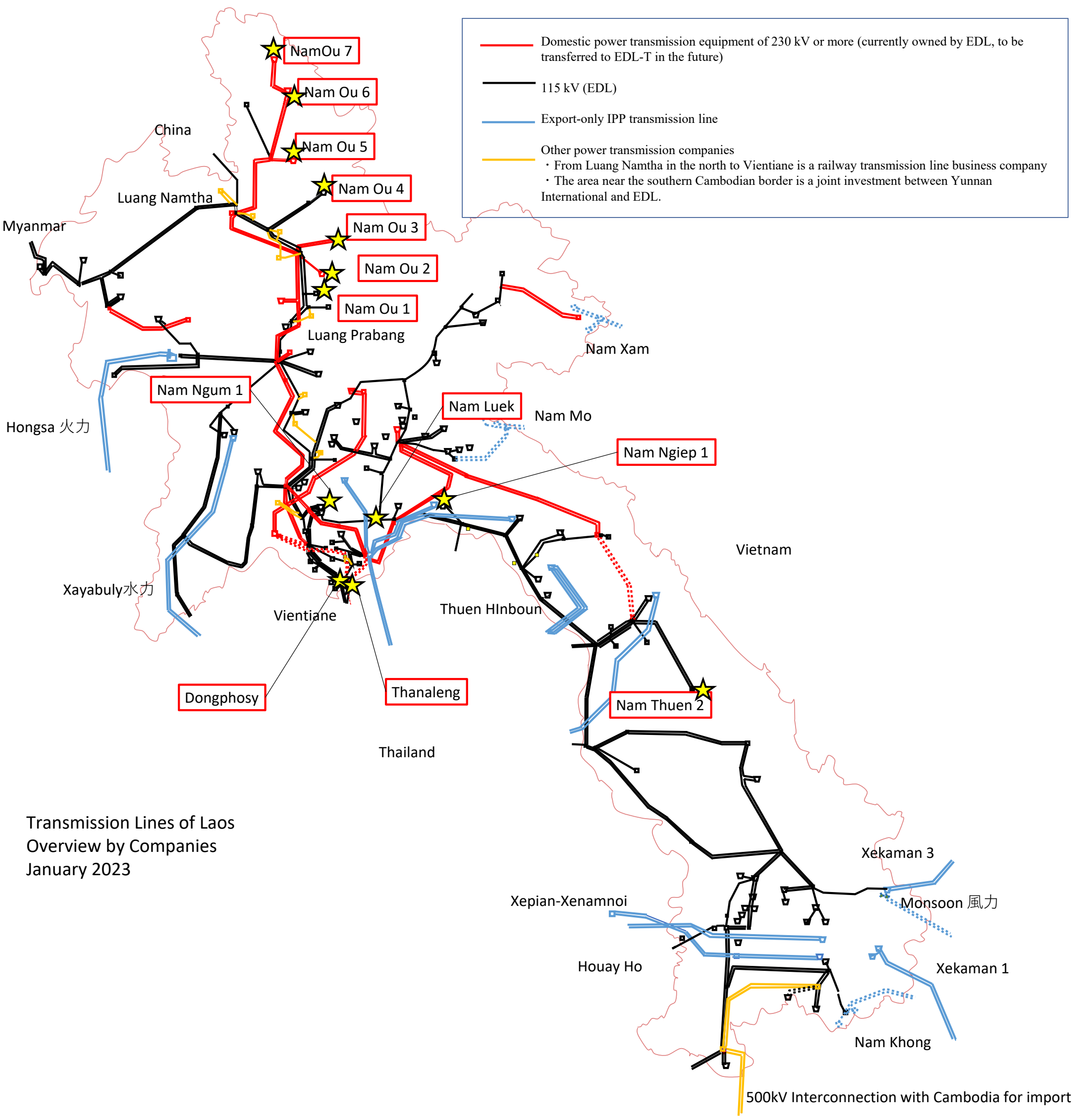
Therefore, in the future, it will be necessary to conduct tests to see if connectivity is possible and consider connection methods, including replacing RTUs where connections are not possible.

(1) Power Plants

- Nam Ngum 1 (1-6Units) (115kV 155MW)
- Nam Leuk (115kV 60MW)
- Nam Ngiep 1 Domestic (115kV 17.8MW)
- Nam Thuen 2 Domestic (230kV 70MW)
- Nam Ou 1-7 (230kV,115kV 1272MW)

(2) Substations

- Dongphosy (115kV)
- Thanaleng (115kV)



(Source: Prepared by the JICA Study Team)

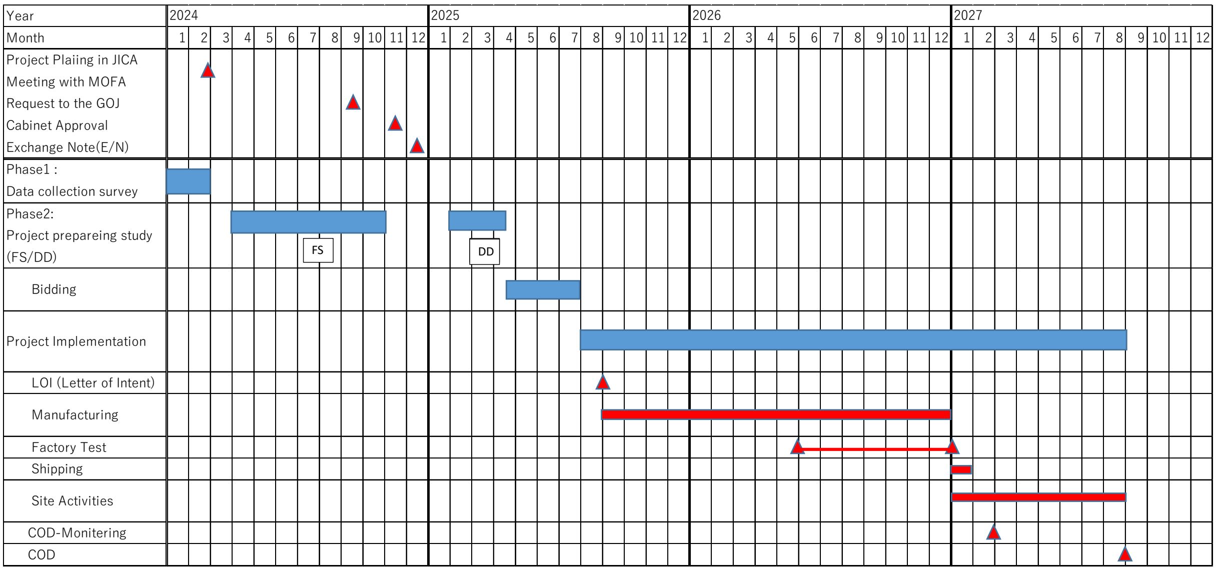
Figure 4-2 Priority Power Plants and Substations

4.2 Tentative NCC System Upgrading Schedule

4.2.1 NCC System Upgrading Schedule

The process was created based on the standard free project procedure period and the manufacturer's standard manufacturing/installation adjustment schedule. According to this, monitoring will begin in April 2027, and the updated power supply system will begin operation in August 2027.

Assuming that the ICT Bureau may only have the equipment once the survey team starts operations in August 2027, EDL's ICT Bureau will carry out emergency measures from January to June 2023 to deal with aging communications servers. As a result, a temporary backup system will be constructed.



(Source: Prepared by the JICA Study Team)

Figure 4-3 Tentative NCC System Upgrading Schedule

4.3 Estimated Project Budget

4.3.1 Cost Estimation Policy

(1) Estimation conditions/methods

・Estimates will be carried out in accordance with the JICA Grant Aid Design and Cost Estimation Manual.

・Project type: Equipment Procurement (single) project.

(2) Disclaimer

EDL, the implementing agency, will oversee the overall implementation of the following projects.

- Taxes related to the project: In principle, tax-exempt

Confirm the government agency, department, and position responsible for the following items.

Check the documents and materials required for various applications, confirm the deadline for application, the process, and the time required until the application is approved.

〇 Business tax: Business income from projects for consultants and contractors engaged in the project is exempt from taxation in Lao PDR.

〇 Income tax: The income of Japanese and third-country employees of consultants and contractors engaged in the project is exempted from taxation in Laos.

〇 Excise tax (consumption tax): Lao PDR consumption tax (excise tax) on items purchased in Laos related to the project (construction materials, equipment, fuel, etc.) will be exempted (refundable upon submission of receipts and required documents). However, if the goods purchased for the project are sold within Laos, consumption tax will be imposed retroactively, and the sales amount will also be taxed.

〇 Customs duty (other): Goods imported into Laos from outside Laos in connection with the project will be exempt from customs duties. Expenses such as bonded warehouse storage fees and related public fees will be exempted. However, if the imported goods are sold within Laos, customs duties will be imposed retroactively, and the sales amount will also be taxed.

4.3.2 Estimation of rough project budget

(1) Project Estimated Budget

The budget for the NCC power supply system renewal project based on the specifications in the previous section is based on a rough estimate based on interviews with manufacturers, including equipment costs (equipment costs, transportation costs, installation adjustment costs, purchase management costs, OM costs) and design management costs. Including this, it is expected to be around 4 billion yen. This amount includes the cost of the NCC main system, backup system, and three RCC workstations. The RTU replacement cost on the slave station side is not included.

It is necessary to carefully examine the status of RTUs at power plants and substations, which are important for LFC control, and to consider replacing the RTUs depending on the status of these RTUs.

Additionally, EDL requested updates to the UPS, batteries, and communication interface cards, but these are not included in the above estimated costs and will need to be considered in the future.

(2) Discussion on EDL burden

Connection of communication equipment to power plants and substation RTUs, replacement of RTUs that do not meet EDL specifications, wiring of communication lines within EDL premises, connection of RTUs to power plant and substation control systems, and control systems It is assumed that the repair costs will be borne by EDL.

4.4 Examination of effects of project implementation

4.4.1 Project effectiveness confirmation indicators

As the investigation revealed, EDL is not properly collecting current operational data and accident record data. For this reason, it is difficult to select indicators that measure the qualitative effects of improving system reliability.

The following items for which numerical data indicating power system quality exist will be considered as effectiveness indicators. The actual values are as follows.

- Percentage of power generation/substations that can be monitored (%):
  80 locations that can be monitored/total of 145 locations to be monitored ≒ 55.2%
  (Refer to Chapter 2 for details on actual values)
- Annual power outage time for 230kV or higher grids:
  1,140 minutes/year in 2022, 2,955 minutes/year in 2023
  (Refer to Chapter 2 for details on actual values)
- Frequency stay time rate within standard value

4.4.2 Qualitative effects

(1) Increase in the number of monitorable sites

With the current NCC system, 45% of the power plants and substations connected to the grid cannot be monitored. By updating the NCC system to enable the use of these functions, it is expected that it will be possible to grasp the status of power plants and substations that are not connected, and it will be possible to understand the system status accurately.

(2) Improving the time (hours/year) until 230kV transmission line accident discovery

Currently, there are no records of relay operations at the time of the accident, so it is not possible to confirm the time until the accident was discovered. Therefore, although the current situation cannot be confirmed quantitatively, it is expected that increasing the number of monitoring points will shorten the time it takes to discover an accident

(3) Enabling AGC function

The current NCC system also does not perform load frequency control (LFC) of generators connected to the grid. Although we confirmed the presence of governor controllers and PSS at some of the power plants we visited, they are not used for frequency adjustment or maintaining synchronization stability.

By updating the NCC system and making these functions available to power plants, it is expected that operations that maintain system quality (frequency and synchronization stability), which have not been possible before, will become possible.

(4) Improving large-scale power outage recovery time by reducing NCC system failure frequency

In the event of a large-scale power outage, if the NCC system cannot be used, it will take time to understand the current situation, and recovery will take time.

Looking at the operating status of the EDL system described in Chapter 2, system outages occur several times a year due to failures, such as the data server being out of service for a long period of about two years. By updating the NCC system, it is expected to improve the reliability of the NCC system and shorten the recovery time from large-scale power outages.

(5) Improving domestic power quality and stabilizing power supply in Laos

Suppose the reliability of the system is improved through NCC system updates. In that case, it will be possible to accumulate primary data for drawing up supply and demand operation plans, and by analyzing this data, it will be possible to make highly accurate power forecasts. By formulating and implementing a supply and demand operation plan based on highly accurate power forecasts, the power quality in Laos is expected to improve, and the power supply will become more stable.

(6) Promote power interchange with neighboring countries, expand clean energy exports, and effectively utilize surplus power

The supply and demand balance prediction will be improved by formulating a highly accurate supply and demand operation plan. In addition, it will be possible to grasp the surplus power generation from these clean energies accurately by utilizing the output prediction function of hydropower, PV, and wind power generation, which we are considering incorporating into the NCC system.

Based on the prediction of surplus output, it will be possible to formulate plans for exporting electricity to neighboring countries. Supply and demand operations based on this plan will be implemented, and clean energy exports to neighboring countries can be expected to expand.

Chapter 5 Proposed measures to improve Laos power system operation

5.1 Formulation of a roadmap for improving Laos system operation capacity

A roadmap has been compiled with measures to ensure that Lao PDR's abundant hydropower generation capacity is effectively utilized in the Indochina region and benefits Lao PDR appropriately. At the same time, we have compiled proposed measures to realize the roadmap.

5.1.1 Overview of Laos power system operation improvement road map

(1) Goals and Stages for improving system operation

The goal is for EDL to be able to control the power flow in the interconnection line with Thailand's EGAT by around 2040 by improving the ability to adjust the frequency of the Laos grid in three stages.

The following three stages have been set as the stages to be achieved before achieving the goal.

- Stage 1: Control of electricity export amount by power supply command (until 2027)
- Stage 2: Automatic constant control of electricity import and export using NCC system (until 2040)
- Stage 3: Zero power supply and demand error control in Laos using the NCC system (from 2040)

(2) Requirements necessary for realizing LFC control

In order to implement LFC control and realize TBC control on the interconnection line with EGAT, two requirements are necessary: equipment and operational capacity.

- Equipment Aspect:
  A power supply system that can monitor and control power generation and substations, and a generator with an AGC function that can be operated according to LFC control signals that satisfy the necessary operational reserves.

- Operational Aspect:
  Develop a manual for the supply and demand operations currently being carried out. As a result, a supply and demand plan is formulated with appropriate basis, and the plan is implemented and recorded based on the power supply order.
  A supply and demand adjustment work manual will be prepared before LFC control becomes possible due to the NCC system update. In parallel, it is necessary to compile AGC functional test guidelines and disseminate them to target IPP operators.

5.2 Proposal of support measures for improving Laos grid operation

5.2.1 Proposal of High-Priority Project

Currently, it is impossible to monitor 45% of the generators and main substations connected to the grid, and they are so deteriorated that they could shut down at any time. Upgrading the NCC system is a highly urgent and high-priority project.

5.2.2 Technical support for improving EDL system operation capacity

The manufacturer will provide training on how to use and maintain the new NCC system, which will be included in the scope of the NCC system update project.

On the other hand, regarding the improvement of NCC operational capabilities mentioned earlier, many items related to data management and planning consideration are performed as preparations before using the functions of the NCC system. In addition, regarding the implementation of LFC control, it also includes items unrelated to the NCC system, such as confirmation tests and operation methods for the generator function that has the AGC function that executes control and the necessity of contractual compliance. For this reason, it is appropriate to implement technical support related to improving operational capabilities in a separate project from the NCC system equipment procurement.

[Equipment]	
NCC system update	2025 – 2027
LFC control implementation	2027 -
[Operation]	
Improving supply/demand management capabilities	2025 – 2027
Improving LFC control implementation capabilities	2026 - 2030

In the 2nd and 3rd Step of the functional equipment schedule shown in 3.1.3(2), the following technical support can be considered in realising the remaining part of the monitoring and control functions as local potions not realised in the 1st Step:

1) Technical support for evaluation of generator governor-free operation and AGC testing.
2) Technical support for capacity building of grid operation for NCC staffs and shift operators
3) Technical support for RTU and NCC maintenance and management staffs to improve their operational capacity.

Possible outcomes of the technical assistance include;

Outcome 1: The NCC system database can be updated in advance of the COD of new power stations and substations to keep the monitoring and control functions up-to-date.

Outcome 2: Demand and supply balance planning and real-time power flow control of international connection lines to the planned values are achieved.

Outcome 3: Testing for AGC implementation can be carried out.