Lao People's Democratic Republic
Ministry of Energy and Mines
Électricité du Laos

Project for Power Quality Improvement through Upgrading Grid Code and Strengthening Its Enforcement System in Lao People's Democratic Republic

Project Completion Report

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Japan International Cooperation Agency (JICA)
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Abbreviations

Abbreviation	Full Name
AC	Alternating Current
ADB	Asian Development Bank
AER	Authority of Electricity Regulation
AGC	Automatic Generation Control
ASEAN	Association of Southeast Asian Nations
BESS	Battery Energy Storage System
BOT	Build-Operate-Transfer
BTB	Back-to-Back
CA	Concession Agreement
CO	Company
COD	Commercial Operation Date
COVID	Coronavirus Disease
CSG	China Southern Power Grid
CT	Current Transformer
DEB	Department of Energy Business
DEEP	Department of Energy Efficiency and Promotion
DEISM	Department of Energy Industry Safety Management
DEM	Department of Energy Management
DEPP	Department of Energy Policy and Planning
DERM	Department of Electricity Regulation and Monitoring
DGM	Deputy General Manager
DMH	Department of Meteorology and Hydrology
DMM	Department of Mining Management
DMS	Distribution Management System
DOI	Department of Industry
DOP	Department of Planning
DPC	Department of Planning and Cooperation
DPC	Department of Planned Cooperation
DSM	Demand Side Management
EAC	Electricity Authority of Cambodia
EDL	Électricité du Laos
EESD	Energy Efficiency and Sustainable Development
EGAT	Electricity Generating Authority of Thailand
EHV	Extra High Voltage
EMS	Energy Management System
EPPO	Energy Policy and Planning Office
ERA	Electricity Regulatory Authority
ERAL	Electricity Regulatory Authority of Laos
ERAV	Electricity Regulatory Authority of Vietnam
ERC	Electricity Regulatory Commission
EU	European Union
EVN	Electricity of Vietnam
FFC	Flat Frequency Control
FL	Fault Locator

FRT	Fault Ride Through
FS	Feasibility Study
FTC	Flat Tie-line power flow Control
GE	General Electric
GF	Governor-Free (operation)
GMC	Grid Code Management Committee
GMS	Greater Mekong Subregion
GSM	Global System for Mobile Communications
GTGOA	Grid-to-Grid Operational Agreement
GW	Gigawatt
HOYA	Hoya Corporation
HUAWEI	Huawei Technologies Co., Ltd.
HV	High Voltage
HVDC	High Voltage Direct Current
IE	Institute of Energy
IPP	Independent Power Producer
IPS	Integrated Power System
IRENA	International Renewable Energy Agency
JCC	Joint Coordination Committee
JETRO	Japan External Trade Organization
JICA	Japan International Cooperation Agency
KEPCO	Korea Electric Power Corporation
KOICA	Korea International Cooperation Agency
LASAP	Laos–Australia Sustainable Energy Partnership
LASEP	Laos Australia Energy Partnership
LBS	Load Break Switch
LEPTS	Lao Electric Power Technical Standards
LFC	Load Frequency Control
LFCR	Load Frequency Control and Reserve
LHSE	Lao Holding State Enterprise
LOLE	Loss of Load Expectation
LOLP	Loss of Load Probability
LTD	Limited
LV	Low Voltage
MEM	Ministry of Energy and Mines
MG	Microgrid
MIH	Ministry of Industry and Handicraft
MME	Ministry of Mines and Energy
MOF	Ministry of Finance
MOIT	Ministry of Industry and Trade
MOM	Minutes of Meeting
MOU	Memorandum of Understanding
MPI	Ministry of Planning and Investment
MSH	Medium Substation Hub（推定）
MV	Medium Voltage
MVA	Megavolt Ampere

MW	Megawatt
NCC	National Control Center
NLDC	National Load Dispatch Center
NPDP	National Power Development Plan
NRCC	Northern Regional Control Center
NTDP	National Transmission Development Plan
OCCTO	Organization for Cross-regional Coordination of Transmission Operators (Japan)
OLTC	On Load Tap Changer
PDM	Project Design Matrix
PDP	Power Development Plan
PDR	People's Democratic Republic
PG	Power Grid
PGI	Power Grid Improvement
PJM	PJM Interconnection
PP	Pilot Project
PPA	Power Purchase Agreement
PPE	Personal Protective Equipment
PSPP	Power Supply Procurement Plan（仮）
PSS	Power System Simulator (e.g., PSS®E)
PU	Per Unit
PV	Photovoltaic
RCC	Regional Control Center
RE	Renewable Energy
RES	Renewable Energy Source
RIEM	Research Institute of Energy Management
SCADA	Supervisory Control and Data Acquisition
SDZ	Saysettha Development Zone
SIM	Subscriber Identity Module
SOP	Standard Operating Procedure
SPS	Special Protection Scheme
SS	System-to-System
TAF	The Asia Foundation
TBC	Tie-line Bias Control
TBEA	TBEA Co., Ltd.
TEPCO	Tokyo Electric Power Company
TL	Transmission Line
TPA	Third Party Access
UK	United Kingdom
USAID	United States Agency for International Development
USAID	United States Agency for International Development
USD	United States Dollar
VC	Voltage Control
VRE	Variable Renewable Energy
VT	Voltage Transformer

Chapter 1 Outline of the Project

1.1. Background

The Government of Lao PDR is promoting the establishment of a System-to-System (SS) interconnection framework to enhance cross-border electricity exchanges with neighboring countries and expand electricity exports. In recent years, the rapid development of hydropower projects within the domestic supply network has resulted in a significant increase in electricity surplus. Facilitating power exports from the domestic grid and enabling optimal and flexible power exchanges between Laos and neighboring countries have emerged as key challenges.

To address this situation, Laos is pursuing the expansion and construction of interconnection lines from the domestic supply system, and the integration of these with export-dedicated transmission lines through an SS interconnection framework. This requires autonomous and stable operation of the national power system.

In this context, the Lao transmission company EDL-T, responsible for operating high-voltage transmission lines of 230 kV and above within EDL's transmission business, commenced operations in January 2024. While the Government of Laos approves EDL-T's investment and asset development plans, the overall system operation continues to be managed by EDL.

In developing the proposed Grid Code and associated implementation and enforcement mechanisms under this project, it is essential to ensure proper planning and operation not only by EDL but also by EDL-T. Furthermore, to realize effective SS interconnection, EDL will need to develop a Grid Code that reflects the characteristics of Laos's transmission system and is harmonized with the grid codes of neighboring countries. In parallel, it is crucial to strengthen the autonomous monitoring and control functions of EDL's national dispatch center, enhance operational capabilities of transmission and substation assets, and reinforce regulatory oversight mechanisms for system performance and corrective action.

1.2. Overview of the Assignment

(1) Overall Goal

Autonomous and stable operation of Laos' wide-area interconnected power system is realized.

(2) Project Purpose

The planning and operational capacities of the Ministry of Energy and Mines (MEM) and Electricité du Laos (EDL) are strengthened.

(3) Output

- A Grid Code is appropriately developed.
- Technical regulations and operational manuals are properly established, enabling effective planning and operation of the interconnected system.
- Operational frameworks, including monitoring functions within MEM and EDL, are strengthened.

(4) Relevant Authorities and Institutions

- Ministry of Energy and Mines (MEM), including the Department of Energy Management (DEM), the Department of Energy Policy and Planning (DEPP), and other related departments.
- Electricité du Laos (EDL)

(5) Implementation Period

February 2021 – June 2025

1.3. Scope of Activities

This project began in February 2021 and is scheduled for completion in June 2025. The Project Design Matrix (PDM) is shown in Figure 1-1.

The objective of the project is to improve power quality within Laos and to realize autonomous and stable operation of the regional interconnected power system. To achieve this, the project aims to strengthen the power system planning and operation capabilities of MEM and EDL, and to formulate a Grid Code that sets out the rules to be followed by all grid users.

In order for EDL to appropriately carry out the tasks stipulated in the Grid Code, a roadmap for the development of related operation manuals has also been prepared.

1.4. Project Implementation Approach

The implementation approach for each project component is outlined below. To ensure the effective execution of activities, practical surveys on transmission system planning and operation, investigations of system accidents and equipment failures, and capacity-building training were conducted in parallel with the grid code development.

(1) Development of the Grid Code

The existing grid code was initially drafted in the 2000s and compiled by EDL in June 2013. However, it was neither legally institutionalized nor officially stipulated as a regulation of the state-owned utility, EDL. Nonetheless, as a standard document of that time, it included the necessary items, and thus served as the foundation for the revised version.

The revision took into account the absence of provisions on renewable energy connections in the existing code and the reality that EDL's current operations were not even in compliance with the previous code. Accordingly, the revised code limited its binding provisions to what EDL can currently comply with, while clearly specifying technical requirements for new facilities. Items to be complied with in the future were organized as a separate section.

In addition, following the 2017 amendment of the Electricity Law, private capital was allowed to enter the transmission business, and new transmission operators, including EDL-T, began operations in January 2024. The revised grid code also reflects this diversification of system players.

(2) Development of Regulations and Manuals

To facilitate appropriate planning and operation of interconnected power systems, a roadmap was developed for the formulation of relevant regulations and technical manuals.

(3) Strengthening Operational Frameworks of MEM and EDL

Currently, the Ministry of Energy and Mines (MEM) supervises EDL's system planning and operation, while EDL submits planning proposals and reports on major system accidents as needed. EDL also monitors the power system in its role as System Operator.

Although strengthening the existing monitoring function within this framework can produce a certain level of improvement, the involvement of other transmission operators, such as IPPs and EDL-T, necessitates a more independent, fair, and technically competent third-party monitoring mechanism.

Therefore, this component is to be achieved by supporting the establishment of a regulatory agency for the power sector in Laos, incorporating monitoring functions into the structure of that agency.

Project Name	Power System Planning and Operational Capacity Development Project
Implementing Agency	Ministry of Energy and Mines (MEM) and Lao Electricity Company (EDL)
Target Group	MEM staff will provide training on power management and planning, while EDL staff will provide training on power system planning and operation.
Project Period	January 2021 to December 2023 (3 years)
Project Site	Vientiane

Outline	Objectively verifiable indicators	verification method	Important assumptions/external conditions
Overall Objective The autonomous and stable operation of Laos's 230kV and wider interconnection system will be realized.	• Regional power supply performance (peak demand, electricity consumption) • Power system quality (frequency 50±0.2Hz, voltage ±5%, forced outage rate) • System forced outage rate (system failures, trouble records, SAIFI, SAIDI) • Stability (emergency islanding capability, emergency operation based on GC) • Power flow does not exceed rated values • Proper control of power plants ensures that interconnection flow is maintained at planned values. • Increase in the number of controlled power plants and decrease in the excess power generation ratio • Continuous review of system codes	• Operational data provided by MEM and EDL	• Power coordination policy in the • Indochina region • Power supply and demand trends in the GMS • Changes in power development plans of neighboring countries • Impact of the establishment of EDL-T (China's policy) •Implementation status of AGC in NCC-EMS •Maintenance of coordinated power trade adjustment policies in ASEAN •Laos' power export policy will be maintained •Maintenance of system operation and management organizations for MEM and EDL •Development of interconnection lines to Thailand • Establishment of cooperation mechanisms with neighboring countries • Establishment and implementation of organizations required under the GMS Grid Code. • Progress in AGC implementation in NCC-EMS • Maintenance of CP configurations for MEM and EDL. • Cooperation with IPPs • Development status of RCC
Project Objectives MEM and EDL will be able to use Grid Code for power system planning and operation.	• Expansion of appropriate power transmission networks and power development plans (supply plans are submitted to MEM on a regular basis) • Establishment of a coordinated review mechanism with neighboring countries (new GC to be announced at regional meetings). • Revision of grid codes approved. • Power quality (frequency, voltage, system outage rate) • Outage rate (system fate, trouble records, SAIFI, SAIDI) • Reports on monitoring, inspection, and review by supervisory authorities approved.	• Forecasts, actual data, forecasting methods, • planning methods, plans, analysis data • Agreement status and discussion reports • Legal regulations • Supply and demand plans, system operation • plans, methods, plans, and data	
Outputs 1. Grid Code are being developed appropriately. 2Rules and manuals are appropriately established, and interconnected systems are appropriately planned and operated. 3. Enhance business systems, including monitoring of MEM and EDL.	• Grid Codes complies with GMS standard and are harmonized with international standards. • Revise grid codes (planning standards, operational standards, operational maintenance standards, accident reporting, power transmission access agreements with system users, generator system connection rules, etc.). • Conduct educational programs to promote understanding (number of sessions). • Develop interconnection line plans. • Power flow and voltage control shall be performed in accordance with GC and manuals. • Accident recovery is conducted in accordance with the GC manual. • Based on the GC and manual, investigate causes and implement countermeasures. • Revise technical specifications and manuals related to power system quality. • • Reflect the systems and regulations required by GMS-RGC in technical rules and manuals. • Revise generator system interconnection regulations. • Control operations are conducted in accordance with the GC and manual. • Implementation and expansion of generator GF operation (operation records) • Conduct operator training in accordance with the manual. • Establish an internal audit system for MEM and EDL. • Propose submitting the EDL self-safety plan and supply plan to the supervising authority. • Establish an organization for future grid code revisions. • Ensure that monitoring and command tasks are appropriately assigned.	• MEM、EDL • Operating plans and operating records • Frequency control method and performance data • System accident reports, etc. • Implementation and expansion of GF generator operation (operation records) • System operation data	

Figure 1−1 Project Design Matrix (PDM) for The Project

1.5. Status of Achievement of Indicators

Figure 1-2 show the classification of indicators of achievement of project goals. The achievement of the indicators is also shown in Table 1-1 to Table 1-5. The table below shows the structure of this report in response to the project goals

Project Goals	Work performed on the project	Corresponding sections of the report
1. Grid Code are being developed appropriately.	Grid code drafting	Chapter 2. Grid Code Development
2. Rules and manuals are appropriately established, and interconnected systems are appropriately planned and operated.	Survey of current status of grid planning and grid operation operations	Chapter 3. Current Status of Grid Planning and Grid Operation Operations
		Chapter 5. Investigation and Countermeasures for Accidents and Failures Occurring in the Power System
	Roadmap for the development of regulations and manuals	Chapter 4. Creating a Roadmap for the Development of a Grid Operations Manual
		Chapter 6. Capacity-building training for system planning and operational work
3. Enhance business systems, including monitoring of MEM and EDL.	Recommendations for the Establishment of an Electricity Regulatory Agency	Chapter 7. Consideration of Electricity Regulatory Agencies

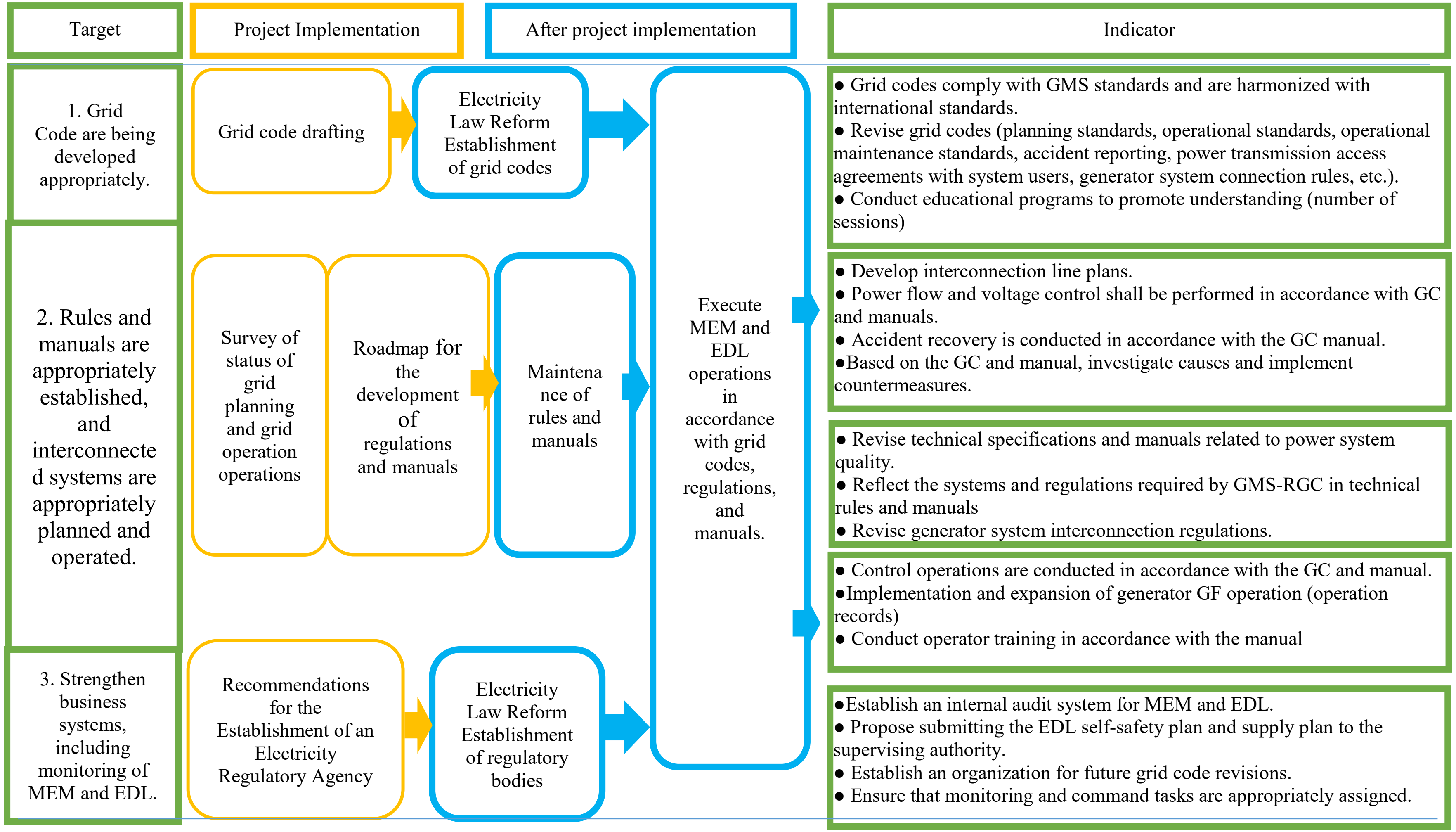


Figure 1-2　Classification of indicators of project goals

Table 1-1 Indicators Achieved (1)

◎: Completely achieved
〇: Generally achieved, but there are ongoing issues.

Results	Indicators	Status of Achievement
1. Grid Code are being developed appropriately.	● Grid Code complies with GMS standard and are harmonized with international standards.	Achieved ◎ Based on the GMS Regional Grid Code developed with ADB support, the draft Lao Grid Code, the Grid-to-Grid Operational Agreement (GTGOA) concluded with Thailand's EGAT, and by referencing the EGAT Grid Code as well as grid codes of other countries including Japan, a new Lao Grid Code was revised to comprehensively cover structures and elements aligned with international standards, while fully reflecting the current operational conditions of the Lao power system.
	● Revise grid codes (planning standards, operational standards, operational maintenance standards, accident reporting, power transmission access agreements with system users, generator system connection rules, etc.).	Achieved ◎ The current, informal EDLao Grid Code was revised, and planning standards, operation standards, operation and maintenance standards, accident reporting, transmission access agreements with grid users, and generator grid connection rules were developed and proposed.
	● Conduct educational programs to promote understanding (number of sessions)	Achieved ◎ To promote understanding, briefings on the overalLao Grid Code proposal were held for MEM and EDL in February and May 2025. These briefings were also attended by EDL-T and EDL-Gen officials. In addition, briefing sessions were held for each individual field, such as grid planning, grid operation, generator connection, power distribution, safety regulations, and transformer accidents, to promote understanding as well as to hear opinions. These sessions were held in July 2021, March, June, September and December 2022, June and September 2023, and March, June and September 2024, for a total of 12 times.

Table 1-2 Indicators Achieved (2)

◎: Completely achieved
〇: Generally achieved, but there are ongoing issues.

Results	Indicators	Status of Achievement
2. Rules and manuals are appropriately established, and interconnected systems are appropriately planned and operated.	● Develop interconnection line plans.	Achieved 〇
		<Current situation> ・Proposed procedures for formulating system plans including interconnection line plans under the EDL and EDL-T frameworks. In 2024, under the leadership of MEM, EDL participated in discussions regarding the interconnection line plan between the northern and central regions based on EDL-T, and the plan was approved. Additionally, it was proposed that the power regulatory authority should implement adjustments to transmission plans as part of its functions. ・Regarding the procedures for developing system plans, a provision requiring MEM to establish guidelines was included in the draft grid code. ・Furthermore, technical criteria for system plans were specified in the draft grid code, drawing on examples from other countries.
		<Issues> Under the international interconnection plan, it is necessary to conduct comprehensive consultations with Thailand, similar to the existing consultative body, from the perspectives of frequency and voltage control, protection coordination, operational responsibility, information sharing, and other aspects, while complying with the grid codes of both countries.
	● Power flow and voltage control shall be performed in accordance with GC and manuals.	Achieved 〇
		<Current situation> In the manual development roadmap, we supported the development of manuals related to power flow and system voltage control, conducted training on power flow and voltage control (June and December 2024), and supported the implementation of power flow and voltage control in accordance with grid codes and manuals.
		<Issues> ・Currently, there are several areas within the system where voltages are consistently high, and phase-advance operation and segmented operation through the opening of transmission lines have become the norm. Therefore, it is necessary to promptly formulate and implement transmission line improvement plans and plans to strengthen phase-regulating equipment. Training content must be continued on an ongoing basis. ・Regarding power flow and voltage control, monitoring by NCC in accordance with grid codes and manuals, along with power system analysis, should be conducted to establish plans for the introduction of necessary transmission lines and power factor correction equipment, and their installation should be advanced steadily.
	● Accident recovery is conducted in accordance with the GC manual.	Achieved 〇
		<Current situation> An existing black start manual is available for the EDL. In addition, the manual development roadmap proposes the development of system operation manuals covering accident recovery systems and procedures, system operation during abnormal conditions, detection and response to precursors, and electrical accident reporting, with the aim of supporting accident recovery systems based on future manuals. The grid code defines accident recovery as the restoration of the system from the restorative state to the normal state, and supports the establishment of accident recovery policies.
		<Issues> It is necessary to continue reorganizing the current black start manual and other manuals in a systematic manner based on the roadmap, integrating and organizing them in a consistent manner, and maintaining a stable manual operation system. It is necessary to conduct regular training and education for NCC, RCC, power plants, etc., and establish a system to ensure that grid codes and manuals are reliably referenced and operated in the event of an accident.

Table 1-3 Indicators Achieved (3)

◎: Completely achieved
〇: Generally achieved, but there are ongoing issues.

Results	Indicators	Status of Achievement
2. Rules and manuals are appropriately established, and interconnected systems are appropriately planned and operated.	● Based on the GC and manual, investigate causes and implement countermeasures.	Achieved 〇
		<Current situation> We proposed regulations requiring accident reports to be submitted to the grid code and supported the establishment of a system for investigating accident causes and implementing countermeasures based on these regulations. In addition, as part of the manual development roadmap, we provided support for the creation of a manual on electrical accident reporting.
		<Issues> The establishment of an EDL operational framework is a prerequisite. It is necessary to establish an investigation system, share measures to prevent recurrence, and maintain a sustainable EDL operational framework that includes an investigation system and shared measures to prevent recurrence.
	● Revise technical specifications and manuals related to power system quality.	Achieved 〇
		<Current situation> In Grid Code, standards for power quality, such as voltage, frequency, supply reliability, and harmonics, have been established. In addition, a roadmap for manuals to be developed in the future in the field of system operation has been formulated, and system voltage control and frequency control have been positioned as items to be addressed in order to maintain power system quality.
		<Issues It is necessary to ensure consistency with actual system operation and to continue regular reviews.
	● Reflect the systems and regulations required by GMS-RGC in technical rules and manuals	Achieved 〇
		<Current situation> The GMS RegionaLao Grid Code (Draft), developed with the support of ADB, has been prepared with reference to the Grid Code of ENTSO-E, the European wide-area grid operator. The roadmap for the development of a grid operation manual, which has been developed, proposes the development of systems and rules required by this GMS RegionaLao Grid Code (Draft), with reference to current manuals and related documents in developed countries in Europe and the United States, including Japan.
		<Issues> Currently, frequency coordination is handled by EGAT of Thailand, and the current operation does not meet the requirements of the draft GMS RegionaLao Grid Code. In order to establish a wide-area grid system through SS interconnection in the future, autonomous grid operation led by Laos is essential. However, frequency adjustment cannot be performed with EDL. For this reason, this item (frequency coordination) was not included in the draft grid code, but was proposed as an alternative guideline. In the future, based on the maintenance roadmap, it will be necessary to develop operational manuals and control equipment for frequency coordination in stages.
	● Revise generator system interconnection regulations.	achievement◎
		The Grid Code now includes a provision regarding the connection of generators to the grid (Connection Code), which specifies the connection requirements for the connection of renewable energy sources in addition to conventional synchronous generators.

Table 1-4 Indicators Achieved (4)

◎: Completely achieved
○: Generally achieved, but there are ongoing issues.

Results	Indicators	Status of Achievement
2. Rules and manuals are appropriately established, and interconnected systems are appropriately planned and operated.	● Control operations are conducted in accordance with the GC and manual.	Achieved ◎
		<Current situation> I Currently, with virtually no manuals in place, we have presented a roadmap for gradually developing manuals and have proceeded with the development of manuals related to power supply system operation and system control. We have proposed that the development of control operation manuals be carried out in stages, divided into periods before and after the update of the power supply system, and have encouraged the implementation of this plan.
		<Issues> It is necessary to ensure that the system operation and control manual is disseminated and training is provided to personnel in the field so that it becomes established in operations, and that continuous reviews are conducted in line with actual operating conditions.
	● Implementation and expansion of generator GF operation (operation records)	Achieved ◎
		<Current situation> We presented a roadmap for the realization of governor-free operation and load frequency control (LFC), proposed the implementation of a feasibility study on the feasibility of existing generators, and provided support for its implementation and expansion.
		<Issues> In order to further expand governor-free operation and load frequency control (LFC) operation, it is necessary to select generators that can handle these operations, clarify technical requirements, conduct trial operations, and establish systematic collection and evaluation of operating records.
	● Conduct operator training in accordance with the manual.	Achieved ◎
		<Current situation> In the manual development roadmap, we proposed skill certification systems for improving capabilities as items to be addressed, and supported the establishment of worker education systems.
		<Issues> The specific design of the skills certification system and the establishment of an operational system, the formulation of an educational curriculum based on the manual, its introduction into the field, and the implementation of periodic training and evaluation are future issues to be addressed.

Table 1-5 Indicators Achieved (5)

◎: Completely achieved
○: Generally achieved, but there are ongoing issues.

<table>
<tr><th>Results</th><th>Indicators</th><th>Status of Achievement</th></tr>
<tr><td rowspan="5">3. Strengthen business systems, including monitoring of MEM and EDL.</td><td rowspan="2">● Establish an internal audit system for MEM and EDL.</td><td>Achieved ◎</td></tr>
<tr><td rowspan="2"><Current situation>
It proposed the creation of an electricity regulatory agency and its functions to ensure transparency and efficiency in the electricity sector as a whole. The functions of the agency would be to advise the MEM from a professional standpoint in regulating electricity prices, granting business licenses, formulating, enforcing, and revising grid codes, mediating complaints and disputes in the electricity market, reviewing draft electricity development plans, and monitoring the progress of projects.
The establishment of an electricity regulatory agency would require legal reform, and the MEM has established a cross-governmental working group to study the issue.</td></tr>
<tr><td>● Propose the system of submitting the EDL self-safety plan and supply plan to the supervising authority.</td></tr>
<tr><td>● Establish an organization for future grid code revisions.</td><td rowspan="2"><Issues>
Support for legal reform and the establishment of an electricity regulatory agency will be handed over to the Australian LASEP and the World Bank after the completion of this project.</td></tr>
<tr><td>● Ensure that monitoring and command tasks are appropriately assigned.</td></tr>
</table>

Chapter 2 Grid Code Development

2.1. Indicators of Output 1 "Grid codes are being developed appropriately."

The achievement of Output1, "Grid codes are being developed appropriately." is shown below.

Table 2-1 Indicators of Output 1 Achieved

◎: Completely achieved
○: Generally achieved, but there are ongoing issues.

Results	Indicators	Status of Achievement
1. Grid Code are being developed appropriately.	● Grid Code complies with GMS standard and are harmonized with international standards.	Achieved ◎ With the support of the Asian Development Bank (ADB), Lao Grid Code has been revised that incorporates the GMS RegionaLao Grid Code (draft), the Grid-to-Grid Operational Agreement (GTGOA) agreed upon with the Thai Electricity Generating Authority (EGAT), the Thai EGAT grid code, and grid codes from other countries including Japan. This new grid code comprehensively addresses the current state of power system operations in Laos and aligns with international standards.
	● Revise grid codes (planning standards, operational standards, operational maintenance standards, accident reporting, power transmission access agreements with system users, generator system connection rules, etc.).	Achieved ◎ The current, informal EDLao Grid Code was revised, and planning standards, operation standards, operation and maintenance standards, accident reporting, transmission access agreements with grid users, and generator grid connection rules were developed and proposed.
	● Conduct educational programs to promote understanding (number of sessions)	Achieved ◎ To promote understanding, briefings on the overalLao Grid Code proposal were held for MEM and EDL in February and May 2025. These briefings were also attended by EDL-T and EDL-Gen officials. In addition, briefing sessions were held for each individual field, such as grid planning, grid operation, generator connection, power distribution, safety regulations, and transformer accidents, to promote understanding as well as to hear opinions. These sessions were held in July 2021, March, June, September and December 2022, June and September 2023, and March, June and September 2024, for a total of 12 times.

2.2. Investigation, evaluation, and identification of issues with existing Lao Grid Code

The current status and issues with the existing Lao Grid Code are described below.

2.2.1. General

The existing Grid Code, first drafted in the 2000s and published by EDL in June 2013, does not have a formal position in the legal system at this time, and remains only as a reference document in the planning and operation of power grids. In order to realize stable and fair operation of power grids in the future, it is necessary to develop a Grid Code that clearly stipulates items to be commonly observed by all grid users, including power generation, transmission, and distribution companies and consumers, and to formally position these items within the legal system.

Since the Grid Code will be a legally binding regulation, it is necessary to ensure that the content of the Grid Code can be complied with in practice, taking into account the current grid planning and grid operation practices under the EDL and the actual status of power grid facilities in Laos.

The power system of Laos is connected to the neighboring EGAT (Electricity Generating Authority of Thailand) power system in Thailand through 115 kV AC transmission, and at present there is still a large dependency in terms of grid operation. With further strengthening of the interconnection expected in the future, the current Grid Code is insufficient to serve as a hub for system-to-system interconnection within the GMS region, and a drastic review is required.

In many countries, electricity regulatory agencies play a central role in the management and supervision of Grid Codes, but in Laos, an electricity regulatory agency has not yet been established, and the establishment of such an agency is an important issue for the future.

2.2.2. Procedures for Power System Planning

In Lao PDR, the Electricity Law stipulates a 10-year National Power Development Strategy (NPDS) and a 5-year Power Development Plan (PDP) as the national power development plan. Individual project plans for power generation, transmission, and distribution are planned and implemented according to these national plans. However, there are no regulations or guidelines for a standard planning process to coordinate and align the individual plans of power system users, such as power generation and transmission companies, with the power development plans stipulated in the Electricity Law and the individual plans among the respective power system users.

2.2.3. Criteria for Power System Planning

The current Lao Grid Code's provision on Grid Planning Criteria states that "The transmission grid shall be planned to operate normally for the contingency of a single outage, i.e., the N-1 redundancy criterion shall be applied," which clearly states that the N-1 criterion shall be applied. However, there are many sections of EDL's current transmission system that do not meet the N-1 criterion of keeping demand within rated capacity with the remaining facilities immediately after a single equipment failure, which deviates from the reality of EDL's system operation.

Regarding the generation capacity that should be reserved for the grid as a whole, it states that "the generation capacity of the grid shall meet the five-day annual loss-of-load probability (LOLP) to meet domestic demand." However, the Grid Code is essentially a set of technical requirements to be followed by users of the power system, and the development of generation plans and their approval is under the jurisdiction of the Ministry of Energy and Mines (MEM) and should be based on a separate body of legislation.

2.2.4. Responsibility for Grid Operation

The current Lao Grid Code lacks clear provisions on the respective responsibilities of grid operators, generators, and transmission facility owners, and is inadequate in terms of basic and important responsibilities, such as the obligation to maintain the supply-demand balance under normal circumstances, the obligation for early restoration in case of abnormalities, the obligation to maintain facilities, and the prohibition of unauthorized shutdowns. Insufficient provisions for basic and important responsibilities, such as the obligation to maintain the supply-demand balance during normal times, the obligation to quickly restore the system in the event of an emergency, the obligation to preserve facilities, and the prohibition of unauthorized outages.

2.2.5. Scheduled Outage Plan

The current Lao Grid Code only specifies the process and timeframe for facility outage planning and coordination, with no provisions for policies on facility outage planning and coordination, mutual coordination methods, or reliability studies of the power system in the event of a facility outage.

2.2.6. Emergency Procedures

The current Lao Grid Code only specifies information sharing and reporting, and does not specify black start generator deployment strategies or specific restoration procedures.

2.2.7. System Connection

The current Lao Grid Code contains detailed descriptions of operations and procedures (Procedures) for grid connection of power generation facilities, and the level of detail is comparable to that in Japan. On the other hand, it is desirable to organize and operate the details of these procedures as a supplemental document to be separately published by the grid owners (EDL and EDL-T) for grid users, rather than including them in the main body of the Grid Code.

In terms of practice, there are cases where system users do not fully understand the technical requirements to be described in the Application Form, and there are also issues such as the fact that the forms necessary for business operations are not yet available in the Grid Code, which requires further institutional improvement.

2.2.8. Technical Requirements for Power Generation Facilities

The only description of technical requirements for equipment in general is currently (1) the minimum type of protective relay required and (2) the operating responsibilities of the circuit breaker (maximum breaking current and accident elimination time).

The technical requirements for power generation facilities are described as follows: (1) power output that can be generated, (2) operating frequency, (3) unbalanced load carrying capacity, (4) regulator, (5) excitation device, (6) black start function, and (7) fast start function.

Comparing the current Lao Grid Code with EGAT's Connection Code, it lacks provisions for technical requirements (FRT requirements, etc.) for inverter-connected power supplies.

2.2.9. Power Distribution System

The description is insufficient from the viewpoint of standard handling in Japan in preventing stand-alone operation, which is a particular problem in power distribution systems. Further enhancement of the description of protective devices as a technical requirement for grid interconnection is desirable.

PV power generation for domestic use is often connected to the distribution system, and it is important to consider the connection rules for VRE power sources such as PV power generation that are required from the distribution system side when considering Grid Codes, grid connection rules, and manuals, but there are no connection rules for VRE.

2.2.10. Safety Regulation

Grid codes on safety generally require items such as safety principles, procedures, and responsibilities related to human life and equipment protection, and coordination among operators, which are already covered, and thus are considered sufficient for the content of the safety provisions included in the Grid Codes. However, there are some discrepancies in some of the descriptions with the current organization and the LEPTS.

2.3. Grid Code Development

2.3.1. Grid Code Development Policy

At the JCC (Joint Coordinating Committee) meeting held in December 2021, the following points were raised by the Minister of MEM (Ministry of Energy and Mining) and confirmed as common knowledge among the organizations concerned.

- ➢ The Grid Code should be developed in a simple and practical form that covers the minimum necessary items to avoid discrepancies in interpretation among the parties involved.
- ➢ In the initial stage, it is desirable to formulate a Grid Code that is concise and easy to use, and then gradually improve and upgrade it through operation.
- ➢ The results of Grid Code improvements by other donors should be properly evaluated and, if necessary, discussed with other countries.

The procedure for formulating this proposed revision is as follows

- ➢ From July 2021 to September 2024, the current status of grid planning and grid operation in the EDL was assessed, the current Lao Grid Code was scrutinized, and the Grid Codes of other countries such as Thailand and Japan and the draft GMS regional unified Grid Code developed by the ADB were referenced.
- ➢ Based on the above, and through ongoing discussions with MEM and EDL, a revision plan was developed in stages for each area, including "grid planning," "grid operation," "connection of generating facilities," and "safety and security regulations," in line with the actual institutional and operational conditions in Laos.

2.3.2. Development of Grid Code for System Planning

- Review of Criteria

This provision was reviewed to ensure that it is feasible for EDLs to comply with it to the extent that it does not impair supply reliability. It was decided to delete the description of "Reliability Requirements for Generation Facilities Planning (LOLP)," which was included in the previous Grid Code.

- Regulations regarding Procedures for Formulating

The first edition of the Grid Code, which is the subject of this report, includes the following new provisions to develop an institutional framework for grid planning:

“The MEM shall develop and publish guidelines for a standardized process for the development of power system plans."

The purpose of this provision is to standardize and ensure transparency in the procedures for developing the grid plan, and to clarify the division of responsibilities and coordination process among the agencies involved in the planning process.

2.3.3. Development of Grid Code for System Operations

- Grid Operation-related Grid Code Development Policy

In revising this Grid Code, the GMS RegionaLao Grid Code was used as the main source of reference, and it was the intention to formulate draft provisions that are in line with the organizational structure and practices of the EDL, especially in areas that are not yet covered in the current Lao Grid Code, such as the Load The GMS RegionaLao Grid Code is the main reference for the revision of this Grid Code.

The draft is based on the structure and content of Chapter 5 (Operation Code) of the current Lao Grid Code, and new items that are missing are added with reference to the following external rules.

* Grid-to-Grid Operation Agreement between EDL and EGAT (GTGOA)

* EGAT Operation Code

* GMS RegionaLao Grid Code (GMS-R)

The main body of the Grid Code should be structured to be concise and easy to use in practical terms, while detailed operational procedures, parameter settings, and other content requiring frequent revision should be maintained and managed in a separate manual.

In addition, provisions that are necessary under the system but difficult to implement at this time will be excluded from this Part, positioned as "Transitory Provisions," and described as issues to be realized in the future, to enable their gradual introduction.

- Operational Responsibility

Provisions for the responsibilities of grid operators, generators, and transmission facility owners were added, including the obligation to maintain the supply-demand balance under normal conditions, the obligation to restore supply and demand quickly in the event of an anomaly, the obligation to maintain facilities, and the prohibition of unauthorized shutdowns.

- Scheduled Outage

Provisions were added for facility outage planning and coordination policies, mutual coordination methods, and reliability studies of the power system in the event of a facility outage.

- Emergency Procedures

Add provisions for black start generator deployment strategies and specific restoration procedures.

2.3.4. Grid Code for Frequency Control

The revision on frequency control was considered based on the basic policy of "Grid Code in accordance with the actual business situation. Since the basic concept is not well understood by the parties concerned at this point, it was decided not to specify it in this volume, but to include it in the Transitory Provision as an issue for future institutional development and capacity building.

The introduction of FTC (Flat Tie-line power flow Control)," which was presented at the on-site hearing held in May-June 2023, is aimed to be automatically controlled by the NCC system in the end, while in the initial stage, the introduction of Manual-FTC (Manual-FTC) was proposed to set hourly planned values (output and power amount) in power transactions with Thailand, and adjust generator output by feeder commands to match them. In the initial stage, we proposed the introduction of manual FTC (Manual-FTC), which sets hourly planned values (output and wattage) in power transactions with Thailand and adjusts generator output according to the hourly planned values by feeding commands. However, since immediate implementation of Manual-FTC is considered to be difficult, it was decided to keep the revision of the frequency control rules to the minimum necessary, referring to the GTGOA (Grid-to-Grid Operational Agreement) and the GMS RegionaLao Grid Code at this time. Therefore, it was decided to keep the revisions to the minimum necessary while referring to the GTGOA (Grid-to-Grid Operational Agreement) and GMS RegionaLao Grid Code.

Deletion of provisions that are not commensurate with the current level of operations (e.g., mandatory governor-free operation) was also considered, but it was decided not to delete them from the current code because they are both basic competencies that a grid operator should have.

The future development of independent supply and demand adjustment and frequency control was proposed as the following three-step roadmap. These provisions on phased measures are not included in the main Grid Code, but are all included in the Temporary Regulations Chapter.

- Phase 1: Introduction of Manual-FTC (manual adjustment of generator output)
- Phase 2: Introduction of Automatic-FTC (automatic control by NCC)
- Phase 3: Integrated LFC operation with AGC implementation and NCC system

To realize Phase 2 and beyond, it is essential to implement Load Frequency Control (LFC) and Automatic Generation Control (AGC) utilizing the power feeding system installed in the NCC. Therefore, we proposed that **Feasibility Studies (FS) and Pilot Projects (PP)** be conducted for future implementation, and that the relevant provisions be promoted to the main body when concrete prospects are obtained.

The following two proposals for revisions regarding frequency control were presented:

1. Simplified Revised Version

   Based on Section 5.7 "Frequency and Voltage Control" of the current Lao Grid Code, with minimal revisions. While maintaining consistency with the current provisions, new concepts such as Ancillary Services and Frequency Regulating Reserves are clearly stated in the Supplementary Provisions to become effective after future conditions are in place, and a new clause is added to require MEM, EDL, and NCC to take responsibility for maintenance of these new concepts. The new article requires MEM, EDL, and NCC to take responsibility for maintenance.

2. Detailed Revised Version

   This is a proposal to completely rewrite Section 5.7 with reference to the content of the GMS RegionaLao Grid Code. It is intended to be used as a guideline for future voluntary revisions by EDL/NCC.

In this project, the Simplified Revised Version will be considered as the official revision proposal for the main body of the Grid Code, and the Detailed Revised Version will be positioned as reference material for future revisions.

2.3.5. Connection Code

The following description of technical requirements has been added. In preparation for the future use of HVDC for interconnection with neighboring countries, this technical requirement for grid interconnection is also considered necessary.

(1) Harmonics (suppression of generation)

(2) AGC (automatic output controller)

(3) Ability of Units to Island

(4) Technical Requirements for Renewable Energy Grid Interconnection

(i) Fault Ride-through Requirements

(ii) Operable frequency range

(iii) Effective power control

(iv) Frequency response

(v) Ramp control of effective power output

2.3.6. Commissioning Test

From the perspective of ensuring the reliability of new power generation facilities when they are connected to the grid, the Grid Code specifies the obligation of power producers to conduct a Commissioning Test (pre-use test of facilities), and has established connection rules that make this a mandatory submission requirement for grid connection applications.

Specifically, the new version of the Commissioning Test has expanded the scope of submission to System Operators in addition to Grid Owners and has made the preparation items more specific and systematic. In addition to electrical drawings and test procedures, the submission documents also specify safety manager information and details of protection settings. In this way, this will enable power producers to clearly understand the technical requirements from the initial stage and improve the transparency of the connection review process. The Rules are expected to encourage compliance with the Grid Code from the planning and design stages of new power generation, and to realize a system operation that contributes to improving the safety and reliability of the grid in the future.

2.4. Power Sector of Laos

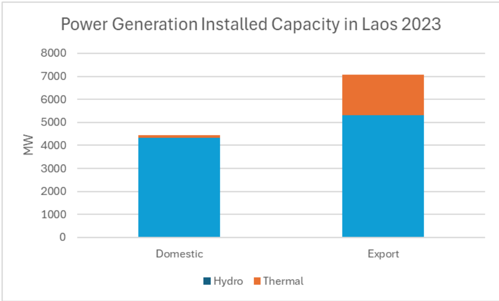
The grid codes targeted in this project are the rules that must be followed by users of the Lao power system, including the EDL, EDL-Gen, EDL-T, IPP, and consumers. Since the characteristics of the Lao power system and the structure of the power sector are related to the content of the grid code revisions, this section describes the characteristics of the Lao power system and the structure of the power sector.

2.4.1. Electric Power System of Laos

Laos spans approximately 1,000 kilometers from north to south, with a land area of 236,800 km² and a population of around 7.7 million[1]. It shares borders with five countries: China, Vietnam, Thailand, Cambodia, and Myanmar. About 70% of the country is covered by forests, and it has abundant potential for renewable energy sources such as hydropower, solar, wind, and biomass. Additionally, coal is also mined domestically. These resources provide Laos with an energy supply that significantly exceeds its domestic energy consumption. Consequently, electricity generated in Laos is not only supplied domestically but also exported to neighboring countries.

As of 2023, Laos had a total installed generation capacity of 11,692.14 MW and an annual power generation potential of 58,884.27 GWh[2]. Figure 2-1 shows power generation facilities in Laos with capacities of 1 MW or more[3]. Hydropower accounts for 94% of the installed capacity of generation facilities for domestic supply. The only coal-fired power plant is the Hongsa Thermal Power Plant, with a total installed capacity of 1,878 MW, of which 1,803 MW is designated for export.

[1] Source: World Bank website (https://data.worldbank.org/indicator/SP.POP.TOTL?locations=LA), accessed in 2023.
[2] STATISTICAL YEARBOOK ENERGY AND MINES 2023, DPC, MEM, 2023
[3] Exports from the EDL to Cambodia in the south are made by the power plants connected to the EDL, as these plants are exported by a transmission system dedicated to exports.



(Source: Prepared from STATISTICAL YEARBOOK ENERGY AND MINES 2023, DPC, MEM, 2023)

Figure 2-1 Power Generation Installed Capacity in Laos (2023)

Lao PDR's power transmission system is divided into transmission system for domestic supply and export-only transmission lines that connect power plants directly to neighboring countries. Each is not connected within Laos. The domestic supply system is connected to the systems of China, Thailand, and Myanmar by 115 kV interconnection lines, and to the system of Cambodia by 115 kV and 230 kV interconnection lines. In order to avoid synchronous interconnection between neighboring countries, the transmission systems for domestic supply that are interconnected with each of the neighboring countries are divided domestically.

Electricity generated by export-only IPPs is supplied to neighboring countries through dedicated transmission lines. For Thailand and Vietnam, the dedicated export transmission lines are directly connected to the IPPs in Laos. For Cambodia, a transmission line owned and operated by EDL is directly connected, and power from power plants procured by EDL is supplied to this system.

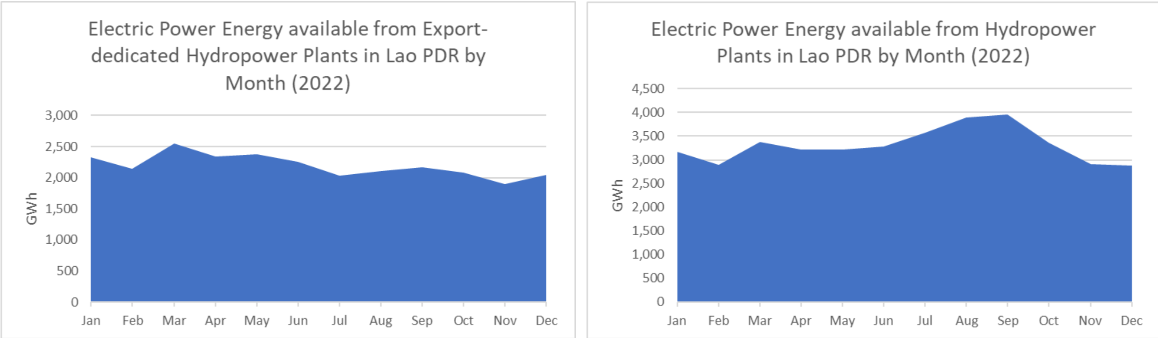
The 500 kV and 230 kV transmission lines for domestic supply are operated by EDL-T, while the 115 kV lines are operated by EDL. Domestic power sales are conducted by EDL, and EDL procures the generated power for domestic supply.

(Source: MEM, based on information from EDL)

Figure 2-2 Power System of Laos

The amount of electricity that can be generated by hydropower plants is higher in the rainy season and lower in the dry season. The monthly electricity production of hydropower plants in Laos in 2022 is shown in Figure

3 3, divided into plants dedicated to export and plants for domestic supply. Export-only hydropower plants have relatively large reservoirs, with the exception of the Xayabouly power plant, which uses the main flow of the Mekong River. The total available power generation capacity of the power system for domestic supply was 13,390 GWh per year. During the rainy season from August to September, the amount of electricity available was about 1,700 to 1,800 GWh, and during the dry season from December to May, the amount of electricity available was about 800 GWh.



(Source: Compiled from data obtained from EDL)

Figure 2-3 Electricity available from Hydropower Plants in Laos for Domestic Supply and for Export-only, by Month (2022)

During the rainy season in August and September, there is a surplus of about 800 GWh to 900 GWh in the power system for domestic supply, but this surplus exceeds the capacity of the current interconnection line with Thailand (about 600 GWh per month on average), and the entire amount cannot be exported to Thailand. In addition, due to the stability constraints[4] of the 230 kV transmission line connecting Luang Prabang and Vientiane in the north, the entire power generated in the north cannot be transmitted. The electricity supply shortfall during the dry season relies on imports from Thailand. Due to fluctuations in the amount of electricity that can be generated in the domestic power system during the rainy and dry seasons, the Laotian domestic power system faces a number of challenges.

Note that the maximum demand for domestic generators in 2022 was about 1,800 MW on August 4, 2022, recording about 10,500 GWh for the year.

2.4.2. Power Sector in Laos

The power sector in Laos is under the jurisdiction of the Ministry of Energy and Mines (MEM). The power system for domestic supply is operated by Independent Power Producers (IPPs) and Electricité du Laos Generation Public Company (EDL-Gen), both of which are privately funded. EDL-Gen was established in 2010 by spinning off the power generation arm of EDL, and is capitalized by EDL and general investors. The domestic transmission and distribution company (115 kV and distribution lines) is EDL (Electricité du Laos), the domestic transmission company (500 kV, 230 kV) is EDL-T, and there are also separate transmission companies, including a railroad transmission company and a transmission company operating a 230 kV (500 kV design) transmission line near the Cambodian border. EDL-T and other transmission operators operate with commission from EDL. The EDL is responsible for system operation of the electricity supply system in Laos.

[4] Limits are imposed on the amount of power transmitted in order to maintain stable grid voltage, generator synchronization, etc.

Table 2 1 Electricity System Operators for Domestic Supply in Laos

Name of organization	Main roles
EDL	Domestic distribution, power sales to customers, power supply procurement, construction, operation, maintenance and management of 115kV transmission system, system operation
EDL-T	Construction, operation and maintenance of 500kV and 230kV transmission systems
EDL-Gen	Power generation projects (mainly existing state-owned hydroelectric facilities), power sales to EDL
IPP	Power generation business (independent), power sales to EDL
Individual transmission providers	Construction, operation, and maintenance of transmission systems for specific areas and purposes

There are two types of power producers in Laos: (1) those that conclude power purchase agreements with EDL for domestic supply and sell power to EDL, and (2) those that conclude direct purchase agreements with power companies in neighboring countries for export only. Even with (1), there are some power plants of operators that export power to the power grids of neighboring countries after signing a contract with EDL. (e.g., Donsahong exported to Cambodia)

Electricity sales business in Laos is regulated by the Electricity Law, and one state-owned company, EDL, is responsible for domestic electricity sales. The domestic consumers in Laos purchase electricity from EDL, which in turn procures electricity from IPPs and EDL-Gen, a domestic power generation company.

Figure 2-4 shows the players in the power sector of Laos.

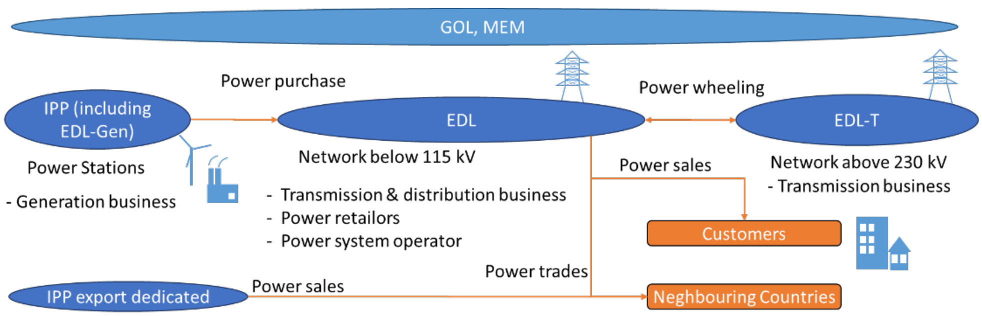


Figure 2-4 Players in the power sector of Laos

The power purchase agreements and transmission agreements in Laos' power sector take the following forms.

- Agreements between IPPs (for domestic supply) and EDL
- Agreements between IPPs (for export only) and Thailand's EGAT and Vietnam's EVN
- Agreements between EDL and Thailand's EGAT for power sharing
- Agreements with China's CSG for power sharing
- Contracts between EDL and Cambodia's EDC for power exports

Under contracts with Thailand's EGAT, both import and export prices are relatively low, and the price difference between imports and exports is small. This makes it convenient for adjusting annual surpluses and deficits during the rainy and dry seasons. On the other hand, if exports exceed imports during the year, electricity must be sold to Thailand at a lower price, and if imports exceed exports, the unit price becomes high. Therefore, for Laos, this contract is advantageous as it allows for a balanced import-export ratio and enables Thailand to adjust the supply accordingly.

2.5. Policy for Grid Code Development

The initial draft of the existing grid code in Laos was prepared in the 2000s and formally compiled by EDL in June 2013. However, it has not been positioned within the legal framework, nor has it been established as a regulation of EDL, a state-owned enterprise. It is treated merely as a reference document when considering matters to be observed in the planning and operation of the power system.

The Laos Grid Code applies to the use of domestic power supply systems by generation companies, transmission companies such as EDL and EDL-T, and consumers.

At the briefing session in August 2021, opinions were expressed that it is necessary to define the power systems to which the grid code applies (boundaries), the demarcation point between the power system and generators, and the relationship with EGAT.

At the JCC in December 2021, the Minister of MEM provided the following comments, which were confirmed among stakeholders. The grid code should be developed in a simple form that covers all essential elements to avoid any misunderstandings among stakeholders:

- It is desirable to create a simple and user-friendly grid code that includes only the minimum necessary contents and to improve it over time.
- It is necessary to review the outcomes of grid code improvements by other donors and also to consult with other countries.

The procedure for formulating the draft revision of the grid code is as follows.

- From July 2021 to September 2024, the current status of the power system plan and power system operation of the EDL, the current grid code of Laos, grid codes of other countries such as Thailand and Japan, and the draft grid code for the region developed by the ADB were referenced. Following consultations with MEM and EDL, draft revisions were developed for each area: power system plan, power system operation, generator connection, and safety regulations.

2.6. Introduction of Japan's System Planning Rules

On January 24, 2022, an interview meeting was held with the Japanese OCCTO regarding the connection code currently being developed in Japan.

On November 29, 2023, Japan's system planning rules were introduced to the Power System Planning & Control Department of EDL. (Refer to Attachment 29 20231128_Planning_Rures_Japan_V1.pdf)

In Japan, provisions equivalent to the Connection Code of Grid Codes are scattered across multiple guidelines and standards, and there is no single Grid Code. Rules regarding the use of power systems are dispersed across the OCCTO's operational regulations, transmission and distribution business guidelines, and technical requirements for transmission and distribution system interconnection, among others.

OCCTO is reviewing the "system interconnection technical requirements" based on laws and regulations in preparation for the large-scale introduction of renewable energy and is also making revisions to various regulations as needed. Japan does not have a single grid code. OCCTO's operational regulations and guidelines for transmission and distribution operations constitute the highest-level rules corresponding to generaLao Grid Codes, and based on these, each general transmission and distribution operator establishes rules for the use of the transmission system.

The JICA Expert Team consulted with their counterparts, referring to examples from Japan, on the technical requirements for power systems that should be observed in formulating the system plan to be included in Laos' grid code, and reflected the results in the grid code. In particular, they explained that the N-1 standard specified in the current Laos grid code has been revised to allow for power generation output suppression in recent years and explained the systematic positioning of the standard under Japan's Electricity Business Act.

2.7. Collection of Grid Codes from Other Countries

In addition to Japan, we collected grid codes from the EU, UK, Malaysia, and also a draft GMS Grid Code developed under ADB initiatives. We also obtained portions of the grid codes from Thailand and Vietnam. Since

Thailand's grid code was in Thai, it was translated into English. These grid codes were used as references in developing the System Planning Code, System Operation Code, and Generation Connection Code.

2.8. Grid Code for System Planning

2.8.1. Planning Criteria

The current Lao Grid Code stipulates the following regarding planning criteria:

"The transmission network shall be planned so that it can operate normally even in the event of a single unforeseen outage, i.e., the N-1 redundancy criterion shall be applied."

However, many sections of EDL's current transmission system do not meet the N-1 criterion, which requires that the remaining equipment be able to supply demand within rated capacity immediately after a single equipment failure. Moreover, it is internationally recognized that the N-1 criterion does not need to be uniformly applied to all transmission lines, and flexible implementation tailored to each country's circumstances is accepted. Therefore, this provision has been revised to a level that is feasible for EDL and can be complied with without compromising supply reliability. (Refer to Attachment 15 Some considerations about planning criteria.pdf and Attachment 70 20240903_Part of System Planning (Chapter4)_V3.pptx)

In addition, the current Grid Code contains the following requirement regarding generation capacity across the system: "The grid's generation capacity shall meet a Loss of Load Probability (LOLP) of 5 days per year in order to satisfy domestic demand."

However, since the Grid Code is meant to provide binding rules for system users, the planning and approval of generation capacity—which falls under the authority of MEM—should be regulated under a different legal framework. Therefore, this reliability requirement for generation planning will be removed from the Grid Code.

2.8.2. Planning Procedures

In Laos, the Electricity Law stipulates that a 10-year "National Power Development Strategy (NPDS)" and a 5-year "Power Development Plan (PDP)" serve as the national power development plans. These are the power policies and power plans approved by the state.Plans for individual projects related to power generation, transmission, and distribution are formulated and implemented in accordance with these national plans. Individual plans of power generation operators such as IPPs and EDL-Gen, transmission operators such as EDL-T, and power system users such as EDL (transmission and distribution operators, power sales, and system operation) must be based on the power development plans stipulated in the aforementioned Electricity Law and must be consistent with the individual plans of other power system users.It is necessary to establish a standard planning process tailored to the power sector in Laos.

Since the ministry responsible for the entire power sector in Laos is MEM, it is necessary for MEM to coordinate these plans in order to plan the power system as a whole. Therefore, it is desirable for MEM to establish guidelines for the planning process, for each organization to formulate plans in accordance with these guidelines, and for MEM to coordinate them. (Refer to Attachment 67 Planning_Procedures.pptx)

The first edition of the grid code being targeted in this study includes provisions such as "MEM must establish and publish guidelines for the standard planning process for power system plans."

2.9. Grid Code for System Operation

2.9.1. Comments on System Operation and Control Sections of Lao Grid Code

At the kickoff meeting held on July 13, 2021, comments were provided on the Lao Grid Code, particularly regarding system operation and control, which had been originally formulated in 2013. Based on the key points of these comments, a revised draft was prepared through interviews with EDL (including the National Control Center, NCC). In addition, while referring to the draft GMS RegionaLao Grid Code and the Grid-to-grid Operational Agreement (GTGOA) established with Thailand's EGAT, as described below, provisions not included in the current Lao Grid Code—especially those related to wide-area supply-demand balancing and frequency regulation, such as the Load Frequency Control and Reserve (LFCR) Code—were identified, and a proposal for incorporation was developed to align with the organizational structure and operational realities of EDL.

(1) Comments on Chapter 5 of the Current Lao Grid Code (General)

- Ensure consistency between operational targets, deadlines, and actual practices.
- Clarify definitions of technical terms and recommend the use of diagrams.

(2) Comments on Specific Provisions

Comments were provided on six sections in total, with emphasis on the following three:

- 5.3 Operational Responsibilities

(Comment) Add provisions on the responsibilities of system operators, generators, and transmission asset owners, including maintaining supply-demand balance under normal conditions, prompt restoration during emergencies, maintenance obligations, and prohibition of unauthorized shutdowns.

(Reason) The current rules lack provisions for the most fundamental responsibilities that each party should bear.

- 5.5.2 Outage and Maintenance Programs

(Comment) Include provisions on the policy for outage scheduling and coordination, methods of mutual coordination, and assessments of system reliability during equipment outages.

(Reason) The current rules only specify the process and deadlines for outage planning and coordination.

- 5.8 Emergency Procedures

(Comment) Include provisions on the deployment strategy for black start generators and detailed restoration procedures.

(Reason) The current rules only address information sharing and report submission.

2.9.2. Policy for Developing OperationaLao Grid Code Related to Supply-Demand Management

In September 2022, a hearing was conducted with the System Operation Department of EDL to assess the actual practices related to demand-supply operations, primarily handled by the National Control Center (NCC), in relation to the Grid Code—specifically Chapter 5: Operation and Control Procedures and Requirements. (Refer to Attachment 13 Questionnaire for the 3rdmeeting with NCCProject.pdf)

The assessment revealed that, in general, the actual operational practices fall short of the standards prescribed by the Grid Code. In response to these findings, the following actions were undertaken:

(1) proposals for improvement measures were considered to enhance operational standards; and

(2) revisions were made to certain provisions that were deemed overly stringent or inconsistent with actual operating conditions.

2.9.3. Detailed Discussion on OperationaLao Grid Code

Based on the fundamental concept of developing a Grid Code that reflects actual operational practices, it was concluded that it is currently inappropriate to include provisions in the main body of the Grid Code that assume the implementation of autonomous frequency control, as the basic concepts of frequency control are not yet sufficiently understood or internalized.

Accordingly, all provisions related to future frequency control will be included in the Transitory Provisions section and positioned as future development tasks.

Regarding the introduction of Flat Tie-line power flow Control (FTC), which was discussed during on-site hearings conducted in May–June 2023, it was proposed that while full automation through the NCC system remains a long-term objective, the immediate priority should be to establish hourly planning for power and energy exchange in electricity imports and exports with Thailand. In parallel, a Manual-FTC process should be developed, whereby generator outputs are adjusted in real time through dispatch instructions to ensure that at least the hourly energy values align with the planned values (e.g., to achieve hourly net-zero exchange).

Due to the significant challenges associated with immediate operational deployment of Manual-FTC, revisions to the current frequency control-related provisions were intentionally kept to a minimum, with careful consideration of the GTGOA and GMS RegionaLao Grid Code. Although the removal of provisions currently exceeding operational capabilities—such as the obligation to operate in governor-free mode—was contemplated, such provisions were retained, because these are fundamental provisions that system operators should implement and manage.

A three-phase roadmap was proposed to guide the future realization of supply-demand balancing and frequency control. The plan starts with the implementation of Phase 1 (Manual-FTC) as previously outlined, followed by gradual enhancements through Phase 2 (Automatic-FTC) and Phase 3 (TBC). Provisions related to these phases were not incorporated into the main Grid Code but were instead included in the Transitory Provisions section.

Realization of Phases 2 and 3 is contingent upon the implementation of Load Frequency Control (LFC) and Automatic Generation Control (AGC), enabled by domestic generators in Laos via the dispatch system installed at the National Control Center (NCC). As a necessary next step, conducting feasibility studies (FS) and pilot projects (PP) was proposed. Upon establishing a clear outlook for implementation through these efforts, promotion of the relevant provisional rules into the main body of the Grid Code was recommended.

Additional points to consider in structuring the Grid Code are as follows:

The list of topics to be covered will be based on the current Lao Grid Code, ensuring a comprehensive and balanced structure without omissions or redundancies.

However, since the current Lao Grid Code has not been formally approved by EDL and does not adequately reflect operational realities, the content will be fundamentally revised or supplemented by referencing Thailand EGAT's Operation Code and the GTGOA (Grid to Grid Operational Agreement between EDL & EGAT) described below, either by replacing existing articles or adding new ones as appropriate.

2.9.4. Developing OperationaLao Grid Code Related to Supply-Demand Management

Regarding the revision of grid codes related to power system operation in Laos, EDL and the JICA expert team held multiple meetings starting in September 2023 to confirm the basic policy for the new codes. The new codes will be based on the current Chapter 5, with missing items supplemented by referring to GTGOA and GMS regional codes, while maintaining a simple structure and separating detailed provisions into manuals.In particular, regarding frequency control, two options were presented: a "simplified revision version" that does not interfere with current operations, taking into account EDL's lack of practical knowledge, and a "detailed revision version" that looks toward the future. While discussing both options, discussions were also held on equipment requirements for the introduction of AGC and GF, clarification of responsible entities, and the establishment of data acquisition and sharing rules, and preparations were made for a field survey in March 2024.

Currently, EDL/NCC does not implement frequency control, so it will take too much time to build up the necessary knowledge. Furthermore, given the current operational situation, it is not advisable to drastically revise the grid code related to frequency control based on examples from advanced countries. Therefore, the following proposal was made as a conclusion to the grid code revision work in this project, and the following plan was formulated.

- Regarding revisions to frequency control, two options will be presented: a simplified revision version that modifies the current Lao grid code to the extent necessary to avoid conflicts with current operational practices, and a detailed revision version that completely rewrites the grid code based on the current code.
- The simplified revision version will respect the provisions of the current Lao Code as much as possible and revise only the minimum necessary parts. However, provisions related to Ancillary Services or Frequency Regulating Reserves, which are unfamiliar in current operations, will have their effective dates postponed until future conditions are established. Additionally, new provisions will be added to the NCC to specify that the NCC is responsible for implementing these conditions. NCC shall be responsible for implementing these conditions, among other new provisions.

Furthermore, we have drafted revision proposals in the following three new areas:

- Data Exchange
- Time Schedule of Operation, Maintenance Planning

- Time Schedule of Scheduling & Dispatch

Please refer to the attached documents for the draft revision of grid codes in the system operation field and the guidelines for frequency control established based on the detailed revision.

Attachment 73 01-2_Lao_Grid Code_(Operation Code)_Manual_r4.1.0.docx

Attachment 74 01-c_Lao Grid Code (Operation Code)_Comparison_r4.1.1.docx

Attachment 75 02-1_Guideline_Frequency Control_Attachment (GC)_r1.0.0.docx

Attachment 76 02-2_Guideline_Frequency Control_Attachment (Mnl)_r1.0.1.docx

Attachment 77 02-c_Guideline_Frequency Control_Comparison_r1.0.0.pdf

The following documents were used in explanations and discussions with the other party during the formulation of grid codes in the system operation field.

Attachment 18 20230530_GC upgrade_Scheduling&Dispatch.pdf

Attachment 19 20230609_GC upgrade_WrapUp.pdf

Attachment 20 20230530_GC upgrade_S&D_App.pdf

Attachment 31 20230922_GC upgrade_policy_fixed_d.pdf

Attachment 32 20230928_GC upgrade_Small Meeting_fixed_d.pdf

Attachment 33 Frequency Control Code Draft_p.pdf

Attachment 43 20240301_GC upgrade_Data Collection_r4_d.pdf

Attachment 44 ①202406xx_GC upgrade_Review of Inverter Based Connection_ENver2_0531.pdf

Attachment 45 ②Lao Grid Code Update Report_GridSTART (DRAFT_1_28_21_r1).pdf

Attachment 54 JCC_Part3_Power System Operation_r1.pdf

Attachment 58 20211215_JCC_Power_Quality_V3

Attachment 64 20250304_JCC_Part3_Power System Operation.pdf

Attachment 68 20240909_GC upgrade_Balancing Planning & Scheduling_d.pdf

2.9.5. Transmission Line Protection Relay

At the Joint Coordination Committee (JCC), it was agreed to consider replacing or upgrading certain transmission line protection relays. Furthermore, in the meeting with EDL in February 2022, concerns were raised about frequent faults and outages occurring on the 115 kV system, and EDL requested improvements to the 115 kV transmission line protection system.

Among protection relay schemes, differential protection relays, which detect internal faults from both ends of a transmission line section, are considered the most reliable in isolating faults. They offer high reliability and do not require setting adjustments even when a new substation is installed along the line—unlike distance protection relays, which typically require such adjustments.

However, under the current Lao Grid Code, the following requirements are specified for transmission lines and transformers:

3.3.3 Protection scheme shall include Primary and Backup protection.

3.3.4 The minimum Line Protection shall include the following:

(a) Distance Protection; and

(b) Overcurrent Protection.

3.3.5 The minimum Transformer Protection shall include the following:

(a) Differential Protection; and

(b) Overcurrent Protection.

While these provisions allow for the installation of differential protection relays, it is recommended that future revisions of the Grid Code mandate their use for important supply areas, high-capacity transmission lines (e.g., 500 kV and 230 kV), short transmission segments where distance relay setting is difficult, and for newly constructed lines.

These provisions in the current Grid Code have not been amended under this revision project.

2.10. Grid Code for System Connection

2.10.1. Policy for Developing Grid Codes related to System Connection

The "Connection Code" section of the Grid Code defines the technical requirements and procedures for system users, such as power producers and large consumers, to connect to the transmission network.

At the briefing session held in August 2021 and JCC in December 2021, the following basic policy regarding the Connection Code was agreed upon by MEM and EDL:

(1) General Matters

The content related to Technical Requirements should be significantly enhanced in both quantity and quality.

While the Procedures are described in detail, such procedural content should be separated from the Grid Code and treated as a standalone document. The detailed procedures should be issued as a publicly available document by the system owner (EDL or EDL-T) for use by system users.

(2) Technical Requirements for Generation Facilities

The current Connection Code specifies only:

① the minimum required types of protection relays, and

② circuit breaker responsibilities (maximum fault current and fault clearing time).

For generation facilities, it also specifies:

① available generation capacity,

② operable frequency range,

③ tolerance for unbalanced load,

④ governor system,

⑤ excitation system,

⑥ black start capability, and

⑦ fast start capability.

In addition to the above, the following technical requirements are considered necessary. These should be determined based on operational needs:

① Harmonic suppression

② AGC (Automatic Generation Control) capability

③ Islanding capability (Ability of Units to Island)

(3) Items Not Currently Included in the Grid Code

- Technical requirements for connecting renewable energy (RE) sources
  - Technical Requirements for Variable Renewable Energy (VRE) such as wind and solar should be specified separately from conventional generation facilities.
  - Specific items to include:

① Fault ride-through requirements

② Operable frequency range

③ Active power control

④ Frequency response capability

⑤ Active power ramp-rate control

- In the future, technical requirements for HVDC interconnection may also become necessary.

(4) Confirmation at JCC Meeting

The requirements and direction for the Connection Code were confirmed at the JCC meeting held in December 2021.

- The current Grid Code largely covers the necessary items for the Connection Code (CC); however, some descriptions should be improved.
    - ➢ Since synchronized interconnection with Thailand will continue and future coordination with Thailand will be necessary, it is recommended to refer to the Thai Grid Code.
    - ➢ It is important to clearly describe the technical requirements for VRE (solar and wind) and future high-voltage direct current (HVDC) interconnections.
- EDL's connection checks at the time of interconnection need to be improved, taking reference from Japanese operational practices. Currently, EDL's system planning department does not conduct tasks related to the connection of generation facilities, such as Grid Impact Studies. As a result, they are not familiar with the technical requirements needed for the Application Form.
    - ➢ It was therefore agreed to introduce case studies from Japan on the procedures for interconnecting generation facilities, in order to deepen understanding of the required tasks.
    - ➢ DEM requested that a standardized format be developed to specify what kind of data should be submitted by IPPs to EDL, and how that data should be collected.

2.10.2. Briefing Sessions on Grid Code Development for System Interconnection

In July 2021, during a meeting with EDL, it was discovered that the company's system planning department was not adequately reflecting the Connection Code in its operations. Due to a lack of system analysis tools and experienced technical personnel, it was difficult to conduct Grid Impact Studies and understand technical requirements. EDL also recognized the issues and shared examples from Japan (TEPCO PG) to facilitate discussion. The meeting deepened understanding of the business content and highlighted the importance of standardizing report formats, marking a step toward future improvements.

2.10.3. Study of Thai Grid Code and Recommendations for Lao Grid Code

Review of Thailand's Grid Code and Recommendations for the Lao Grid Code (Connection Code)

(Attachment 6)

The Lao power system is interconnected with Thailand's EGAT (Electricity Generating Authority of Thailand) system via 220 kV AC transmission lines. Given the current strong operational relationship and the expectation of further interconnection in the future, a study was conducted on the Thai Grid Code to extract technical requirements that should be incorporated into the Lao Grid Code.

In Thailand, EGAT operates under a single-buyer model, purchasing electricity from its own power plants, independent power producers (IPPs), and neighboring countries, and supplying it to distribution companies and large consumers. Small Power Producers (SPPs) of 90 MW or less are permitted to sell power not only to EGAT but also directly to consumers.

The Connection Code section of EGAT's Grid Code is composed of the following seven parts:

Part 1: Power Producers with Power Purchase Agreement (PPA) over 90 MW

Part 2: Power Producers with PPA of 90 MW or less

Part 3: Hydro Floating Solar Power Producers

Part 4: Third Party Access (TPA)

Part 5: Codes of Conduct between EGAT and the Distribution Department of the Electricity Authority for Connection Requests

Part 6: Other Types of Power Producers

Part 7: General Appendix

Among the above, Parts 1 and 2 primarily describe the technical requirements for generator interconnection. As of the time of the study, Part 3 did not contain specific content and is assumed to be under review. Part 2 applies to SPPs of 90 MW or less, and provides more detailed procedures than Part 1, including system impact study processes and specific technical requirements for inverter-based generation systems (e.g., Fault Ride-Through (FRT) requirements).

Part 7 (General Appendix) contains comprehensive templates, including generator data forms to be submitted during the interconnection review process. These are considered particularly useful references for the revision of the Lao Grid Code.

When compared to EGAT's Connection Code, the current Lao Grid Code lacks provisions for technical requirements concerning inverter-based generation (such as FRT). These requirements are increasingly standardized in many countries' grid codes and should be incorporated in the Lao Grid Code revision. Additional technical requirements for generation facilities were also identified as candidates for inclusion.

Based on the above findings, the following basic policy for revising the Lao Grid Code (Connection Code) was established and shared with MEM and EDL stakeholders for feedback:

- Make full use of the existing Lao Connection Code where possible
- Supplement missing items by referencing the Thai Connection Code
  - Examples: FRT requirements, data collection forms, etc.
- Simplify the current application procedure descriptions; transfer detailed procedural descriptions to internal EDL manuals
- Items currently found in the Planning Code or Operation Code that are also relevant to the Connection Code should be added accordingly

The following documents were used during explanations and discussions with the other party regarding the establishment of Grid Code for system connection.

Attachment 2 Appendix of Outline of Generator Connection Business at TEPCO PG.xls

Attachment 3 Generator Connection Guideline of TEPCO PG.pdf

Attachment 55 Part4_Generator connection_ver4.pdf

Attachment 59 20211215_JCC_ConnectionCode_ver1_e

Attachment 63 20250228_GC upgrade_Draft_Connection_Code_ver3.1.pdf

Attachment 69 20240904_GC upgrade_Draft_Connection_Code_ver3.pdf

2.11. Generator Connections to Distribution Network

In Laos' power distribution system, protection device requirements during grid connection were insufficient, and there was a particular need to establish rules for preventing independent operation. With the rapid increase in the introduction of VREs such as solar and wind power in the power distribution system, it is urgent to establish connection rules and technical standards to address this issue. In this revision, provisions regarding the prevention of independent operation were added to the Grid Code.

2.12. Safety Regulations

2.12.1. Safety Provisions within the Grid Code

The safety-related provisions in the Lao Grid Code (Lao Grid Code, June 2013 version) are included in Section

2.5 of Chapter 2 and Section 5.9 of Chapter 5, as outlined in the excerpt below:

Chapter 2: Performance Standards

2.5 Safety Standards

2.5.1 Implementing Lao Electric Power Technical Standards

2.5.2 Governing Safety Requirements

2.5.3 Complying with Lao Electric Power Technical Standards

2.5.4 Submission of Safety Records and Reports

Chapter 5: Operation and Control Procedures and Requirements

5.9 Safety Coordination

5.9.1 Safety Coordination Procedure

5.9.2 Safety Coordinator

5.9.3 Safety Logs and Record of Inter-System Safety Precautions

5.9.4 Location of Safety Precautions

5.9.5 Implementation of Safety Precautions

5.9.6 Cancellation of Safety Precautions

The main contents of the safety provisions in the existing Lao Grid Code are as follows:

1) The Lao Grid Code shall conform to the "Lao Electric Power Technical Standards (LEPTS)" and the "Guideline on Operating and Managing the Lao Electric Power Technical Standards" established under the Lao Electricity Law.
2) LEPTS defines safety requirements for the installation, operation, and maintenance of electrical facilities and mandates compliance to ensure the safety of employees, contractors, and the general public.
3) Safety records and reports must be submitted every six months.
4) The Code specifies a set of safety rules and local site safety instructions to implement safety measures for electrical equipment.
5) Grid Owners and Users are required to appoint Safety Coordinators and establish a safety management, communication, and cooperation structure.

Detailed safety rules are stipulated separately. Grid Code safety provisions are generally expected to cover key elements such as safety principles, procedures, responsibilities for protection of human life and equipment, and coordination between operators─all of which are already included, and thus the current content is considered sufficient. However, some descriptions are inconsistent with the current organizational structure and LEPTS definitions, and minor revisions are required.

The key safety-related provisions described in LEPTS are as follows (article numbers only):

3-2 Fundamental Requirements

Article 58: Prevention of Electric Shock and Fire Caused by Electrical Facilities

Article 59: Insulation of Electrical Circuits against Grounds

Article 60: Provision of Earthing on Necessary Points in Electrical Facilities

Article 61: Protection against Overcurrent and Earth Faults

Article 62: Isolation from High-Voltage and Medium-Voltage Electrical Facilities

Article 63: Prevention of Danger Due to Breakage of Electrical Conductors

Article 64: Prevention of Damage to Other Facilities

Article 65: Prevention of Danger Due to Collapse of Supporting Structures

Article 66: Prevention of Electrical and Magnetic Interference

Article 67: Prevention of Serious Obstacles to Power Generation and Power Supply, and Prevention of Damage to Other Electrical Facilities Caused by Damage and Destruction of Electrical Facilities

This section outlines the need for care when installing electrical facilities to prevent accidents that could cause electric shock, fire, or other harm to people or property.

3-3 Common Rules for Electrical Facilities

3-3-1 Protective Safety Installations

Article 69: Prevention of Entry of Any Person Other than Operators to Closed Electrical Operating Areas where High-Voltage and Medium-Voltage Electrical Facilities are Installed

Article 70: Protection of Operators against Dangers of High-Voltage and Medium-Voltage Electrical Facilities in a Closed Electrical Operating Area

Article 71: Prevention of Danger of Low-Voltage Hydropower Electrical Plants

Article 72: Prevention of Climbing onto Supporting Structures

Article 73: Prevention of Damage by Small Animals to Electrical Facilities

Article 74: Prevention of Damage by Rainwater to Electrical Facilities

Article 75: Prevention of Fire Caused by Electrical Equipment

This section stipulates that signs warning of the danger of electrical equipment to non-workers must be installed, and that appropriate measures must be taken to prevent unauthorized access to such facilities.

The "Guideline on Operating and Managing the Lao Electric Power Technical Standards" referenced in the Lao Grid Code was revised in December 2018 and renamed:

“Guideline on Operating and Managing Lao Electrical Power Technical Standards and Safety Rules for Operating and Maintenance, December 2018.”

This guideline supplements the LEPTS and outlines the selection of chief engineers, safety rule formulation, documentation, and reporting obligations for the investigation, design, construction, operation, and maintenance of hydropower plants, transmission lines, substations, and customer-owned electrical facilities.

In addition, the Safety Unit at EDL headquarters (Transmission Standard Section, System Planning Dept.) has issued several practical safety rules (available only in Lao) and conducts annual visits to branches nationwide to provide staff training, audits, village-level safety seminars and awareness activities, and accident response. These include:

- Regulations on labor safety, protection, and disciplinary action (revised September 2018)
- Safety requirements for work in hydropower dams (revised 2017)
- Regulations on safety in transmission lines and substations (revised October 2020)
- Safety requirements for operating mechanical vehicles (heavy machinery) on-site
- EDL regulations on Personal Protective Equipment (PPE) (revised 2021)
- Safety manual for handling electrical equipment in the distribution sector (revised 2021)
- Regulations on responsibilities of EDL and electricity users during short-circuit incidents
- Other pamphlets and safety awareness posters related to equipment security

2.12.2. Referenced Detailed Safety Rules

(1) In Section 2.5.1 of the Lao Grid Code, it is stated:

2.5.1 The Lao Grid Code shall implement the Lao Electric Power Technical Standards (LEPTS) and the

Guideline for Operating and Maintaining the Lao Electric Power Technical Standards under Electricity Law set by the MIH.

Since both the "Lao Electric Power Technical Standards (LEPTS)" and the "Guideline for Operating and Maintaining LEPTS" are frequently revised, the Grid Code should either specify the applicable edition or include wording such as "the latest version of...".

Additionally, since the aforementioned "Guideline" was revised and renamed in December 2018, the text in the Lao Grid Code should be updated accordingly.

As is common throughout the document, "MIH (Ministry of Industry and Handicraft)" should be updated to the current "MEM (Ministry of Energy and Mines)".

(2) Section 5.9.1.1 of the Lao Grid Code states:

5.9.1.1 Grid Owner and Users shall adopt a set of safety rules and local safety instructions for safety precautions implementation on HV and EHV equipment.

However, LEPTS Article 57 defines the voltage classifications in Laos as follows:

Article 57 Classification

The classifications used in Chapter 3 shall be as prescribed in the following paragraph.

1. Classification of voltage

AC voltages shall be classified into low-voltage, medium-voltage and high-voltage, and the range of each nominal system voltage is shown in Table 57-1.

Table 57-1 Classification of voltages for AC

Classification of Voltage	Range of Nominal System Voltage
Low-Voltage	100 V or higher, but not exceeding 1 kV
Medium-Voltage	Over 1 kV but not exceeding 35 kV
High-Voltage	Over 35 kV

(Source: Lao Electric Power Technical Standards, February 2004)

Accordingly, the LEPTS does not include a definition of “EHV” (Extra High Voltage), as used in the Lao Grid Code. Only LV (Low-Voltage), MV (Medium-Voltage), and HV (High-Voltage) are defined. Therefore, references to “EHV” in the Lao Grid Code should either be deleted or revised to say “MV and HV equipment.”

The Grid Code has been revised based on the above content.

2.13. Discussion on Draft Grid Code Revision

On September 4, 2024, and January 24 and 29, 2025, discussions were held at MEM between the JICA Expert Team and MEM, EDL, and EDL-T regarding the draft revision of Lao Grid Code. The discussions focused on three main areas: system operation, system planning, and system interconnection. Topics included the policy for setting FRT, renewable energy connection standards, updating regulations for communication equipment, the entity responsible for conducting system impact studies, handling of ancillary services, clarification of design standard wording, and the necessity of institutional and organizational reforms. The draft revision was compiled taking into account technical comments from EDL-T .Going forward, it will be necessary to clarify role divisions in anticipation of the establishment of a regulatory authority and to advance the development of operational rules and various manuals. The details of the discussions are referenced in Sections 10.5 and 10.6.

2.14. Issues with the Grid Code

2.14.1. Grid Impact Study

When planning to connect a generator to the power system, it is necessary to assess and confirm the potential impacts on the grid. This assessment is called a Grid Impact Study, which is conducted to verify whether the generator connection meets the requirements necessary for the stable operation of the power system.

The Grid Impact Study analyzes the voltage, frequency, power flow, and fault currents of the power system after the generator is connected, using system simulations. Based on the results, it may suggest specifications for the generator or the need for additional transmission lines.

Generally, the Grid Operator, who is responsible for the overall stability of the power system, conducts the Grid Impact Study.

However, EDL currently does not have the capacity to conduct a System Impact Study independently. In practice, the feasibility studies for new power plants are reviewed by developers or donors, and EDL or MEM approves the findings. Therefore, under current conditions, it is difficult for EDL's National Dispatching Center, which has the functions of a System Operator, to carry out Grid Impact Studies. Accordingly, the draft Grid Code maintains the current practice, whereby the Grid Owner is responsible for conducting the study. Similarly, EDL-T, as the Grid Owner, is responsible for conducting Grid Impact Studies for facilities connected to its system.

Ideally, however, the System Operator, responsible for stable and fair operation of the entire power system, should conduct Grid Impact Studies. This point should be reconsidered in future revisions of the Grid Code.

2.14.2. System Protection

As mentioned in Section 4.2, there have been incidents in the 115 kV system where faults may not have been cleared due to protection system failures, leading to blackouts. Current differential relays are generally more reliable than distance relays in identifying fault locations. Thus, many countries now adopt current differential protection as the main relay scheme for transmission lines. However, it requires a communication link between substations at both ends.

In Laos’s current 115 kV power system, many sections still use distance relays as the main protection relay. Since transitioning to current differential relays is costly and difficult to implement in the short term, the revised Grid Code continues to stipulate, as before, that distance relays are to be adopted as the minimum standard for main protection.

In the future, Grid Code revisions should consider mandating current differential protection for key transmission lines.

2.14.3. AGC System

An AGC (Automatic Generation Control) system automatically adjusts the output of multiple generators to maintain system frequency and regional power flow stability. Currently, frequency control in Laos’s system is maintained through synchronization with EGAT's (Electricity Generating Authority of Thailand) system via interconnection lines, with EGAT controlling its own generation.

However, the domestic Lao power system has expanded with increasing demand and new generators. As a result, EDL should begin managing supply-demand balance and frequency control using generators within Laos. Moreover, with the scheduled return of Houay Ho in 2029 and Nam Theun 2 in 2035 to Lao ownership, these large reservoir-based power plants may be used to supply the domestic system. In that case, the system operator within Laos will need to manage their output.

At present, EDL’s energy management system (EMS) is not functional, and many generators lack AGC-compatible features or are not technically capable. Therefore, AGC is not currently implemented in the domestic system.

Since introducing AGC involves significant time and cost, the revised Grid Code does not mandate AGC operation for now. Instead, it is included in the "Provisions" chapter as a future compliance requirement, and the enforcement of AGC-related provisions will be deferred until the necessary conditions are met. In addition, comprehensive Load Frequency Control (LFC) using AGC functionality is presented as a guideline, intended to serve as a foundation for future revisions of the Grid Code.

2.14.4. Renewable Energy Connections

In renewable energy generation, DC power sources or induction generators with variable speed are often used. The electricity generated is converted to the grid's frequency via inverters, then fed into the system. Therefore, the connection code for renewable energy facilities mainly consists of specifications related to inverters, which define the requirements for maintaining system voltage, frequency, and power flow.

This revision establishes renewable energy connection rules by referencing Thailand's EGAT and Japan's connection codes.

In recent years, inverter-based renewable energy sources have increasingly incorporated various control functions aimed at enhancing system stability. Many countries, including Japan, now explicitly include these features in their Grid Codes. These include:

Synthetic inertia to suppress rapid frequency deviations,

Output control functions similar to AGC, and

Voltage control functions for advanced inverter response.

As Laos is expected to expand its adoption of renewable energy, future revisions of the Grid Code should consider enhancing these connection rules to include such advanced inverter control functions.

2.14.5. Electricity Regulatory Agency

In many countries, the electricity regulator plays a central role in managing Grid Codes. This includes leading code revisions, mediating conflicts between stakeholders, and enforcing compliance.

However, at the time this Grid Code draft was formulated, no regulatory authority had yet been established in Laos. Therefore, the preamble to the code includes the following provision:

After the establishment of a regulator, part of the roles of MEM on the Grid Code shall be transferred to the regulator.

Once the electricity regulatory authority is established and its responsibilities regarding the Grid Code are defined, specific provisions outlining the regulator's obligations should be added to the code.

Chapter 3 Current Status of Power System Panning and Operation

3.1. Indicators of Output 2 "Rules and manuals are appropriately established, and interconnected systems are appropriately planned and operated."

The achievement of Output 2, "Rules and manuals are appropriately established, and interconnected systems are appropriately planned and operated." is shown below.

Table 3-1 Indicators of Output 2 Achieved (1)

◎: Completely achieved
○: Generally achieved, but there are ongoing issues.

Results	Indicators	Status of Achievement
2. Rules and manuals are appropriately established, and interconnected systems are appropriately planned and operated.	● Develop interconnection line plans.	Achieved ○
		<Current situation> ・Proposed procedures for formulating system plans including interconnection line plans under the EDL and EDL-T frameworks. In 2024, under the leadership of MEM, EDL participated in discussions regarding the interconnection line plan between the northern and central regions based on EDL-T, and the plan was approved. Additionally, it was proposed that the power regulatory authority should implement adjustments to transmission plans as part of its functions. ・Regarding the procedures for developing system plans, a provision requiring MEM to establish guidelines was included in the draft grid code. ・Furthermore, technical criteria for system plans were specified in the draft grid code, drawing on examples from other countries.
		<Issues> Under the international interconnection plan, it is necessary to conduct comprehensive consultations with Thailand, similar to the existing consultative body, from the perspectives of frequency and voltage control, protection coordination, operational responsibility, information sharing, and other aspects, while complying with the grid codes of both countries.
	● Power flow and voltage control shall be performed in accordance with GC and manuals.	Achieved ○
		<Current situation> In the manual development roadmap, we supported the development of manuals related to power flow and system voltage control, conducted training on power flow and voltage control (June and December 2024), and supported the implementation of power flow and voltage control in accordance with grid codes and manuals.
		<Issues> ・Currently, there are several areas within the system where voltages are consistently high, and phase-advance operation and segmented operation through the opening of transmission lines have become the norm. Therefore, it is necessary to promptly formulate and implement transmission line improvement plans and plans to strengthen phase-regulating equipment. Training content must be continued on an ongoing basis. ・Regarding power flow and voltage control, monitoring by NCC in accordance with grid codes and manuals, along with power system analysis, should be conducted to establish plans for the introduction of necessary transmission lines and power factor correction equipment, and their installation should be advanced steadily.
	● Accident recovery is conducted in accordance with the GC manual.	Achieved ○
		<Current situation> An existing black start manual is available for the EDL. In addition, the manual development roadmap proposes the development of system operation manuals covering accident recovery systems and procedures, system operation during abnormal conditions, detection and response to precursors, and electrical accident reporting, with the aim of supporting accident recovery systems based on future manuals. The grid code defines accident recovery as the restoration of the system from the restorative state to the normal state, and supports the establishment of accident recovery policies.
		<Issues> It is necessary to continue reorganizing the current black start manual and other manuals in a systematic manner based on the roadmap, integrating and organizing them in a consistent manner, and maintaining a stable manual operation system. It is necessary to conduct regular training and education for NCC, RCC, power plants, etc., and establish a system to ensure that grid codes and manuals are reliably referenced and operated in the event of an accident.

Table 3-2 Indicators of Output 2 Achieved (2)

◎: Completely achieved
○: Generally achieved, but there are ongoing issues.

Results	Indicators	Status of Achievement
2. Rules and manuals are appropriately established, and interconnected systems are appropriately planned and operated.	● Based on the GC and manual, investigate causes and implement countermeasures.	Achieved ○
		<Current situation> We proposed regulations requiring accident reports to be submitted to the grid code and supported the establishment of a system for investigating accident causes and implementing countermeasures based on these regulations. In addition, as part of the manual development roadmap, we provided support for the creation of a manual on electrical accident reporting.
		<Issues> The establishment of an EDL operational framework is a prerequisite. It is necessary to establish an investigation system, share measures to prevent recurrence, and maintain a sustainable EDL operational framework that includes an investigation system and shared measures to prevent recurrence.
	● Revise technical specifications and manuals related to power system quality.	Achieved ○
		<Current situation> In Grid Code, standards for power quality, such as voltage, frequency, supply reliability, and harmonics, have been established. In addition, a roadmap for manuals to be developed in the future in the field of system operation has been formulated, and system voltage control and frequency control have been positioned as items to be addressed in order to maintain power system quality.
		<Issues It is necessary to ensure consistency with actual system operation and to continue regular reviews.
	● Reflect the systems and regulations required by GMS-RGC in technical rules and manuals	Achieved ○
		<Current situation> The GMS RegionaLao Grid Code (Draft), developed with the support of ADB, has been prepared with reference to the Grid Code of ENTSO-E, the European wide-area grid operator. The roadmap for the development of a grid operation manual, which has been developed, proposes the development of systems and rules required by this GMS RegionaLao Grid Code (Draft), with reference to current manuals and related documents in developed countries in Europe and the United States, including Japan.
		<Issues> Currently, frequency coordination is handled by EGAT of Thailand, and the current operation does not meet the requirements of the draft GMS RegionaLao Grid Code. In order to establish a wide-area grid system through SS interconnection in the future, autonomous grid operation led by Laos is essential. However, frequency adjustment cannot be performed with EDL. For this reason, this item (frequency coordination) was not included in the draft grid code, but was proposed as an alternative guideline. In the future, based on the maintenance roadmap, it will be necessary to develop operational manuals and control equipment for frequency coordination in stages.
	● Revise generator system interconnection regulations.	achievement◎
		The Grid Code now includes a provision regarding the connection of generators to the grid (Connection Code), which specifies the connection requirements for the connection of renewable energy sources in addition to conventional synchronous generators.

Table 3-3 Indicators of Output 2 Achieved (3)

◎: Completely achieved
○: Generally achieved, but there are ongoing issues.

Results	Indicators	Status of Achievement
2. Rules and manuals are appropriately established, and interconnected systems are appropriately planned and operated.	● Control operations are conducted in accordance with the GC and manual.	Achieved ◎
		<Current situation> I Currently, with virtually no manuals in place, we have presented a roadmap for gradually developing manuals and have proceeded with the development of manuals related to power supply system operation and system control. We have proposed that the development of control operation manuals be carried out in stages, divided into periods before and after the update of the power supply system, and have encouraged the implementation of this plan.
		<Issues> It is necessary to ensure that the system operation and control manual is disseminated and training is provided to personnel in the field so that it becomes established in operations, and that continuous reviews are conducted in line with actual operating conditions.
	● Implementation and expansion of generator GF operation (operation records)	Achieved ◎
		<Current situation> We presented a roadmap for the realization of governor-free operation and load frequency control (LFC), proposed the implementation of a feasibility study on the feasibility of existing generators, and provided support for its implementation and expansion.
		<Issues> In order to further expand governor-free operation and load frequency control (LFC) operation, it is necessary to select generators that can handle these operations, clarify technical requirements, conduct trial operations, and establish systematic collection and evaluation of operating records.
	● Conduct operator training in accordance with the manual.	Achieved ◎
		<Current situation> In the manual development roadmap, we proposed skill certification systems for improving capabilities as items to be addressed, and supported the establishment of worker education systems.
		<Issues> The specific design of the skills certification system and the establishment of an operational system, the formulation of an educational curriculum based on the manual, its introduction into the field, and the implementation of periodic training and evaluation are future issues to be addressed.

3.2. Outline

This chapter investigates the operational status of the power system in Laos, the condition of equipment maintenance, system configuration, load balancing capabilities, the current status of interconnection with Thailand, and the operational status of protective relays, and identifies key issues.

The contents of this chapter were shared with MEM and EDL as progress reports during the project implementation period.

In response to the challenges faced by EDL, such as inadequate data management, excessive reliance on manual operations, and insufficient measures for the introduction of renewable energy, this chapter highlights the need to revise grid codes, establish new operational manuals, and upgrade the NCC (National Control Center) system. Furthermore, aiming to reduce dependence on Thailand, we presented a roadmap to achieve autonomous supply and demand management and frequency control (GF, LFC, AGC) within Laos, proposing a phased implementation plan targeting 2030 and the conduct of a feasibility study (FS) to assess its feasibility.

3.3. Investigation and Issue Identification of the Current Power System Planning and Operation

The current status and issues of EDL's grid planning and grid operations work are described below.

3.3.1. Power System Analysis

- Power flow and voltage calculations are performed by the grid analysis software. There were some points that should be corrected in the parameters of the transmission and substation facilities in the input data.

- Stability analysis to simulate the dynamic characteristics of disturbances in the grid has not been performed. The necessary generator parameters and controller models are not in place.
- PDPATII and PLEXOS have been provided as tools to simulate supply and demand, but have not been fully utilized.

3.3.2. Grid Operation and Demand/Supply Operation Plan

- NCC is studying grid operation plans by season (rainy and dry season), monthly, weekly, and real-time time horizon. The focus is on how to control power low from the central region to the southern region, study of transmission line overload conditions, and study of power import/export power flow conditions to/from Thailand.
- There is a power flow agreement on the stability between the north and Vientiane.
- Seamless business operations from medium- and long-term plans to annual, monthly, and weekly plans for supply and demand operations are not being carried out.
- The NCC has a power generation plan and a power import/export plan on an annual basis, with plans for MW values, but the plans do not quite match up with the actual power flow, due in part to inadequate feed-in information.

3.3.3. Frequency Control

- Frequency adjustment is performed by Thailand. Supply and demand operation work is dependent on Thai EGAT's generator operation, and EDL and NCC do not proactively conduct planning, command, and control.
- EDL's national feeder stations do not implement frequency control, so even if the principles of FFC, TBC, and FTC are known, there is no know-how on how to obtain and operate such information data in practice. It will take time to foster knowledge for this purpose.
- There are no generators with capacity available for primary or secondary control in the Laotian power system for domestic supply.
- In the future, the company must decide whether to re-sign the CA for a large-capacity IPP generator for direct export to Thailand, whether it will be an export-only unit as is, or whether it will be connected to the Laotian grid.

3.3.4. Supply and Demand Management

- The output of power plants in Laos is basically regulated by paralleling units, and any excess or deficiency in the balance automatically flows to the interconnection line.
- The NCC has a power generation plan and a power import/export plan on an annual basis and a MW value plan, but the plan does not match the actual power flow due in part to inadequate feed-in information.

Data and information collection

- NCC has obtained some data as real time. （However, NCC does not have operational characteristic data such as generator start-up and shutdown characteristics. (Commissioning Department has it as test data,)
- For the past two years, we have continued to send input forms to IPP and request data provision for models and parameters for generator dynamic analysis for grid analysis, but IPP has not responded to our request.

3.3.5. Power Line Protection Relay

- Many cases of accidents and power outages on the 115 kV system caused a request for improvements to the 115 kV transmission line protection system.
- Distance relays are applied to the main protection relays on the 115 kV transmission section; during an accident on the 115 kV system, an event was observed in which the protection system failed to eliminate the accident and may have resulted in a power failure.
- The protection relay settling values are reviewed at the following times

  - New settings for new transmission lines and transformers and coordination review of existing relays
  - Review upon discovery of alignment defects
- The only stabilizing relay (SPS) is the overload transfer protection system.

3.3.6. Power Flow Regulation

- Adjustment of interconnection line power flow is performed by commands from Thailand and transmission line protection relays on the Lao side.
- Power flow overloads and deviations from the target range of system voltage are occurring.

3.3.7. NCC/RCC System

- Inadequate system monitoring and system operation and accident recording functions of the NCC and RCC systems.

3.3.8. Power Plant Output Control, GF, AGC Functions

- The NCC system does not have the data necessary to take advantage of the EMS functions. It is difficult for the manufacturer to modify the system.
- For existing generators, it is very difficult to achieve these functions because they were not designed to support governor-free (GF) operation or automatic generation control (AGC) from the time of construction. At the very least, modifications to the control system or additional equipment would be required.

3.3.9. Accident Restoration

- Operator training that is maintained in writing, such as recovery procedure manuals and blackout recovery operation procedures, is properly implemented.

3.3.10. Voltage Control

- Basically, there is a lack of phase-regulating facilities in the direction of voltage reduction, and the voltage tends to remain high.
- Even during the heavy tide period of the rainy season, there were scattered areas where the generators were either operating at zero power factor or in advance phase operation.
- One of the 230 kV Thavieng-Lak20 transmission lines (two lines) has been shut down even during the heavy-main current period to prevent overvoltage. To prevent overload and overvoltage on the transmission line and phase advance operation of generators, the transmission line has been opened and the power system has been divided for a long period of time, resulting in a serious decline in supply reliability.

3.3.11. Services related to Grid Connection

- EDL's Grid Planning Division has been conducting grid connection work such as Grid Impact Study, but has not been able to fully implement it due to the lack of grid analysis tools and sufficiently skilled staff. EDL does not have the capacity to conduct System Impact Studies on its own, and the EDL or MEM approves the contents of the F/S for new power plant construction plans, which are verified by the project operator or donor.

3.3.12. Commissioning Test

- A dedicated committee (Commissioning Testing Committee) has been established for pre-use testing, consisting of several divisions such as the Technical Standard Division, System Planning Dept. and others, to ensure that the testing is conducted properly.

3.3.13. PV in the Distribution System

- Experienced several shutdowns due to instantaneous voltage drops on the grid side
- EDL-Gen Solar power factor is operating at 100% but on a voluntary basis
- The VRE side is left to decide on the configuration and set values of the protective device.
- Technical requirements for grid interconnection are not always in place.

3.3.14. Power Distribution SCADA

- So far, KEPCO's pilot project for power distribution automation, Thailand's power distribution project, HUAWEI's smart meter project (China Exim Bank), and GE Canada's project have been implemented but are not fully functioning.

Investigation and countermeasures for accidents and failures that occur in the power system

- There have been sporadic accidents involving 115/22 kV transformers, five of which occurred within the past five years.
- Failed to confirm transformer maintenance procedures and rules set forth by EDL
- The company owns general maintenance equipment for transformers, such as voltage and ammeter, hydrometer, insulation resistance meter, etc. Vacuum gauges are not owned. Only one insulating oil analyzer is owned, and the number of units is insufficient.
- No measures to investigate the cause of the accident or prevent recurrence have been taken, and no information and reporting operations have been established to provide occupied companies with information on the cause of power outages and restoration prospects.

manual

- Although interviews have been conducted on the actual status of each of these operations, including grid operation, supply and demand operation, interconnection line power flow management, and grid control, there are no documents equivalent to manuals for these operations.

3.4. Propose Measures to Improve Grid Operation

The following roadmap was proposed and technical training was conducted to build a technical foundation for independent operation of supply, demand, and frequency control in Laos and to promote understanding among related organizations. In addition, a phased implementation plan for the introduction of GF and LFC and a direction for the development of an operation manual for standardization of operations were agreed upon.

3.4.1. Presentation of Roadmap for Realization of Governor-Free Operation (GF) and Load Frequency Control (LFC)

- The need to achieve governor-free operation (GF) and load frequency control (LFC: Load Frequency Control) by generators in Laos to independently maintain and improve the real-time supply-demand balance and frequency quality in the country has been a general awareness among MEM and EDL stakeholders. A general awareness has been formed. However, in order to improve the feasibility of implementing the Grid Code, it is essential to clearly indicate which of the existing and planned generation facilities are suitable for implementing GF and LFC (AGC) functions and to provide a concrete roadmap and technical support for implementation. To this end, we proposed a roadmap for generator operation control in February 2023, consisting of the following contents.
    - FY2024: Conduct a feasibility study (FS) of existing generators that could be subject to GF and LFC (AGC) installation.
    - FY2025-2029: Pilot projects (PP) on supply-demand and frequency control are implemented in phases using generators selected based on the FS.
    - From FY2030 onward: Full-scale operation of GF and LFC (AGC) in Laos.
    - For the time being (until 2030), EGAT will rely on FFC (Flat Frequency Control) by the generators owned by Thai EGAT to maintain the overall supply-demand balance and frequency including the Lao PDR system.

As a result, after 2030, Laos plans to implement its own LFC (AGC) and shift to supply-demand and frequency control based on the TBC (Tie-line Bias Control) method. If Laos implements TBC, it will at least be responsible for supply and demand adjustment within the Laotian grid, which will be a fairer form of operation. Furthermore, after FY2040, Thailand's EGAT will also shift to the TBC system, with a view to establishing a system in which both countries share responsibility for frequency control at their respective power generators.

3.4.2. Maintenance of Manuals in the Field of Grid Operation

In the field of grid operation in Laos, manuals based on the Grid Code are required to constantly improve the quality of operations. Currently, there are no manuals for grid operation, supply-demand adjustment, and management of interconnection lines, and it is necessary to visualize the actual status of operations and develop them step by step.

Manual development will proceed in the following steps

- Identification of target items: Priority is given to areas that are highly effective in improving business quality.
- Confirmation of the actual status of operations: Visualize the flow of operations through on-site interviews.
- Redesigning the way of proceeding: Through advanced case studies and on-site studies, we formulated a plan for improvement.
- Trial introduction and verification: Trial within the scope that does not interfere with business operations, and identify issues.
- Formal establishment: Feedback is reflected and formalized into a manual.
- Dissemination and monitoring: Penetration of the system to all concerned parties and continuous evaluation of the operational status.
- Ongoing updates: Content updates in response to system revisions and business changes.
- Chronological implementation plan
- 2026～ 2027: Three fields were selected as initial target fields: (1) system maintenance, (2) supply and demand operation, and (3) interconnection line power flow control. These are areas that can be handled by current operations, and we will proceed with phased trials and the establishment of manuals.
- 2028～ 2029: Expand to (4) regulating power maintenance, (5) distant operation and operational safety, and (6) renewable energy output forecasting. Start maintenance based on the status of updating the feed-in system.
- 2030～ 2035: Expand the scope of maintenance to all remaining sectors. Aim to complete systematic maintenance as policies for the introduction of new feed-in systems and interconnected operations are put in place.
- In the initial stages, it is important to establish the design philosophy and quality maintenance methods of the manual itself, and careful implementation is key to smooth deployment later.

3.4.3. Conduct Training and Grid Code Briefings

With the aim of improving technical capabilities in grid planning and operation in Laos, technology transfer related to grid analysis and supply-demand operation planning was conducted. in the analysis using PSS/E and DigSILENT, there were many incomplete data and incorrect settings, requiring assistance from the basics, such as understanding PU methods and impedance. In addition, a simulation model considering regulating reservoir hydropower was introduced for supply and demand operations, and practical skills for EDL and DEPP were strengthened through training. TEPCO PG's grid connection practices were also introduced to deepen understanding of form maintenance and study flow. Training on oscillographs and solar output forecasting tools was also provided.

3.5. System Planning

System planning is formulated by the Power System Planning and Control Department of EDL. This department consists of four groups: the System Planning Division, the Engineer and Design Division, the Loss Reduction and DSM Division, and the Technical Standard Division. Among them, the System Planning Division is responsible for system planning.

	Organizations engaged in power system planning	
	1. System Planning Division	
	2. Engineer and Disign Division	
	3. Loss Reduction and DSM Division	
	4. Tectnical Standard Division	
	Power System Planning Division	
	1. Mr. Khamsouk BOUNLAVONG	Head of Division
	2. Mr. Chitpanya PAMISITH	Deputy Head of Division
	3. Mr. Sithamma SOUVANNASAN	Deputy Head of Division
1. Power System Analysis Unit	**2. Power Development Plan Unit**	**3. Demand forcast and Data Analysis Unit**
1. Mr. Kaiphasone KEOMANIVONG; Head of Unit		1. Miss Alisack YANSANA; Head of Unit
		2. Ms. Khetsalin LUANGAMAT; Deputy Head of Unit
1.1. Power System Analysis Group	**2.1. Power Development Plan Group**	**3.1. Demand forcast and Data Analysis Group**
1. Mr. Khounsombad KHOMPHAMY, Head	1. Miss. Khamphouvin SOUMBONKHANH, Head	1.Mr. Daosamai KEOMANIXAY; Deputy
2. Mr. Peeza LATTHASING; Deputy	2. Mr Hongsakoun KONGSAP ; Deputy	2.Mr. Phonpadit LINTHAVONG; Engineer
3. Mr. Soudpanya THONGPORK; Engineer	3. Miss. Aksonsavanh PAKAISON; Deputy	3.Mr. Ganthanachack VORABOUT; Engineer
4. Mr. Sengdavone CHANTHAVONG; Engineer	4. Mr. Sayphasith DOUANGPHACHANH; Engineer	4. Mr.Souksakhon NORIN; Engineer
5. Mr.Aeksacksy PHILAVONG; Engineer	5. Mr. Thanomsak PHOLSENA; Engineer	5. Ms. Thavisouk HEAUNGPASEUTH; Engineer
	6. Mr. Anoudeth MONECHANDY; Engineer	

Figure 3-1 Organizational Structure for System Planning Activities

Power system analysis software such as PSS/E and DIgSILENT is currently in use. While load flow and voltage calculations are being conducted, stability analysis—which simulates the dynamic behavior of the power system during disturbances—has not yet been implemented. This is because the necessary generator parameters and control system models have not been adequately developed.

It is also noted that EDL-T commenced full-scale operations in January 2024. EDL-T is now responsible for planning 500 kV and 230 kV transmission lines for the domestic power supply system in Laos. However, since these plans also affect EDL and other power utilities, the planning and approval process must include consultations with MEM, EDL, and other stakeholders to ensure the protection of power system users' interests and maintain fairness. This procedure should be reflected in the revisions to the Grid Code regarding system planning. The same approach should apply to EDL's transmission planning.

3.5.1. Stability of Nam Ou Hydropower Plant

A north–south interconnected transmission system, comprising 230 kV and 115 kV lines over a distance of more than 600 km, has been developed and is currently operated from the Nam Ou hydropower stations in the northern region, through Vientiane, to the EGAT system in Thailand. Since the commissioning of Nam Ou 2, 5, and 6 in 2016, power oscillations have been observed during periods of high export flows to EGAT. In response, EDL has limited the power flow between Luang Prabang and Hin Heup to approximately 200 MW to maintain system stability.

The JICA Power System Master Plan proposed the reallocation of Nam Ou 3–7 (total installed capacity: 972 MW) for exclusive export to Vietnam. Conversely, the National Power Development Plan (NPDP) considers these plants as supply sources for the domestic grid in anticipation of increasing demand in the northern region.

However, power system analysis indicates that even if the output from Nam Ou 3–7 is consumed locally in northern areas—thereby minimizing power flow toward Vientiane and the EGAT system—system stability cannot be maintained in certain cases unless the output is curtailed to approximately 50% of the installed capacity.

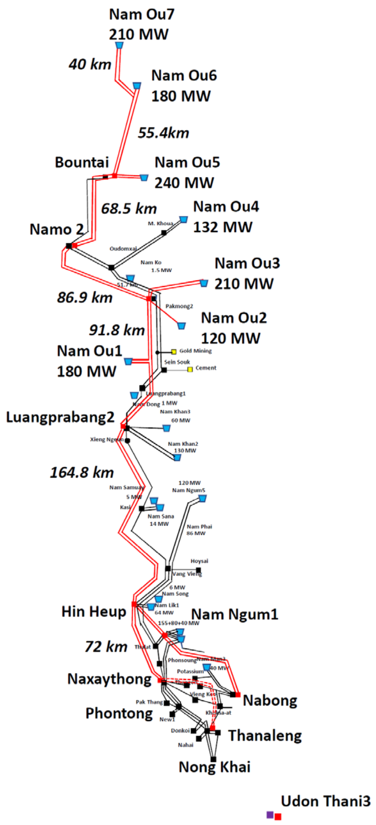


Figure 3-2 Transmission Line from Northern Laos to Nong Khai via Vientiane Area

In order to fully utilize the power generated by Nam Ou 3–7 for domestic supply—even if the electricity is consumed locally within the northern region—it is necessary to strengthen synchronous interconnection through the construction of new 500 kV transmission lines to large-scale systems such as EGAT, or to install large-capacity voltage support equipment.

Accordingly, the following options need to be considered to maximize the utilization of generation from Nam Ou 3–7:

- Retain the Nam Ou plants within the domestic grid and promote local consumption in the northern region, while limiting power flow toward the Vientiane area, and establish synchronous interconnection of the domestic grid at 500 kV with either Thailand or China.
- Disconnect Nam Ou 3–7 from the domestic grid and directly connect to Vietnam via multiple 230 kV routes or to China via a 500 kV line.

In 2024, EDL-T, in coordination with EDL, proposed a plan to construct a new 230 kV transmission line from Udomxai Province in the north, through Bolikhamsai, to Khammouane Province, to transmit power from northern plants including Nam Ou to the central region. While power flow analysis including this line has been conducted, system-wide stability analysis has not yet been carried out. Therefore, further analysis and evaluation of system stability remain necessary.

3.5.2. System Configuration

(1) Synchronous Interconnection with Thailand

At the JCC meeting held in December 2021, EDL expressed interest in enhancing synchronous interconnection with EGAT and exploring the operation of a unified Thailand–Lao power system.

One of the objectives of this project is to enable the Lao domestic power system to autonomously manage its own supply-demand balance, thereby allowing the Lao side to control power flows on the interconnection lines and contribute to frequency regulation in the Thailand–Lao synchronous grid.

Currently, however, frequency regulation is conducted by the Thai side. Power flow on the interconnection lines is controlled either by instructions from Thailand or by transmission line protection relays on the Lao side. Output adjustments of Lao domestic power plants are generally carried out by connecting or disconnecting generating units, and any resulting imbalance is automatically transferred through the interconnection lines.

In line with the above policy direction, the proposed amendments to the Lao Grid Code were developed as follows:

Referring to the GMS RegionaLao Grid Code, provisions not included in the current Lao Grid Code—especially those related to regional supply-demand balancing and frequency regulation, such as the Load Frequency Control and Reserve (LFCR) Code—were extracted. A draft version adapted to the organizational structure and operational practices of EDL was prepared.

(2) Three-Block Operation of the Lao Power System

During meetings with DEPP in February 2022, including a high-level interview with the Director General, a proposal was made to divide the Lao power system into three operational blocks: the northern region (synchronously connected with China via 500 kV lines), the central region (synchronously connected with Thailand), and the southern region (synchronously connected with Cambodia and/or Vietnam). The aim is to export power from each region to its respective neighboring country, thereby utilizing surplus domestic generation.

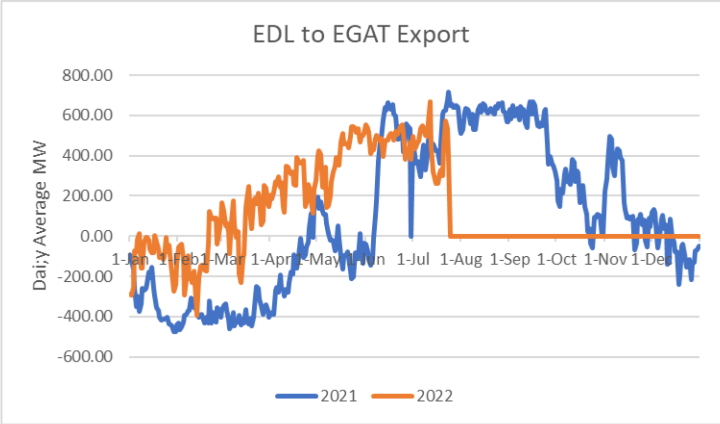
As with synchronous interconnection with Thailand, further examination is required on how to manage supply-demand balancing and power flow control within the Lao domestic system in the context of this three-block configuration.

3.5.3. Current Export/Import between Lao and Thai Grids

Figure 3-3 shows the daily average electricity import/export volumes between the Lao domestic power system and Thailand from 2021 to the latter half of July 2022. A comparison of the dry season (January to May) reveals that in 2021, electricity imports from Thailand were dominant, indicating a significant power shortage during the dry season. In contrast, during the same period in 2022, Laos was largely exporting electricity, reflecting an increase in surplus generation.

Throughout January to June 2021, Laos was consistently importing electricity. However, in 2022, import volumes declined, and by March, the trend had shifted to net exports, indicating an increase in surplus electricity. This shift is considered to be largely attributable to the commissioning of Nam Ou 3 (210 MW), Nam Ou 4 (132 MW), Nam Ou 7 (210 MW), and the Nam Ngum Extension project in 2021, which significantly increased generation capacity.

Additionally, slower-than-expected growth in domestic demand in 2022, along with interannual differences in rainfall, may have contributed to the observed changes. Going forward, the emergence of large-scale consumers and the potential for substantial demand growth warrant continued close monitoring of the supply-demand balance.



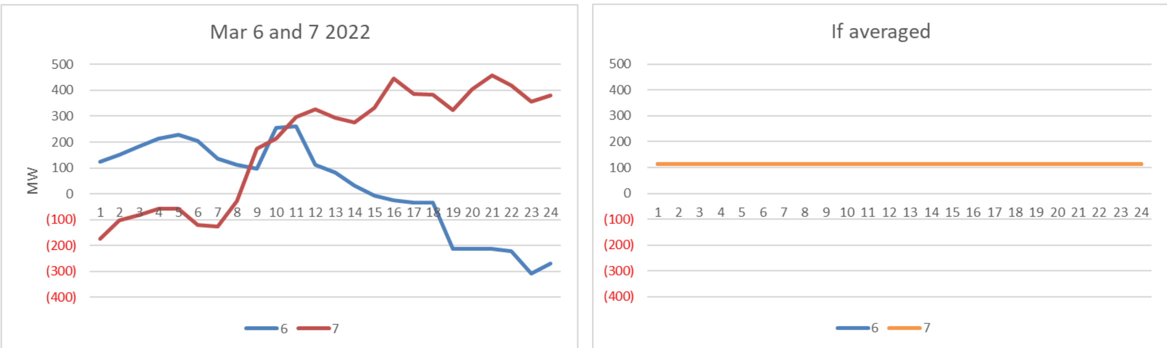
(Source: Data from EDL NCC)

Figure 3-3 Daily Average Power Import/Export between Lao Domestic System and Thailand (2021–July 2022)

When viewed on an hourly basis, import and export volumes fluctuate, as exemplified by the data for March 6–7, 2022 shown in the left panel of Figure 3-4, where imports and exports alternated throughout the day. Despite these fluctuations, the aggregate power flow from the Vientiane area to Thailand over the two-day period was in the export direction. Therefore, in cases where the unit import price exceeds the export price on an hourly basis, adjusting the flow to maintain consistent hourly exports— as illustrated in the right panel of Figure 3-4—can result in improved financial outcomes.

The Vientiane area is characterized by a relatively high share of reservoir-based hydropower, which allows for real-time adjustment of generation output in accordance with the supply-demand balance by modulating water discharge over short timeframes. As such, it is technically feasible to maintain a relatively stable power flow along the interconnection lines. From the perspective of power flow management as well, controlling interconnection flows to desired levels is considered a necessary operational requirement.

Figure 3-4 Hourly Power Import/Export from Vientiane Area to Thailand (March 6–7, 2022)



(Source: Data from EDL NCC)

3.6. System Operation

3.6.1. Survey on Actual Operational Practices

Between early 2023 and August 2023, site visits were conducted to key facilities including substations, power plants, the National Control Center (NCC), and Regional Control Centers (RCC), accompanied by interviews with operational personnel from Électricité du Laos (EDL), NCC, and RCC regarding the actual practices of system operations. As a result, the following key findings were reaffirmed:

- System operations are not being conducted in accordance with the existing Laos Grid Code. Furthermore, internal operational manuals and documentation within EDL are either insufficient or not properly shared among staff.

- Specific issues were identified, including insufficient data required for power system analysis, improper relay protection settings, instances of power flow overloading and voltage deviations beyond target ranges, and inadequacies in system monitoring, operational control, and disturbance recording functions within the NCC and RCC.
- These deficiencies have led to reduced reliability of power supply, with frequent outages reported even in Special Economic Zones (SEZs), where stable and high-quality electricity supply is particularly needed. No clear root cause analysis or recurrence prevention measures have been established, and there is no system in place for informing or reporting outage causes and recovery timelines to tenant companies.

These issues largely pertain to what may be broadly categorized as "system operation functions," and more specifically, to the "operation of transmission and distribution facilities" (i.e., narrow-sense system operation). On the other hand, with regard to the other key pillar of system operation—namely, "supply-demand balancing and frequency control operations" (hereafter referred to as "supply-demand operations")—preliminary surveys and interviews were conducted with NCC operational staff in the September 2022 field mission.

From the interviews to date, it was understood that supply-demand operations are almost entirely dependent on generator dispatching by Thailand's EGAT, and that EDL and NCC do not independently conduct planning, instruction, or control. Moreover, there is no seamless operational planning framework in place covering the full time horizon from medium- and long-term supply-demand planning to annual, monthly, and weekly planning. However, for the formulation of the Grid Code, further in-depth interviews and documentation related to operational procedures—especially in the near-real-time domain of "day-ahead scheduling and real-time dispatch operations"—have been insufficient. Accordingly, during the May–June 2023 field missions, particular emphasis was placed on investigating this area.

3.6.2. Roadmap and Feasibility Study for Governor-Free Operation and Load Frequency Control (LFC)

The necessity of implementing Governor-Free (GF) operation and Load Frequency Control (LFC) using Lao-based generators, in order to autonomously maintain and improve real-time supply-demand balance and frequency quality within the Lao power system, is already generally understood among stakeholders at the Ministry of Energy and Mines (MEM) and Électricité du Laos (EDL). However, for the Grid Code currently under development to be accepted and implemented by Lao operational personnel, it is essential to present concrete implementation measures—specifying which existing or planned generators will be utilized and how these functions will be realized.

Accordingly, in February 2023, a proposal was made to present a roadmap for achieving GF and LFC, along with a new feasibility study (FS) to assess the technical viability of implementing GF and LFC (AGC) functions using existing generators. (See Figure 3-5 and Attachment 17 Suggestion for the Next Step.pdf.)

The proposal consists of the following key elements:

- To establish GF and LFC (AGC) functions in Laos by 2030:
  - Conduct a feasibility study in FY2024 to identify suitable generators.
  - Implement a pilot project (PP) over approximately five years (FY2025–FY2029) to demonstrate supply-demand balancing and frequency control using selected generators.
- Until 2030, rely on Thailand's EGAT generators for system-wide supply-demand balancing and frequency control, including the Lao grid, through the Flat Frequency Control (FFC) scheme:
  - FFC is a control method that detects only the deviation between system frequency and the target value, automatically adjusting the output of designated generators to maintain constant frequency.
  - Under this scheme, EGAT generators maintain the frequency of the entire interconnected system, including Laos, using only generators located in Thailand.
- From FY2030 onward, operationalize GF and LFC (AGC) in Laos. For LFC, adopt the Tie-line Bias load frequency Control (TBC) method to maintain frequency domestically while managing scheduled

power flows with Thailand across international interconnection lines. EGAT would continue to operate FFC as a backup to help stabilize the overall system frequency:

- TBC is a method that detects deviations both from the frequency target and from scheduled tie-line flows, and calculates the Area Requirement (AR)—i.e., the supply-demand imbalance—for each area. The control objective is to bring AR to zero.
- Transitioning to TBC would enable Laos to manage its internal supply-demand fluctuations with its own generators, providing a more equitable operational arrangement.

- From FY2040 onward, consider the possibility of Thailand's EGAT also transitioning to TBC, so that both countries take full responsibility for frequency control using their own generating resources. (This transition would only proceed if Thailand agrees; there is no need to pursue it unilaterally.)
  - In fact, such a transition is technically feasible. For example, in Japan's 60 Hz western region, frequency control is not conducted via FFC; instead, each regional control area operates under TBC using its own generating stations.

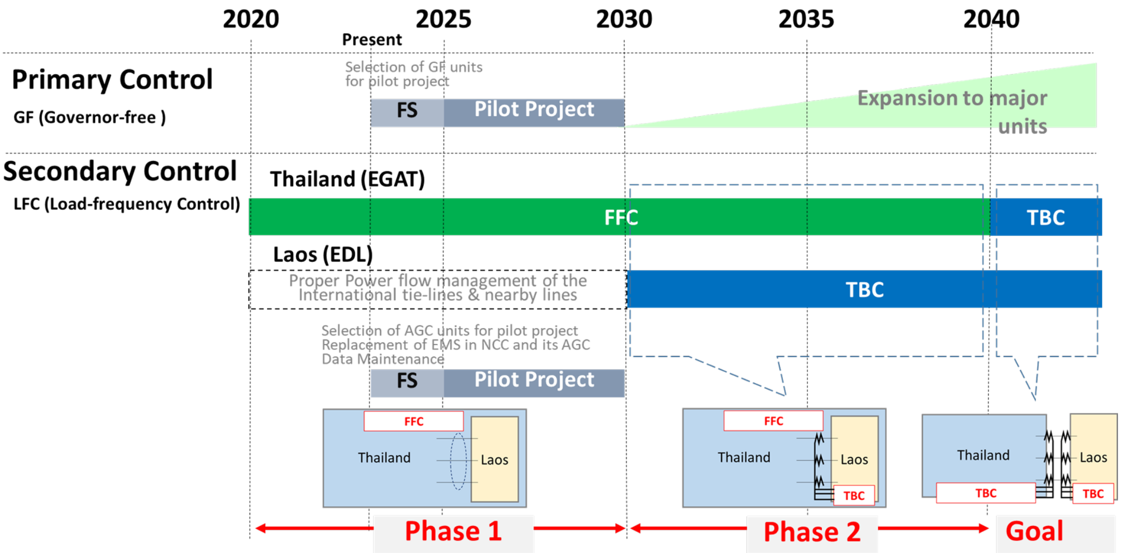


Figure 3-5 Roadmap for Frequency Control Improvement in Lao-Thai Synchronous Interconnection

Candidate hydropower p/s in Laos for frequency regulation function

P/S	Basin	Effective Water Storage [x 10^6 m3]	% investment by Lao PDR	% investment by EDL-gen	Unit Capacity [MW]							
					1G	2G	3G	4G	5G	6G	7G	8G
Nam Ngum 1	NamNgum	4,700		100%	17.5	17.5	40	40	40	40	40	40
Nam Theun 2	Nam Thuen	3,378	25%		250	250	250	250	35	35		
Nam Ngum 2	NamNgum	2,970		25%	205	205	205					
Nam Lik 1/2	NamNgum	826		10%	50	50						
Nam Khan 2	Nam Khan	635		100%	65	65						
Houy Ho	Sekong	527		20%	75	75	2.1					
Nam Ngum 5	NamNgum	251		15%	60	60						
Houy LamPhan Yai	Sekong	128		100%	44	44						
Nam Phay	Nam Ngum	52		15%	43	43						
Nam Ou2	Nam Ou	25		15%	40	40	40					
Nam Ou5	Nam Ou	11		15%	80	80	80					
Nam Chian	Nam San	8		100%	52	52						

Candidates for our proposal of pilot project: GF+AGC / GF

Candidates currently being negotiated by EDL for use in a AGC pilot project: AGC

[GF] + [GF+AGC] = 2,993 MW

Figure 3-6 Candidate Hydropower Units for GF and LFC (AGC) in Laos

In response to the above proposal from the JICA Expert Team, EDL provided the following comments and questions:

- Implementing GF or AGC using existing generators, including those owned by IPPs, would be extremely difficult since such functionalities were not considered at the time of construction. At a minimum, retrofitting would be required, and the associated cost implications would be critical.
- EDL expressed understanding that such functionalities can be mandated for new generators through provisions in the Grid Code going forward.
- Regarding the power plants listed in the final slide (Figure 3-6): Are these facilities capable of implementing GF and AGC?

  → The table merely represents a preliminary screening of candidate plants based on parameters such as reservoir capacity and unit capacity. The proposal suggests prioritizing these plants for site visits during the feasibility study (FS), followed by detailed discussions with local experts and technical assessments to narrow down suitable candidates.

As noted above, the proposal was not met with explicit opposition; however, no concrete steps have yet been taken as of this time.

As additional information, during meetings with EDL held as part of the field survey in May–June 2023, the same slide (Figure 3-5) was presented. In those discussions, an alternative approach to LFC (AGC)—namely, Flat Tie-line power flow Control (FTC)—was also suggested as a potential method.

3.6.3. Status of Power System Analysis

On August 3, 2021, a meeting was held with the National Control Center (NCC) and the EDL Technical Department to follow up on the questionnaire presented in March. The meeting focused on clarifying unanswered or ambiguously answered items through interviews.

- At the NCC, power system analysis is conducted across various time horizons: by season (rainy and dry), monthly, weekly, and in real time.
- Key considerations for the rainy season include controlling power flows from the Central to the Southern

region, assessing transmission line overloading conditions, and evaluating export of electricity to Thailand.

- For the dry season, the focus is primarily on analyzing power flow conditions based on electricity imports from Thailand.
- NCC utilizes DigSILENT as its primary analysis tool. The EDL Technical Department uses both PSS/E and DigSILENT in parallel.
- The main areas of analysis include power flow, voltage, and system stability calculations. Short-circuit capacity is not analyzed at present, as existing values are well below the circuit breaker ratings (31.5 kA and 40 kA for 115 kV and 230 kV systems, respectively).
- A key challenge in obtaining data for analysis lies in acquiring dynamic simulation models and parameter settings for generators. For the past two years, requests have been sent to IPPs using standard input formats, but no responses have been received.
- Regarding generator dynamic modeling parameters currently entered into PSS/E, it was stated that only "typical" data are being used. (While the exact meaning is unclear, it is assumed that they are using default generator models and parameter values pre-installed in PSS/E.)
- There are no significant obstacles in obtaining fundamental data for static power flow analysis, such as active/reactive power, transmission line and transformer impedance, and thermal capacity. It was noted that static power flow analyses are always conducted using the most up-to-date numerical data, network configurations, and planned equipment outages.
- As an example of data sharing and development of common analysis models with other transmission system operators (TSOs), past collaboration with Thailand's EGAT was cited. However, due to the impact of COVID-19, no recent joint studies have been carried out, with the most recent example dating back to 2018.

3.6.4. Management of Operational Security Limits

- At the NCC, routine system management is limited to monitoring power flows (including overload conditions), the operational status of the overload protection system (automatic transfer trip system), and managing constraint-related parameters. Frequency control is entirely dependent on EGAT.
- Parameter changes are appropriately managed.

3.6.5. Preparation of Restoration Procedures and Emergency Drills

- Restoration procedures, including blackout recovery operation manuals, are documented. (Provision of sample documents has been requested for a later date.)
- Operator training is being conducted appropriately. The main training activities are as follows:
  - Joint training sessions with EGAT held at the EDL Training Center located adjacent to the EDL headquarters building.
  - On-site practical training on equipment operation at substations and other facilities.
  - Fundamental operational skills are acquired through on-the-job training.
- To become an NCC operator, the following education and training are required:
  - A three-month training course at the EDL Training Center.
  - One week of joint training with EGAT.
  - A written examination.

3.6.6. Management of Protection Relays

- The review of protection relay settings is being appropriately conducted at the following key stages:
  - When new transmission lines or transformers are commissioned, new relay settings are applied and coordination with existing relays is reviewed.

- When relay setting issues or malfunctions are identified.

- The only system currently in place for system stabilization (Special Protection Scheme, SPS) is the overload transfer protection system.

[Challenges]

- For transmission lines of 230 kV and above, current differential protection is applied. However, for the more prevalent 115 kV lines, distance protection remains the dominant scheme. (The current Lao Grid Code also designates distance protection as the standard method.)
- Distance protection requires careful coordination between relays, particularly with respect to reach settings (fault detection range) and timer settings (tripping delays).
- Inadequate coordination can result in unintended relay operations and breaker tripping, unnecessarily expanding the outage area. Such unnecessary expansion of outage areas not only increases the frequency of power interruptions for individual customers but also prolongs restoration time. This is particularly problematic for industrial users in sectors where product quality is sensitive to power disruptions, potentially leading to customer complaints and posing a barrier to economic development through industrial promotion and investment attraction.
- In recent years, new substations have been installed between existing transmission line segments, particularly in the Vientiane area due to increasing demand. In such cases, it is necessary to review and adjust the reach and timer settings of distance relays. However, these updates are often overlooked.
- Moreover, with the increasing proximity between substations and shortening of transmission line lengths, coordinating protection relay settings becomes technically more challenging. In such cases, transitioning to current differential protection is generally recommended at an early stage. However, progress in implementing such equipment upgrades appears to be limited.

3.6.7. Implementation of Commissioning Tests

- During commissioning tests, a dedicated Commissioning Testing Committee is established, comprising members from multiple departments including the Technical Standards Division and System Planning Department. The testing procedures are implemented appropriately.

The challenges identified through this activity and the proposed direction for future investigations and actions are summarized below:

- (Challenge 1) Inability to collect dynamic simulation data for existing generators
- Despite exhaustive efforts by EDL, it is no longer practical or efficient to invest additional time and resources in searching for missing data. Therefore, for the time being, the only feasible approach is to continue using standard models in PSS/E to capture overall system behavior trends.
- The current priority should be the immediate development and approval of grid connection rules for generators, including making the submission of dynamic data a mandatory requirement under the Grid Code for any new generator applying for grid connection.
- Subsequently, to institutionalize these rules in practice, it will be essential to raise awareness among generator operators via the GMC (Grid Code Management Committee), and to conduct regular outreach activities such as seminars hosted by the GMC to promote understanding of the Grid Code more broadly.

(Challenge 2) The main protection system for most 115 kV transmission sections relies on distance relay schemes, and inadequate settings have led to unnecessary line trips, lowering supply reliability

- It is recommended to conduct a site visit to the Phonetong Substation, which manages protection relays, in order to investigate the protection philosophy, the policy for determining relay settings, actual relay setting values, and locations and frequency of outages caused by misoperations.
- Based on the findings, necessary considerations should be reflected in the revision of the Grid Code and in the development of relevant operational manuals.
- For areas where unnecessary outages occur frequently, it is recommended to upgrade the protection

scheme from distance relays to current differential protection.

3.6.8. Power Flow Management in System Operation

- Particularly during the rainy season, the Lao power system experiences heavy power flows. To avoid transmission line overloading, the domestic grid is at least divided into three regional subsystems: Northern–Central 1, Central 2, and Southern.
- The grid separation points and the reasons for separation are as follows:

Between Central 1 (C1) and Central 2 (C2)

Separation point: Pakxan–Khonsong (This transmission line remains open throughout both rainy and dry seasons.)

Reason for separation:

- If this line were not opened, the output from the Nam Chaine, Nam Guang, and Nam Ngiep 2 hydropower plants would be added to the southbound flow on the 115 kV Thanaleng–Nong Khai interconnection with Thailand, leading to overloading.
- By opening this line, the output from these power plants is more likely to flow into Thailand via the Pakxan–Bungkan interconnection, thereby reducing the southward flow on the Thanaleng–Nong Khai line. In effect, it enhances the northbound pressure and mitigates the overloading.

Between Central 2 (C2) and Southern (S)

Separation point: Thakhek–Pakbo (Opened only during the rainy season.)

Reason for separation:

- If this line were not opened during the rainy season, the single circuit interconnection between Pakbo and Mukdahan (Thailand) would become overloaded. During the dry season, this separation is not applied; instead, the Pakbo–Mukdahan line is taken out of service.
- Additionally, due to severe overloading issues on the Thanaleng–Nong Khai and Phonetong–Nong Khai interconnections, other lines such as Vieng-Keo–Khoksa-at and Donkoi–Thanaleng are also opened to relieve stress.

3.6.9. Future AGC Operation

On August 23, 2021, a meeting was held with EDL to discuss the future implementation of AGC (Automatic Generation Control) in Laos. The Lao domestic power system and the Thai power system are synchronously interconnected and operate at the same frequency, with frequency control currently managed through the output regulation of generators within EGAT's system. However, generators in the Lao domestic system do not participate in frequency regulation. As a result, fluctuations in the supply-demand balance within the Lao system are effectively absorbed by output adjustments from generators in the Thai system, leading to corresponding fluctuations in power flows on the 115 kV interconnection lines between Laos and Thailand. It is therefore necessary for Lao domestic generators to autonomously control their output and help stabilize the power flows on the 115 kV interconnection.

Generators within the Lao domestic supply system generally have small unit capacities. At present, adjustments to large-scale fluctuations in the supply-demand balance rely on the manual synchronization and disconnection of generating units throughout the day, as well as transfer-tripping through protection relay systems during emergencies. However, achieving finer control will require the implementation of automatic generator output control mechanisms in Laos, such as governor-free (GF) control and AGC—neither of which are currently in operation.

AGC control requires generators with a sufficiently wide output adjustment range and fast response to control signals (According to the Grid Code, the required response time is less than 25 seconds to ramp from 0 MW to rated output).

In June 2022, EDL expressed its intention to conduct a pilot project aimed at verifying AGC functionality using domestic supply generators at the Nam Theun 2 hydropower plant. Discussions between EDL and the Nam Theun 2 project entity have already commenced.

3.6.10. Output Control of Power Plants

EDL has expressed its intention to use an Energy Management System (EMS) to perform hydropower output control that responds to supply-demand conditions. However, the data infrastructure required to support EMS functions within the NCC system has not been established, and system modifications by the manufacturer are considered difficult.

Moreover, even under the current manual-based operation framework—prior to EMS implementation—the system is not being operated appropriately. Fundamental aspects of system operation remain unclear, including the collection of information and data from individual power plants, the identification of power plants targeted for AGC control, and the setting of control reference values for generators.

In addition, if large-scale variable renewable energy sources such as solar power are introduced in the future, it will become even more important to implement appropriate generator control that can respond dynamically to fluctuations in the supply-demand balance.

3.6.11. Voltage Control in System Operation

- There is a general shortage of reactive power compensation equipment capable of absorbing reactive power (i.e., lowering voltage), resulting in a systemic tendency for voltage levels to remain elevated.
- Even during the high loading season in the rainy period, multiple instances were observed where generators operated at zero power factor or in leading power factor mode.
- One circuit of the 230 kV Thavieng–Lak20 double-circuit transmission line is intentionally taken out of service during the rainy season (high power flow period) as a mitigation measure against overvoltage and to avoid leading reactive power operation of generators at Nam San 3A and Nam Chain.
- While leading reactive power operation of hydropower generators may be permissible under certain conditions, in light of the current situation where generators are unable to reach rated output due to steady-state stability constraints, this practice should be considered suboptimal and in need of improvement.

Key issue and proposed direction for further analysis and system planning:

(Issue): To prevent transmission line overloading, sustained overvoltage, and leading power factor operation of generators, operational practice has involved prolonged disconnection of transmission circuits, effectively segmenting the power system. This has resulted in a significant reduction in system reliability.

This indicates a structural weakness in the institutional and procedural capacity for transmission system planning and implementation that takes actual operational conditions into account. Accordingly, the following actions are recommended:

- Review and formalize operational workflows and incorporate them into the Grid Code.
- Based on established planning criteria, expedite the formulation and implementation of reinforcement plans for transmission infrastructure and reactive power compensation facilities.

3.7. Overload Protection Relay

3.7.1. Background of the Survey

The international interconnection lines with Thailand (115 kV Nong Khai–Phonetong 2 lines and Nong Khai–Thanaleng 1 line) are used for power transmission from multiple hydropower plants in central and northern Laos. However, due to the vulnerability of the transmission lines, output restrictions have been imposed on a regular basis. The Luang Prabang 2 substation, located at the midpoint, is connected to a large load of 230 MW supplied by a Chinese company. If this load trips, there is a high risk of the international interconnection lines becoming overloaded. Against this backdrop, the JICA expert team initially proposed the introduction of an overload protection device that continuously suppresses generator output as a pilot project. However, due to constraints on the operating range of the generators, it was determined that sufficient effectiveness could not be achieved, and the pilot project was revised. Ultimately, the scope was changed to the installation of oscilloscopes at three substations within Vientiane City. This section outlines the field survey conducted at that time.

3.7.2. Investigation of Overload Protection Relay through Continuous Adjustment of Generator Output

The international interconnection lines with Thailand—115 kV Nong Khai – Phonetong (2 circuits) and 115 kV Nong Khai – Thanaleng (1 circuit)—are transmission routes that are prone to overloading.

As shown in the power system diagram on the next page, many reservoir-type and run-of-river hydropower plants, including the Nam Ngum and Nam Ou hydropower groups, are interconnected to the upstream northern network of the above three interconnection lines. However, due to steady-state stability constraints associated with long-distance transmission via these weak transmission lines, the electricity generated by these hydropower plants cannot be transmitted at full capacity and must be curtailed even under normal operating conditions.

In addition, at the Luang Prabang 2 substation, located midway between the northern power sources and the Thailand interconnection points, a large-scale load (data center) contracted by a Chinese company with a capacity of 230 MW is connected via two 230 kV circuits. Therefore, although overloading on the international interconnection lines with Thailand is usually avoided through a delicate power flow balance, there is a risk of immediate overloading if the large data center trips.

In response, the survey team proposed the implementation of an overload protection system during the kick-off meeting held on July 15.

This system is designed to detect overloading on the 115 kV Nong Khai – Phonetong (2 circuits) and 115 kV Nong Khai – Thanaleng (1 circuit) lines, transmit a signal to the Nam Ngum 1 hydropower station, and automatically reduce its output.

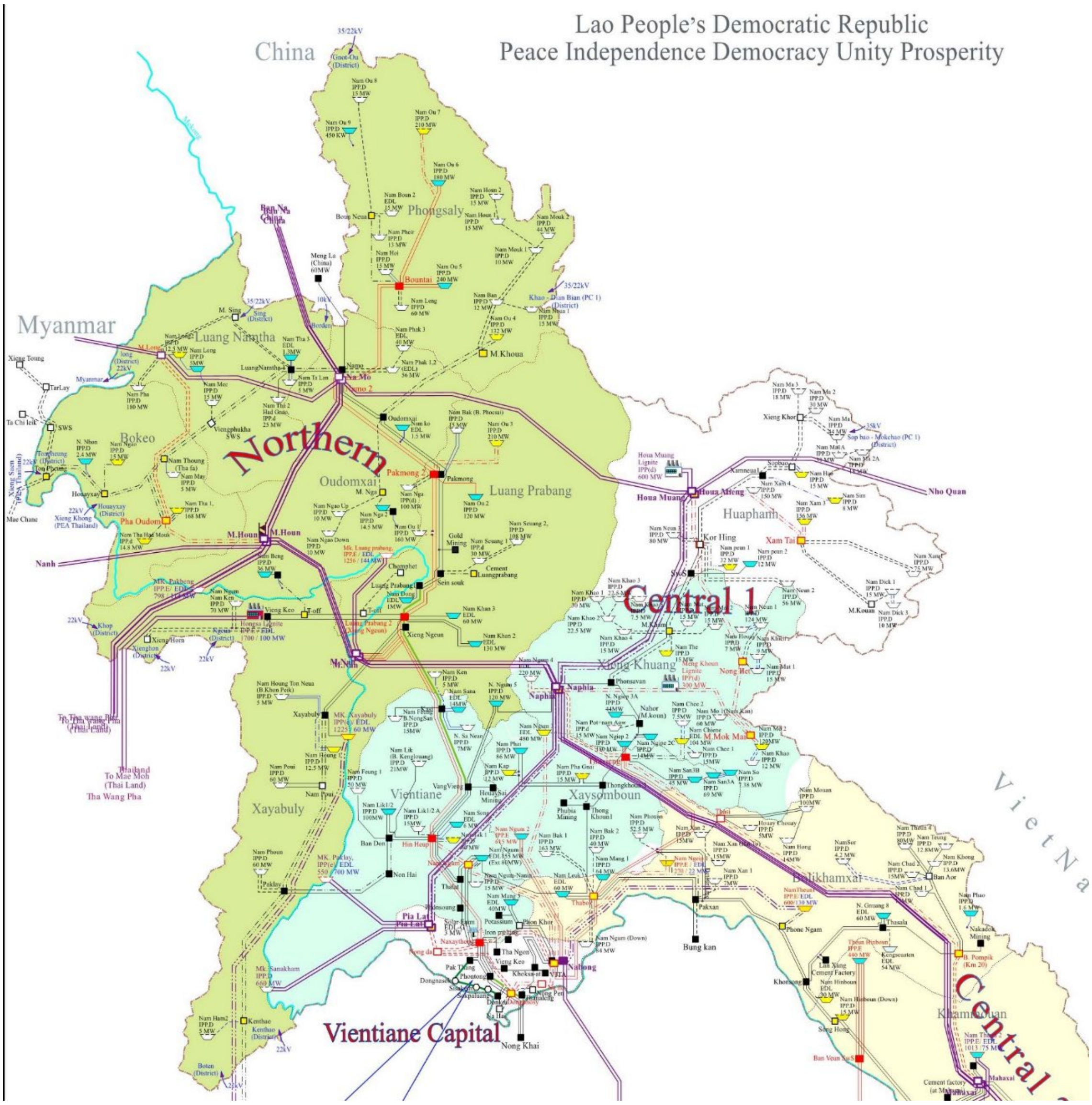


Figure 3-7　Power System in Northern Laos and Vientiane Area

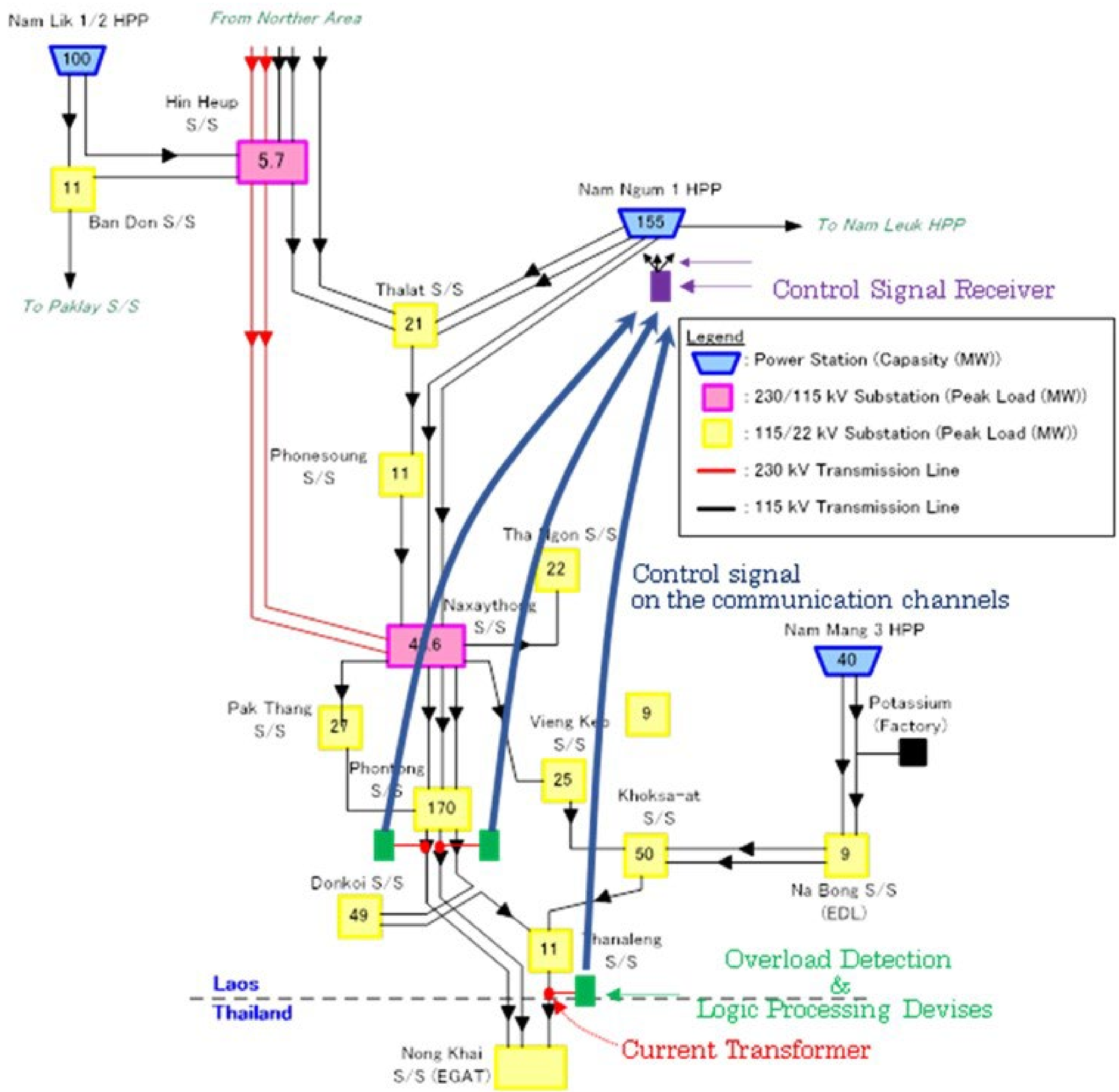


Figure 3-8 Overload Protection System (Initial Proposal by JICA Expert Team)

At the kickoff meeting held on July 15, 2021, an agreement was reached to proceed with the consideration of installing the proposed device. However, during a discussion with experts from EDL and NCC held on July 23, the following facts came to light:

- An overload protection system had already been implemented in 2020. This system performs transfer tripping of circuit breakers on transmission lines upstream of power plants or of individual generator breakers within power plants in response to overloads that occur during N-1 contingencies on 115 kV or 230 kV transmission lines.
- A distinguishing feature of the overload protection device planned for application in the current pilot project is its ability to continuously and automatically adjust generator output based on the degree of overload on the equipment. However, to realize this functionality, each generator must be equipped with an interface to receive AGC (Automatic Generation Control) signals. It was confirmed during the discussion that such interfaces are currently not installed on all generators.

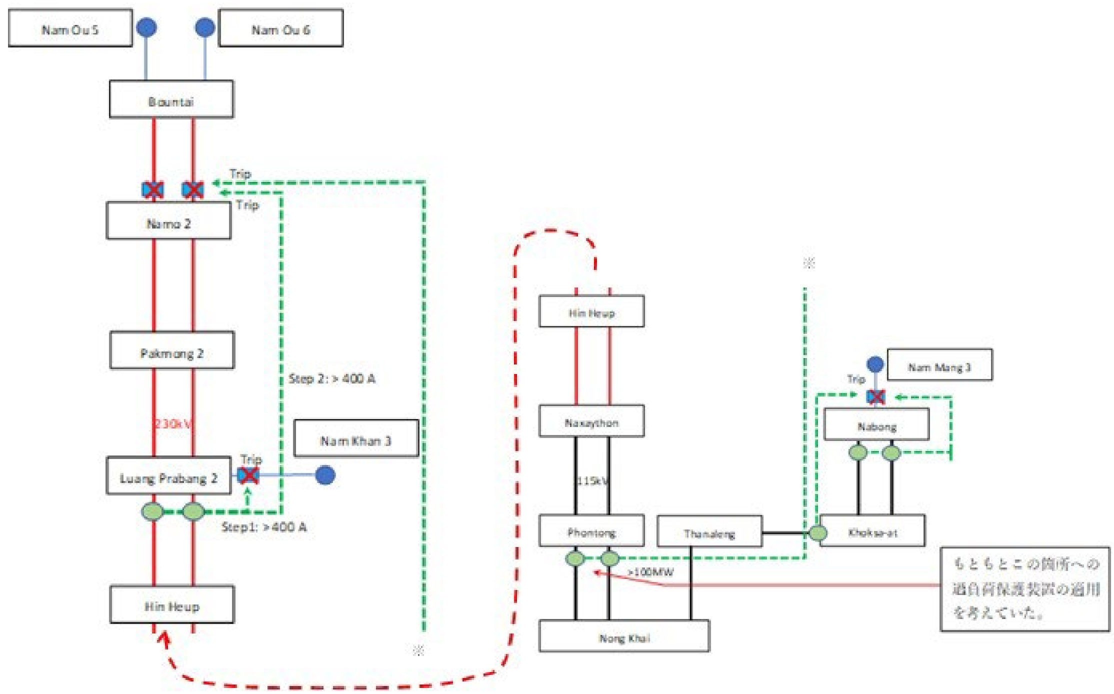


Figure 3-9　Existing EDL Transfer Trip Relay System

However, since the absence of AGC functionality on the generators might have limited impact on the application of the overload protection device, a site survey was conducted at the Nam Ngum 1 hydropower plant on August 6.

A summary of the survey findings is as follows:

(1) How to control the output of the generator

- The NCC and the power plant control room system are connected by optical fiber, and the telemetry data and supervisory information of the power plant is transmitted, but the output instruction is still issued by telephone.
- Based on the availability of the generator unit, the NCC sends the generation schedule for the day on a daily basis, and the NCC sends out real-time instructions by telephone at each timing of output change, and the station staff adjusts the output set point in the red frame on the screen, below.
- In reality, most of the time, the generator is operating at rated output (100%) or stop (0%), and rarely in the intermediate output range.
- The adjustable range of output is extremely narrow, as follows:
  - Units 1 & 2: 12MW (min. output) to 17.5MW (rated)
  - Units 3, 4 & 5: 28MW (min. output) to 40MW (rated)

(2) Contribution to frequency control

- Governor-free operation is not carried out.
- The opening degree of the guide vanes does not move according to the frequency.

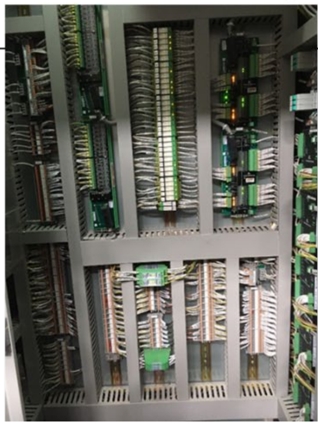
(3) Direct control panel (Governor Controller)

- The generator is normally operated in "REMOTE" mode from the control room, but can be controlled manually from the direct control panel by setting it to "LOCAL" mode and "MANU (manual)" mode.
- The upper control limit can be adjusted by “RAISE” or “LOWER” operations with the guide vane opening limit switch, “GATE LIMIT”, and the output is adjusted by “RAISE” or “LOWER” operations with the guide vane position switch, “GV POS”.

Overall view of direct control panel | Enlarged view of the switches for direct operation

(4) Possibility of automatic output control by overload protection relay

- As shown in the picture below, automatic control is possible by interrupting the output "up" and "down" signals from the overload protection relay to the “RAISE” and “LOWER” positions of the “GV POS” switch on the back of the board.
- Specifically, the overload detection point on the transmission line will monitor the power flow, and while the overload continues, the output "down" signal will continue to be sent to the power plant, and while the "down" signal continues, the power plant will continue to reduce output according to the generator’s ramping rate.
- There may be space for a terminal device to receive the signal from the overload detection point, but there is not much room to connect the control cables inside the direct control panel. This must be taken into account when designing.



Conclusion

As summarized in the survey results, it is technically possible to receive curtailment signals from the overload protection device via the governor controller and automatically and continuously reduce generator output. However, it was concluded that the operational range of the generator is too narrow to take advantage of the benefits of continuous curtailment.

Therefore, as the currently applied generator trip-type overload protection device is considered to offer comparable or greater benefits, it was agreed at the wrap-up meeting on August 19 to reconsider the pilot project, including a review of its content.

3.8. NCC Operational Survey

3.8.1. Real-Time Grid Monitoring

- The parameters currently monitored in real time by the NCC include active power, reactive power (both generator output and load demand), bus voltage, and system frequency.
- In the future, there are plans to expand monitoring capabilities to include supply reserve margins, and to install Phasor Measurement Units (PMUs)[5] for acquisition of phasor data.
- There is currently no exchange of real-time power supply information with neighboring countries such as Thailand or Vietnam.

3.8.2. Survey on NCC's Supply-Demand and Frequency Regulation Operations

The actual status of compliance with the relevant provisions of the current Laos Grid Code concerning generator Scheduling & Dispatch—defined as the set of procedures governing the final adjustments to generator operations and the issuance of dispatch instructions on the day prior to and the day of actual operation—was assessed with reference to Attachment 18, "20230530_GC upgrade_Scheduling&Dispatch.pdf."

The explanation of the Scheduling & Dispatch process provided in the introductory slides revealed that the level of understanding among EDL and NCC operational personnel was insufficient. It was also confirmed that no systematic operational procedures aligned with the Grid Code have been established for this function.

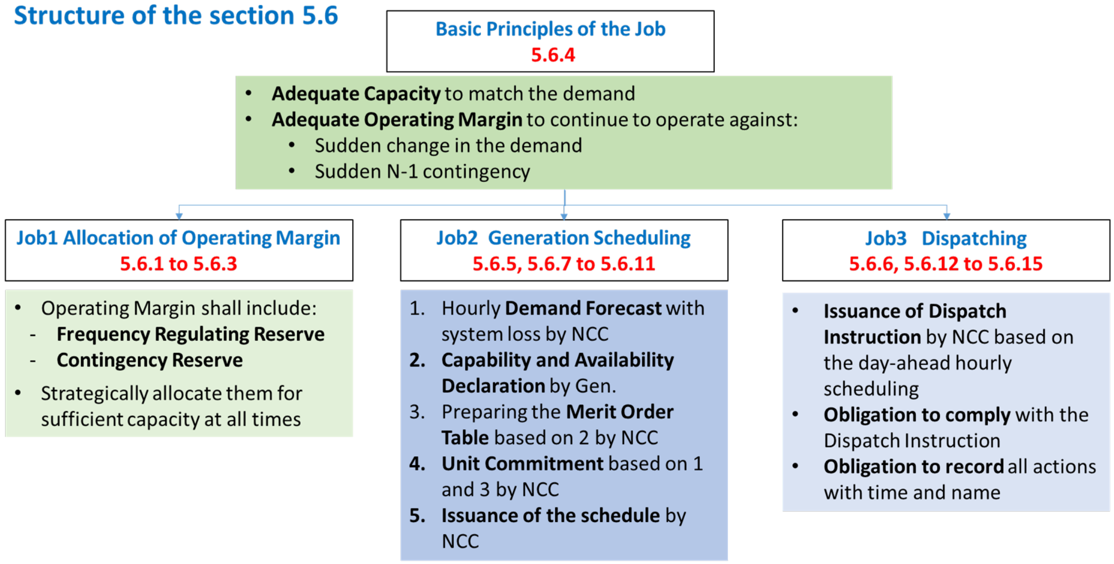
(Refer to Attachment 18 20230530_GC upgrade_Scheduling&Dispatch.pdf)

(Refer to Attachment 19 20230609_GC upgrade_WrapUp.pdf)

[5] A Phasor Measurement Unit (PMU) is a device that measures key parameters of the power system—such as phase angle, voltage, and current—and tags this data with an absolute timestamp obtained via the Global Positioning System (GPS), enabling real-time, time-synchronized monitoring of system conditions.
Traditionally, system state monitoring has been conducted through SCADA (Supervisory Control And Data Acquisition) systems. However, SCADA is limited to measuring the magnitudes of parameters such as voltage and current, and cannot directly capture phase angles. Additionally, for analyzing complex fault phenomena such as transient events, it was necessary to individually collect data from oscillographs and other devices installed at substations.
In contrast, monitoring the power system using PMUs allows for real-time acquisition of high-frequency, time-series waveform data. This makes it possible to instantly assess the system's dynamic (transient) conditions. As such, PMUs are highly effective in enhancing operator awareness of abnormalities in the power system.

1. Introduction

Structure of the section 5.6



Furthermore, during the discussion on securing reserve and regulating capacity (Job 1: Allocation of Operating Margin), it became apparent that there was no understanding of the classification system defined in the Grid Code—specifically, Frequency Regulation Reserve and Contingency Reserve. Neither the locations where reserves should be secured nor the required reserve quantities are being properly planned or managed.

2. Questionnaire

Job1: Allocation of Operating Margin

5.6.1 The Operating Margin of the Grid shall include the generating capacity for **the Frequency Regulating Reserve**, which is required to respond to changes in Demand during normal conditions and **the Contingency Reserve** needed to respond to a sudden reduction in generation during emergency conditions, in accordance with the Grid operating criteria.

5.6.2 The System Operator shall allocate **the Frequency Regulating Reserve** to strategically locate Generating Plants in order to achieve the required levels of Primary Response and Secondary Response to Frequency changes in the Grid.

5.6.3 The System Operator shall allocate **the Contingency Reserve** to strategically locate Generating Plants to cover against uncertainties in Generating Plant availability.

Questions

Are reserves for frequency control properly secured? What amount of each:
- For primary response ?MW or ?%
- For secondary response 0MW (Is it correct?)
- For tertiary response ?MW or ?%

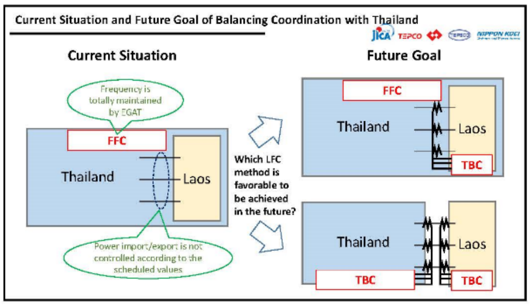
Are reserves **strategically** allocated?

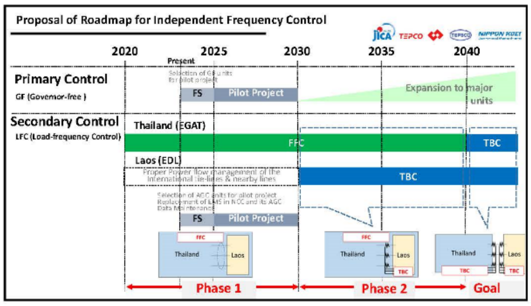
If not, what do you think of:
- removal of these clauses; or

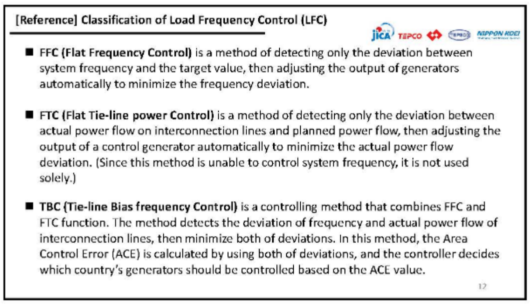
-transfer to the section of "transitory provisions", assuming total reliance on the frequency regulation by EGAT? (See next 2 slides)

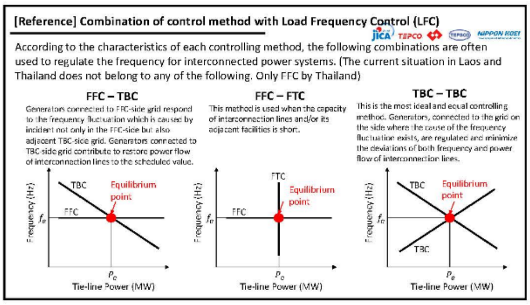
Under the current circumstances, it may become necessary to revise the Grid Code related to supply-demand operations to reflect the assumption that rely entirely on Thailand's EGAT Flat Frequency Control (FFC) (supply-demand balancing is not be conducted within Laos independently). Therefore, several slides previously used in past presentations were presented again to reconfirm EDL's intentions regarding the roadmap for Governor-Free (GF) operation and Load Frequency Control (LFC) in Laos (see Attachment 20, "20230530_GC upgrade_S&D_App.pdf").

- In response to the question, "To what extent should the current Grid Code incorporate future operational phases?", the reply was, "Provisions regarding future frequency control should also be included. Laos aims to become a hub for electricity supply in Southeast Asia in the near future."
- Furthermore, the basic concepts of FFC, Tie-Line Bias Control (TBC), and Flat Tie-Line Control (FTC) related to LFC strategies were revisited and discussed. As a result, the opinion was expressed that "While dependency on Thailand's FFC will continue for the time being, transitioning to a FFC (Thailand) – FTC (Laos) configuration in Phase 2 could be one strategic option. Ultimately, aiming for a TBC (Thailand) – TBC (Laos) configuration might be appropriate."









3.8.3. Current Status of EDL's NCC System (August 2023)

The NCC system at EDL, established in 2013, has in recent years become unable to incorporate data from newly constructed power plants and substations resulting from network expansion, which is now hindering power system operation. The following factors are considered as potential causes of the inability to integrate the necessary system information:

- The existing NCC system has reached its full data handling capacity.
- Communication with the Chinese manufacturer of the current NCC system has been lost, making it impossible to perform system upgrades.

As a result, EDL is planning to upgrade the NCC system using a product from a new manufacturer.[6]

Although communication infrastructure has been installed at many sites, it is assumed that there are challenges in establishing data connectivity between the NCC central system and the local information exchange systems within power plants and substations.

(Refer to Attachment 22 20230718_NCC_Situations_V1.pdf)

3.9. Distribution SCADA

3.9.1. Meeting with EDL

In August 2021, among the projects introduced to JICA by the President of EDL was the "SCADA/DMS Upgrade Project in Vientiane Capital." In February 2021, a meeting was held with EDL to clarify the details of this request.

The objective of the project is to improve the reliability of power supply. Although pilot projects such as KEPCO's distribution automation, Thailand's distribution project, HUAWEI's smart meter project (funded by China Exim Bank), and GE Canada's project have been implemented, they have not functioned adequately. Therefore, EDL requested a new integrated SCADA project that would leverage and build upon these existing

6 In the meeting with the EDL President in September 2022, the urgent need to improve the NCC system was raised. Furthermore, during the meeting between the Minister and the EDL President in December 2022, the President emphasized that the upgrade and functional enhancement of the NCC system was the highest priority issue.

initiatives.

However, EDL has not clearly identified the problematic components or the functions that need to be included, and it is expected that integrating existing projects into a single system will be challenging. Thus, continued on-site investigations are planned, and the JICA Expert Team will propose an outline of a potential project.

3.9.2. Current Status Assessment

To understand the current situation of the distribution SCADA system at EDL, interviews and field surveys were conducted on the following dates:

Tuesday, September 6, 2022

Wednesday, September 14, 2022

Thursday, December 1, 2022

Tuesday, December 6, 2022

Regarding the basic plan for the introduction of distribution SCADA in the Vientiane area, it was found that EDL is planning a phased implementation by dividing the Vientiane Capital (VC) area into two tiers: Tier 1 and Tier 2.

Tier 1 consists of the central area of the capital, covering 4 districts, while Tier 2 consists of the surrounding outer area, covering 5 districts. As of December 1, 2022, there were 53 distribution lines in Tier 1 and 47 in Tier 2.

Tier 1 is gradually being equipped with distribution SCADA as described later. Although there is a plan to introduce automation in Tier 2 through a PGI scheme, distribution automation has not yet been implemented there.

This information is summarized in Table 3-1.

Table 3-4 Outline of Distribution SCADA in Vientiane Capital

Tier	VC One	VC Two
Coverage	4 districts	5 districts
Feature	Centre of VC	Outskirts of VC
Nos. of 22kV feeder	53 feeders	47 feeders
Implementation of SCADA	46 feeders implemented	Not yet
	7 feeders in progress	PGI is planning to implement?

Implementation Status in Tier 1

Out of the 53 distribution lines in Tier 1, SCADA has already been introduced to 46 lines, and the remaining 7 lines are in the process of being implemented. In Tier 1, three separate systems have been introduced in phases:

Phase 1

Around 2012–2013, SCADA was introduced to 14 distribution lines through assistance from South Korea (KEPCO and KOICA). The communication between the central system and field devices relied on a mobile phone system (likely GSM). Due to the high cost of communication fees (such as SIM cards), this system is no longer in use. Although the central system remains installed in the system room at the Seasaked Substation, it is currently incapable of monitoring or controlling the field devices. However, it appears that the RTUs (Remote Terminal Units) at field locations have been updated to match the communication standards of subsequent phases, and that the automatic LBS (Load Break Switches) and other field equipment continue to be used.

Phase 2

Around 2014–2017, SCADA was introduced to 20 distribution lines through assistance from the Kingdom of Thailand. Communication between the central system and field devices was done via a wireless system. However, due to the construction of relatively tall buildings throughout the city after the system began operation, communication frequently failed even under normal conditions. Moreover, severe weather conditions further degraded communication quality, rendering the system unusable. As with Phase 1, the central system remains installed in the system room at the Seasaked Substation, but field monitoring and control are not possible. The RTUs have been updated to align with newer communication standards, so it appears that automatic LBS and related field equipment are still being utilized.

Phase 3

Beginning around 2018, SCADA is being introduced with assistance from China (Huawei). As noted above, 46 distribution lines, including those from Phases 1 and 2, have already been covered, and installation is ongoing for the remaining 7 lines in Tier 1. Communication between the central system and field devices uses optical fiber networks. In addition to automatic LBS, automatic circuit breakers (CBs) are also installed on poles at the first switching point of distribution lines. In standard fault isolation demarcation, costly CBs are typically installed only at the substation outlets, and field distribution lines are equipped with automatic LBS (or auto-reclosers/sectionalizers), since they do not require high short-circuit current breaking capacity. However, EDL has reportedly accepted the default Chinese system design—including the use of such expensive CBs on distribution lines—without independent evaluation or modification.

3.9.3. Future Direction

As summarized above, the Chinese Huawei distribution SCADA system is being introduced to all 53 distribution lines in VC One (Tier 1). Meanwhile, preparations for introducing distribution SCADA in VC Two (Tier 2) are underway.

As previously mentioned, EDL appears to accept donor-side equipment planning standards—such as the installation of costly and possibly over-specified CBs on distribution lines—without questioning their appropriateness. Therefore, if Japan is to have an opportunity to introduce its own SCADA systems in the future, it would be appropriate to consider implementing a capacity development program for EDL personnel in advance. This program should cover planning for distribution facilities, maintenance and operation practices (including SCADA), to ensure a rational and sustainable system design and operation.

Chapter 4 Roadmap for Developing Power System Operation Manuals

4.1. Overview of System Operation Manuals

To achieve continuous improvement in the quality of operations within the field of power system operation in Laos, it is essential to develop operational manuals based on the grid code. Although interviews have been conducted to understand the actual conditions of various operations such as system operation, supply-demand management, interconnection line flow management, and system control, there appear to be no existing documents equivalent to manuals.

As we proceed with the development of these manuals, it is advisable to refer to current manuals and related documents from Japan and other advanced countries in Europe and North America. Below is an overview that serves as a goal image for the development of manuals in the field of power system operation.

Table 4-1 Draft Roadmap for System Operation Manual Development

Field		Manual Target Items	
1	System Operation	1-1	System Operation
		1-2	System Operation in Abnormal Conditions
		1-3	System Voltage Regulation
		1-4	Operation of Extra High Voltage Receiving Substations
		1-5	Settings and Operation of Comprehensive Stabilization Excitation Devices
		1-6	Detection of Precursors to Power System Abnormalities and Countermeasures
		1-7	Transmission System Control
		1-8	Transmission System Interconnection Operation
		1-9	Interconnection Line Management
		1-10	Transmission System Operation
		1-11	Electrical Accident Reporting
		1-12	Safety Tasks Related to System Operation
		1-13	Handling of System Operation-Related Outsourcing
2	Supply-Demand Operation	2-1	Supply-Demand and System Operation
		2-2	Frequency Regulation and Supply-Demand Operation
		2-3	Management of Supply-Demand and System Operation Tasks
3	System Protection	3-1	Development and Planning of System Protection Devices
		3-2	Settings and Operation of Protection Relay Devices
		3-3	Automation of Receiving Status Transmission for Extra High Voltage Receiving Substations
4	System Control	4-1	Tasks Related to Power Supply Equipment
		4-2	Planning Tasks Related to Power Supply Equipment
		4-3	Construction Tasks for Power Supply Equipment
		4-4	Maintenance of Power Supply Equipment
		4-5	Implementation and Operation Management of Two-Tier Control System
		4-6	Supervision of Power Supply Equipment Construction
5	Shutdown Planning	5-1	Handling of Electrical Equipment Work Suspension
6	Capacity Enhancement	6-1	Skill Certification System
7	Operational Management	7-1	Determination of Power Supply Command and Autonomous Operation Scope
		7-2	Determination of Switchgear Numbers
		7-3	Establishment of System Operation Guidelines
		7-4	Notification of Planned Changes in Electrical Equipment
		7-5	Regular Reports on Supply-Demand and System Operation
		7-6	Emergency and Disaster Response Tasks
		7-7	Regulations for Reallocation of Job Authorities

(Source: Compiled by JICA Expert Team)

4.2. Direction of Manual Development

I. Extraction of Target Items

Select target areas where the introduction of manuals is expected to yield clear benefits and contribute to improved operational quality.

II. Assessment of Current Operational Practices

Conduct detailed interviews to understand current operational practices in the target areas. Verify the findings through the exchange of visualized materials.

III. Redesign of Operational Procedures

Based on the current practices, redesign the operational procedures by referring to best practices in countries like Japan and through thorough discussions with personnel involved, aiming to achieve enhanced work quality.

IV. Identification of Issues through Pilot Implementation

Implement the revised operational procedures on a trial basis within a scope that does not interfere with actual operations. This will allow for the identification of issues and evaluation of whether the procedures are aligned with on-the-ground realities.

V. Formal Establishment of New Manuals

Review and discuss the content that has been verified. After making necessary revisions, formally establish it as a manual.

VI. Dissemination, Internalization, and Monitoring over a Certain Period

It is essential to ensure that the contents of the established manual are well-shared and understood among all relevant personnel. During this time, conduct monitoring from multiple perspectives to identify any potential issues in the content.

VII. Continuous Quality Improvement through Regular Updates

Amid updates to related systems and revisions of business content, it is crucial that the manual remains a living document, continuously updated to reflect changes and support ongoing improvements in work quality.

4.3. Initial Target Items for Manual Preparation

As the development of manuals is expected to improve operational quality, the following areas are proposed as initial target items, focusing on those considered important and likely to yield significant benefits.

Given the substantial impact of the timing of the planned update to the Central Dispatching System and the functions to be included, it will be necessary to select the target areas based on that information going forward.

Table 4-2 Overall Structure of Manuals in System Operation Field

Target Items			Main Topics for Consideration
1	System Maintenance	1-1	Establishment of EDL's Organizational Structure (for normal and abnormal conditions)
		1-2	Maintenance and Repair Operations
		1-3	Cybersecurity (related to power dispatching system operation)
2	Supply-Demand Operation Planning (including demand forecasting)	2-1	Development of Workflow Involving Related Organizations
		2-2	Formulation of Grid Codes and Manuals
		2-3	Introduction of Analytical Tools
3	Interconnection Line Power Flow Control	3-1	Constant Export/Import Power Control via Offline Commands (manual FTC)
		3-2	Constant Export/Import Control Using NCC System (automatic FTC)
		3-3	Zero Supply-Demand Error Control Using NCC System (TBC)
4	Development of Balancing Capability	4-1	Enhancement of Monitoring and Control Functions in the Dispatch System
		4-2	Gradual Introduction of AGC-Enabled Units
		4-3	Expansion of AGC-Enabled Units to BOT Expired Plants, etc.
5	System Operation (Remote Control and Operational Safety)	5-1	Introduction of Functional Features
		5-2	Definition of Control Scope and Work Allocation
6	Renewable Energy Output Forecasting	6-1	Implementation of Forecasting Functions
		6-2	Preparation of Information Required for Forecasting
		6-3	Development of Workflow Using EMS

(Source: Compiled by JICA Expert Team)

4.4. Draft Roadmap for System Operation Manual Development

The direction and indicative timeline leading up to the full development of the manuals are presented below. It is assumed that, in the context of future power system conditions, progress on the control methods for power exports and imports via the interconnected system with Thailand will advance in parallel with the development of the Grid Code.

The proposed roadmap is as follows.

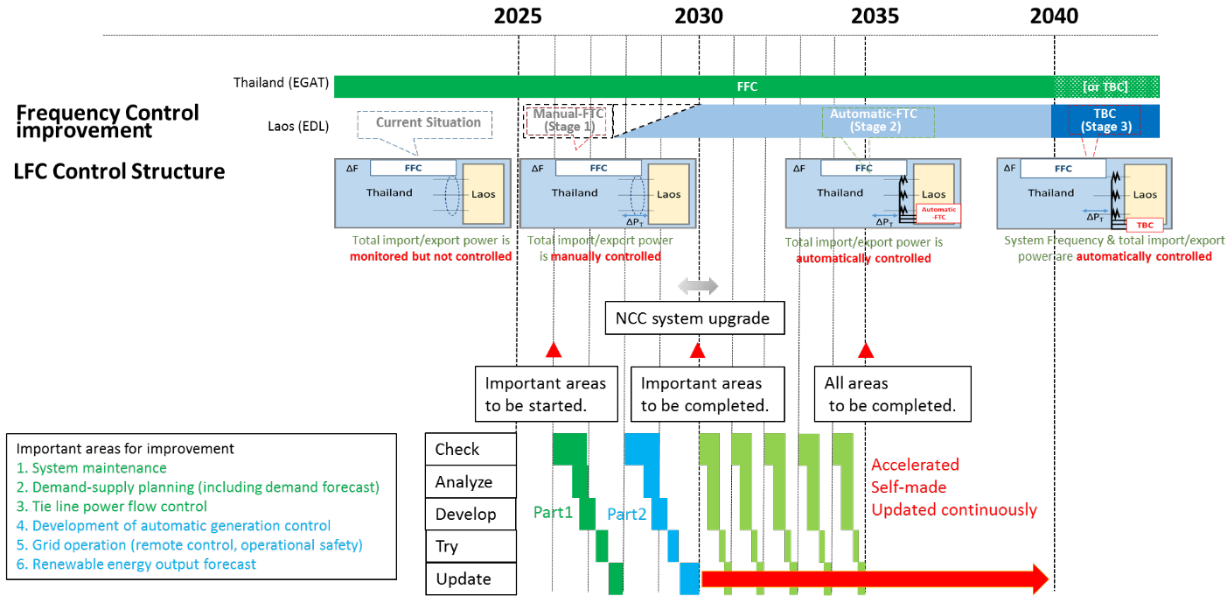


Figure 4-1 Draft List of Manuals for Initial Development

4.5. Sample Application Form for VRE Grid Connection

Supplementary Explanation on Specific Steps

I. 2026–2027

Manual development will proceed through the steps of confirming actual operations, analyzing, redesigning procedures, pilot implementation, and formalizing manuals for the three initially selected fields:

① System Maintenance,

② Supply-Demand Operation Planning, and

③ Interconnection Line Power Flow Control.

These areas have been selected because they are expected to benefit from improved operational quality under the current conditions and can be addressed even before the details of the power dispatch system upgrade are finalized.

It is extremely important to embed the approach of clearly defining the operational objectives and thoroughly examining the methods that lead to quality improvement, thereby establishing a foundational method for manual development and quality maintenance.

Given the local context in Laos, it is considered essential to take adequate time to carefully handle this phase in order to ensure the smooth progress of subsequent stages.

II. 2028–2029

Manual development will next be undertaken for the following three areas:

④ Development of Balancing Capability,

⑤ System Operation (Remote Control and Operational Safety), and

⑥ Renewable Energy Output Forecasting.

These areas are scheduled for a later phase because their manual development depends on the finalized specifications of the updated power dispatch system.

III. 2030–2035

After the first four to five years of focusing on critical and high-impact manual development, it is assumed that the process can then be extended to all remaining fields.

By this time, the introduction of the new power dispatch system will be underway, and the approach to interconnection line power flow control is expected to be more clearly defined, allowing for smoother planning of subsequent developments.

It is anticipated that over the following five years, manual development across all operational fields will be fully achievable.

Figure 4-2 Application Form for Connection Review

様式1
様式AK1特高-20240410

【特別高圧】 記載例(太陽光・系統用蓄電池・蓄電池併設)

●●年 ●●月 ●●日

接 続 検 討 申 込 書

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or ●●株式会社 御中

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事 業 者 名 ●●●●株式会社
申込者氏名 ●●●●

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(6) 発電設備等変更の有無 有を選択された場合、〇 内の該当項目に〇をご記載ください。	☑ 新規 ☐ 有〔 増設 ・ 減設 ・ 更新 ・ 廃止 ・ その他 ( ) 〕 ☐ 無
(7) 契約種別※2(予定) 受給契約の契約種別をご選択ください。 ※契約種別によって技術検討の結果が変わることはありません。	☑ 一般送配電事業者又は配電事業者と受給契約を締結予定(FIT制度の適用予定の場合) ☐ 上記以外の事業者と受給契約を締結予定(FIP制度の適用含む) ☐ 未定 ※2:入札の対象(FIT/FIP)をご確認のうえ、ご記入下さい。
(8) 連絡先	【連絡先】 住所 〒●●●−●●●● 東京都●●区●● ●丁目●番地●号 事業者名 ●●●発電株式会社 所 属 ●●●部 担当者名(フリガナ) ●●●● (●●●●) 電 話 ●●●−●●●−●●●● FAX ●●●−●●●−●●●● e-mail ●●●@●●●
	【技術的事項に関する連絡先(上記と異なる場合のみ記載)】 住所 〒●●●−●●●● 東京都●●区●● ●丁目●番地●号 事業者名 ●●●株式会社 所 属 ●●●グループ 担当者名(フリガナ) ●●●● (●●●●) 電 話 ●●●−●●●−●●●● FAX ●●●−●●●−●●●● e-mail ●●●@●●●
(9) 特記事項	・蓄電池特別措置適用の有無(予定):「有り」 系統用蓄電池を設置する場合、託送供給等約款附則に定める「揚水発電設備等が設置された需要場所に接続供給を行なう場合の特別措置」適用の有無(予定)を記載ください。

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記載例（太陽光の場合）

様式２

●●年　●●月　●●日

発電設備等の概要

発電設備等設置者名　●●●●●

> 発電に限らず、電力系統に接続しアクセス設備を使用可能とする希望日をご記載ください。（発電所の所内電力受電時期等）

1．希望時期

（１）アクセス設備※3の運用開始希望日	2022年　10月　1日
（２）発電設備等の連系開始希望日（試運転）※4	2023年　2月　1日
（３）発電設備等の連系開始希望日（営業運転）	2023年　6月　30日
（４）発電量調整供給又は振替供給の終了希望日 〔発電量調整供給又は振替供給の希望契約期間〕	年　月　日・希望なし 〔　　年間〕

> 試運転で系統連系する予定時期をご記載ください。（発電機の連系開始までには技術要件が整うことが必要です）

> 託送供給開始（営業運転開始）の予定時期をご記載ください。

※3：アクセス設備：発電場所と送電系統を接続する設備　※4：運転開始前の試運転など、送電系統への送

> 連系エリアの一般送配電事業者及び配電事業者の託送供給等約款又はその他要綱等に定める契約受電電力に対する標準電圧を参考に、ご希望の受電電圧をご記載ください。接続検討の結果、近傍の送配電設備の状況等により、希望受電電圧と異なる電圧でご回答することもあります。この場合は、予め推奨する連系電圧が最適であることを説明いたします。

2．希望受電電圧・予備電線路希望の有無

（１）希望受電電圧※5		66　kV
（２）予備電線路希望の有無		☑ 有　☐ 無
	希望する予備送電サービス	☑ A（予備線）　☐ B（予備電源）（
	予備送電サービス契約電力	9,000　kW

> 発電設備のアクセス線の予備電線路の希望有無をご記載ください。予備電線路がない場合、アクセス線の作業停止や事故停止等に伴って、運用上の制約が発生します。
> ※無の場合は、以下項目の記載は省略可。

> ・予備送電サービスAとは、常時利用変電所から常時利用と同位の電圧で利用する場合をいいます。
> ・予備送電サービスBとは、常時利用変電所以外の変電所を利用する場合または常時利用変電所から常時利用と異なった電圧（高圧または特別高圧に限ります）で利用する場合をいいます。

※5：接続検討の結果、希望受電電圧以外となる場合もございます。

3．電源種別

> 該当する電源種別を選択してください。

☐ 火力（LNG：Conv）　☐ 火力（LNG：CC(1,100℃級)）　☐ 火力（LNG：A… …00℃級)）　☐ 火力（LNG：MACC(1,500℃級)）
☐ 火力（石炭）　☐ 火力（石油）　☐ 一般水力※6　☐ 小水力※7　☐ 揚水　☑ 太陽光　☐ 風力（陸上）　☐ 風力（洋上）
☐ バイオマス（専焼）※8※9　☐ バイオマス（石炭混焼）※9　☐ バイオマス（LNG混焼）※9　☐ バイオマス（石油混焼）※9　☐ バイオマス（液体燃料）※9
☐ 廃棄物（バイオマス（専焼）を除く）※9　☐ 原子力　☐ 地熱　☐ 蓄電池　☐ その他（　　　　）

※6：発電機定格出力1,000kWを超えるもの。　※7：発電機定格出力1,000kW以下のもの。
※8：バイオマスに該当する廃棄物のみを燃焼するものを含みます。
※9：地域資源バイオマスに該当する場合は、様式1「（9）特記事項」にその旨記載願います。なお、その場合で燃料貯蔵や技術に由来する制御等により出力抑制が困難となる見込みである場合も様式1「（9）特記事項」にその旨記載願います。

4．発電設備等の定格出力合計※10

（１）変更前	—　台	—　kW（　℃）	℃）
（２）変更後	5　台	9,500 kW（ - ℃）	℃）

> パワーコンディショナ単位で、太陽光パネルとパワーコンディショナの定格出力のいずれか小さい方を合算した値をご記載ください。（可能最大出力）

※10：ガスタービン等、外気温により発電出力が変化する場合には、各温度における発電出力を記載

5．受電地点における受電電力（送電系統への送電電力）※11

（１）変更前	最大※12	—　kW（　℃）
（２）変更後	最大	9,000 kW（ - ℃）
	最小	-1,000 kW（ - ℃）

> 受電地点における受電電力（系統への送電電力）の最大値、最小値をご記載ください。最小値は、停止時の系統からの供給電力をマイナス表記します。
> 最大：発電機最大出力（4項の数値）
> 　　　ー 自家消費最小電力（6項の数値）
> 最小：ー 自家消費最大電力（6項の数値）

※11：ガスタービン等、外気温により発電出力が変化する場合には、各温度における受電電力
※12：連系地点において、受電電力がない（連系地点からの需要供給のみ）場合は、０を記載

> 自家消費する電力（所内電力を含む）の最大値（最小値）とその負荷の力率をご記載ください。力率はご不明な場合「不明」と記載。

6．自家消費電力（発電に必要な所内電力を含む）

最大	1,000　kW	（力率　95 %）
最小※13	500　kW	（力率　95 %）

※13：発電の有無に拘わらず必要となる負荷設備の容量を記載

7．サイバーセキュリティ対策

【留意事項】系統連系に際して、サイバーセキュリティ対策の実施、セキュリティ…
その確認をさせていただきます。

> 【参考：「発電事業」の要件　資源エネルギー庁HPより】
> 「発電事業」は、以下のいずれの条件にも該当する発電用の電気工作物について、小売電気事業等の用に供する電力の合計が1万kWを超えるものであること。
> ①出力計1,000kW以上
> ②託送契約上の同時最大受電電力が5割超
> ③年間の逆潮流量（電力量）が5割超
>
> 【参考：「小規模事業用電気工作物の例」経済産業省HPより】
> 出力10kW以上50kW未満の太陽光発電設備と出力20kW未満の風力発電設備

対策	☑ 系統連系技術要件に基づいた以下のサイバーセキュリティ対… ・事業用電気工作物（発電事業の用に供するものに限る。）は、…準拠すること。 ・自家用電気工作物（発電事業の用に供するもの及び小規模事業用電気工作物を除く。）に係る遠隔監視システム及び制御システムは、「自家用電気工作物に係るサイバーセキュリティの確保に関するガイドライン」に準拠すること。 ・上記以外の発電設備等は、以下の対策を講じること。 1：外部ネットワークや他ネットワークを通じた発電設備等の制御… 2：発電設備等の制御に係るシステムへのマルウェアの侵入防止対策
	セキュリティ管理責任者　☐ 様式１（８）連絡先【連絡先】の記載と同じ ☐ 様式１（８）連絡先【技術的事項に関する連絡先】の記載と同じ ☑ その他　氏名　●●●●

> 発電設備のセキュリティ管理責任者について、いずれかをご選択ください。その他を選択された場合、氏名をご記載ください。

様式３

記載例（太陽光の場合）

●●年　●●月　●●日

発電設備仕様（逆変換装置）

発電設備等設置者名　●●●●●

1～10　号発電機　（既設 ・ 新設 ・ 増設）

1．全般

（１）原動機の種類（風力、太陽光など）	太陽光発電
（２）台数（逆変換装置またはＰＣＳの台数）	5 [台]

2．逆変換装置

（１）メーカ·型式	【メーカ】 ***	【型式】 ***	
（２）電気方式	三相３線式 ・ 単相３線式 ・ 単相２線式		
（３）定格容量	2,000 [kVA]		
（４）定格出力	1,900 [kW]		
（５）出力変化範囲	0 [kW] ～ 1,900 [kW]		
（６）定格電圧	0.69 [kV]	運転可能電圧範囲	0.92 [pu] ～ 1.08 [pu]
（７）力率（定格）		95 [%]	
（８）力率（運転可能範囲）		遅れ 90 [%]～進み 95 [%]	
（９）電圧・無効電力制御	Volt-Var制御・電圧一定制御・無効電力一定制御・力率一定制御・その他（　）		
（10）定格周波数		50 [Hz]	
（11）連続運転可能周波数	48.5 [Hz] ～ 52.5 [Hz]	運転可能周波数	47.5 [Hz] ～ 53.5 [Hz]
（12）周波数低下時の運転継続時間※1	0.97pu時（50Hzエリア：48.5/60Hzエリア：58.2 [Hz]）	10 [分]	
	0.96pu時（50Hzエリア：48.0/60Hzエリア：57.6 [Hz]）	1 [分]	
（13）並列時許容周波数	50Hzエリア：50.1/60Hzエリア：60.1 [Hz]	50.1 [Hz]	
	設定可能範囲	50.1 [Hz] ～ 51.0 [Hz]	
~~（14）周波数調定率設定可能範囲　（風力の場合）~~	－ [%] ～ － [%]（設定刻み － [%]）		
~~（15）不感帯設定可能範囲　（風力の場合）~~	[Hz] ～ [Hz]（設定刻み － [Hz]）		
（16）自動同期検定機能（自励式の場合）		有 ・ 無	
（17）系統並解列箇所		添付　様式５の４　参照	
（18）通電電流制限値		120	
（19）系統事故時の力率制御時間		5 [ms]	
（20）主回路方式		自励式（電圧形 ・ 電流形）	
		他励式	
（21）出力制御方式		電圧制御方式・電流制御方式・その他（　）	
（22）事故時運転継続（ＦＲＴ）要件適用の有無		有 ・ 無	
（23）高調波電流歪率	総合	5 [%]	
	各次最大	第 5 次　3 [%]	
~~（24）発電機の出力特性　（風力の場合）~~		添付　様式５の１４～１６　参照	
~~（25）出力変動対策の方法　（風力の場合）~~		添付　様式５の１７　参照	
~~（26）蓄電池設置（出力変動対策）の有無　（風力の場合）~~		有※1 ・ 無	
~~（27）ウィンドファームコントローラーの有無（風力の場合）~~		有 ・ 無	
（28）蓄電容量	出力 500 [kW]	時間 2.5 [h]	

※１：北海道エリアの場合は、「0.97pu時」は「連続」が要件となるほか、「0.96pu時」欄の記載は不要
※２：「有」の場合、蓄電池設備仕様および蓄電池システムの諸元を算定するためのシミュレーションに発電データ等の提出が必要となります。（任意様式）

【留意事項】

○ 異なる仕様の逆変換装置がある場合は、本様式を複写し、仕様毎にご記載ください。
○ 電圧変動の検討などで、さらに詳細な資料を確認させていただく場合があります。

太陽光の場合は記載不要です。

事故時運転継続（ＦＲＴ）要件適用の有無をご記載ください。ＦＲＴ要件の詳細は、系統連系規程をご参

太陽光の場合は記載不要です。

発電設備に具備する電圧・無効電力制御機能について記載ください。

発電機並列時に系統周波数が並列時許容周波数（50Hzエリア：50.1Hz／60Hzエリア：60.1Hz）以下となっていることを確認する装置または機能の設定可能範囲をご記載ください。

発電機の並解列箇所の分かる図を様式５の４にご記載ください。

系統事故発生から指定力率に制御完了する時間を記載ください。接続検討申込時には記載困難な場合、協議させていただきます。なお、系統事故時とは系統連系規程の電圧低下時のFRT要件で言えば、「電圧低下開始」時となります。

インバータの主回路方式（転流方式を含む）をご記載ください。（※スイッチング方式ではございません。）

逆変換装置の高調波電流歪率をご記載ください。ご不明な場合は、メーカーへお問い合わせください。別途示す上限値を超過する場合には、再検討が必要となる場合があります。

蓄電池定格出力[kW]および定格出力時の出力可能時間[h]を記載ください。
なお、記入いただく容量は、構内の蓄電池容量全体であり、また、PCS出力にて制約を受ける場合は、PCS出力にて記載ください。

様式５の５

接続検討時に記載いただきたい項目
受電電力（電力系統に流入する電力）の運転パターンをご記載ください。
※時間毎で想定しうる最大値を設定してください。
※時間毎の受電電力が不明の場合は、様式２　「5．受電地点における受電電力（同時最大受電電力）」により検討させていただきます。

※用紙の大きさは、日本産業規格A3サイズまたはA4サイズとしてください。

記載例（太陽光の場合）

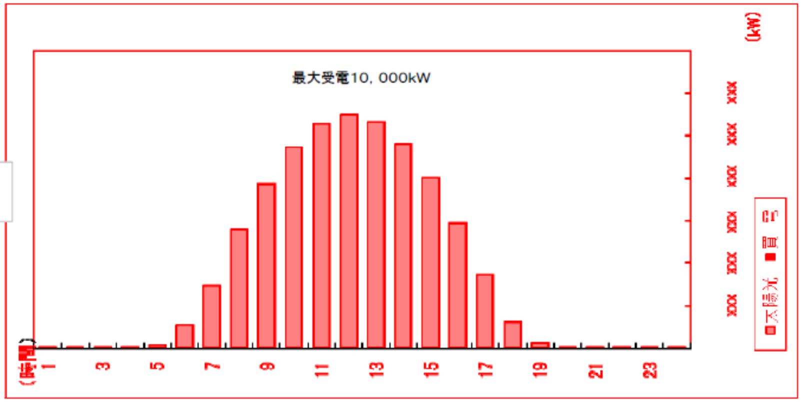
●●年　●●月　●●日

発電設備等設置者名　●●●●●

設　備　運　用　方　法

－　発電機運転パターン、受電地点における受電電力パターン　－

季節別のパターンの提出を求める場合もあります。



	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24 (kW)
発電	0	0	0	0	0	1000	3000	4000	6000	8000	9000	10000	9000	8000	6000	4000	3000	1000	0	0	0	0	0	0
買電	200	200	100	100	100														500	500	500	500	300	200

Source：OCCTO　https://www.occto.or.jp/access/kentou/files/AK1T_kisairei_taiyoukou_20240410.pdf

Chapter 5 Investigation and Countermeasures for Power System Accident

5.1. Investigation on 115/22 kV Transformer Failure

5.1.1. Background and Objective

Transformer failures at substations in the transmission system are generally relatively rare. However, in recent years, several incidents involving 115/22 kV transformers have occurred sporadically at substations under the jurisdiction of Électricité du Laos (EDL), with five major accidents reported within the past five years.

In response to this situation, the Department of Energy Management (DEM) of the Ministry of Energy and Mines (MEM) requested that the JICA Expert Team investigate the causes of these transformer failures and provide recommendations for countermeasures, as an additional scope under the "Project for Power Quality Improvement through Grid Code Development and Operational Capacity Enhancement."[7] (See Attachment 11 and Attachment 12)

Following this request, the JICA Expert Team began investigating transformer-related incidents in June 2022. This investigation was conducted as an additional assignment entitled "Investigation of Accidents and Failures in the Power System and Recommendation of Countermeasures," initiated in June 2022.

The objectives of this study are as follows.

1) Identify conditions and causes of 115/22 kV transformer failures/accidents

2) Check protection and maintenance status and system for 115/22 kV transformers

3) Based on the above, analysis of 115/22 kV transformer accident trends and recommendations for proper protection and maintenance

The scope of the investigation into transformer failures, as agreed upon with EDL, is as follows:

1) Identification of the Causes of 115/22 kV Transformer Failures

- Collection of transformer failure reports prepared by EDL and estimation of possible causes
- On-site investigation at the substation where the transformer failure occurred (115 kV Thanaleng Substation), including:

  Inspection of the accident status involving the 115/22 kV transformer

  Interviews with substation operators

While the true cause of transformer failure cannot be definitively determined without disassembly inspections by the manufacturer or reproduction of the accident conditions, the investigation will estimate the most probable causes based on possible triggering events, installation conditions, and maintenance practices.

2) Assessment of the Maintenance Status of 115/22 kV Transformers

- Review of the maintenance organization and system (staffing, maintenance frequency, etc.)
- Review of maintenance procedures (collection of maintenance manuals)
- Confirmation of the maintenance equipment currently in use

3) Recommendations for the Protection and Maintenance of 115/22 kV Transformers

- Development of recommendations for appropriate transformer protection and maintenance based on the investigation results
- Preparation of a report summarizing the above findings and proposals

[7] Minutes of Meetings on Opinions for Extension of the Period of Assignment of Project for Power Quality Improvement through Upgrading Grid Code and Strengthening Its Enforcement System, dated April 26, 2023.

5.1.2. Investigation (June 2023)

(1) Collection of Transformer Failure Reports Prepared by EDL and Estimation of Failure Causes

In June 2023, a list of transformer failures since 2008 was obtained from EDL's Power Plant and Transmission System Maintenance Center. As the list was entirely in Lao, it was translated into English. According to the list, 16 transformer failures have occurred since 2008, with brief descriptions of the causes provided, allowing for analysis of the incidents.In general, the causes of internal failures in oil-immersed transformers may include the following:

i) Degradation of Insulating Paper

This is the most common cause of transformer failure. Insulating paper is used to maintain electrical insulation within the transformer, but it degrades over time due to heat, moisture, and oxygen. As it deteriorates, insulation performance declines, eventually leading to failure.

ii) Deterioration of Insulating Oil

Insulating oil also deteriorates under the influence of heat, moisture, and oxygen. Its degradation results in reduced dielectric strength and can lead to transformer failure.

iii) Damage to the Core

The transformer core, which generates the magnetic field, may become damaged due to overcurrent or overheating. Such damage degrades magnetic performance and can lead to failure.

iv) Failure of Cooling Equipment

Cooling systems are used to control the transformer's temperature. If they fail, the transformer may overheat and consequently fail.

v) Natural Disasters

Events such as earthquakes or typhoons can result in flooding and damage to transformers.

Based on these typical causes, the team estimated the likely failure mechanisms by considering maintenance conditions and the layout/design of protection systems.

(2) On-Site Investigation of the 115 kV Thanaleng Substation

Thanaleng Substation is located in the southern part of Vientiane Capital, near the Thai border along the Mekong River. It is connected to EGAT's Nongkhai Substation in Thailand via a 115 kV transmission line and is used to measure power imports and exports between the two countries.

A single-line diagram of the Thanaleng Substation is shown in Figure 4-1.

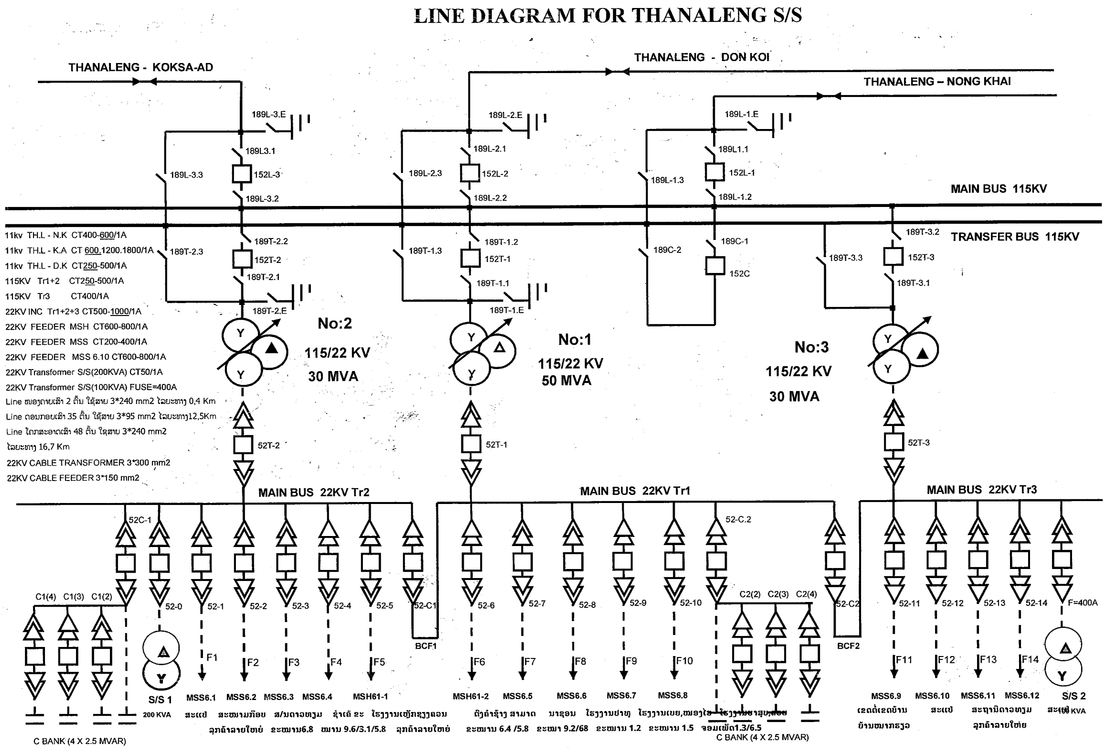


Figure 5-1 Single Line Diagram of Thanaleng Substation

The summary of the transformer failure that occurred at Thanaleng Substation is as follows:

- Date and Time of Occurrence: June 16, 2022, at 22:29
- Affected Transformer: 115/22 kV Transformer No. 2, rated at 30 MVA (see Figure 4-2)
- Manufacturer: TBEA Hengyang Electric (China; manufactured in 2004)

Figure 5-2 Failed 115/22 kV Transformer No.2 (Taken by JICA Expert Team)

- The immediate trigger of the incident was a short-circuit fault that occurred on 22 kV Feeder No. 5 (MSH 6.1.1) at the above-mentioned time, which caused fault current to enter Phase B of Transformer No. 2, resulting in burnout of the core on that phase.

According to interviews with substation operators:

- The exact location of the short-circuit fault on the 22 kV Feeder MSH 6.1.1 could not be identified, but it was suspected that a tree might have come into contact with the distribution line.
- The main protection for the transformer was a current differential relay, and there is a record indicating that it operated correctly during the fault. However, it remains unclear whether the 22 kV circuit breaker functioned properly.
- The affected feeder mainly supplies power to a nearby steel plant, and the load just before the fault was 15.98 MW. Due to frequent voltage fluctuations caused by the electric furnace at the steel plant switching on and off, the transformer's On-Load Tap Changer (OLTC) had a significantly higher number of operations compared to other transformers. When checking the OLTC counter of the transformer, it showed 27,050 operations. While this may not have been the direct cause of the accident, it is considered a factor that could accelerate OLTC degradation.
- The transformer underwent routine inspections and cleaning primarily by substation operators, as well as more detailed inspections and maintenance, including insulation resistance measurements, by the EDL maintenance team on an annual basis. However, since its installation in 2004, the transformer has never undergone an overhaul by the manufacturer.

In addition, on-site inspection confirmed that no surge arrester is installed on the 22 kV side of the transformer to provide direct protection. (Although a surge arrester is installed on the 22 kV feeder side.) Surge arresters are used to protect electrical equipment from overvoltages caused by lightning surges or switching surges. While they cannot protect against ground faults or short-circuit currents, they are normally installed near both the primary and secondary terminals of the transformer to provide direct protection. This design is common in most substations across Laos.

Based on the above, the conclusion of the on-site investigation is that the immediate trigger of the incident was likely an overvoltage surge caused by a short-circuit on the 22 kV feeder, which entered the transformer and caused insulation breakdown and burnout of the transformer core due to overcurrent.

In addition, the absence of proper transformer protection (a design deficiency), deterioration of insulating oil since its installation in 2004 (maintenance deficiency), and frequent sharp load fluctuations (e.g., rapid on/off operations) likely contributed to the gradual degradation of the transformer, reducing its tolerance to fault current. These factors are considered underlying contributors to the incident.

(3) Verification of the Maintenance Status of 115/22 kV Transformers

a) Confirmation of Maintenance Organization and Structure (Personnel, Maintenance Frequency, etc.)

An organizational chart of EDL's maintenance unit, the Power Plant and Transmission System Maintenance Center, was obtained; however, as it was entirely in Lao, it was translated into English.

According to EDL, as of June 2023, the Power Plant and Transmission System Maintenance Center consists of 42 personnel at headquarters, and 10 maintenance staff at each of its three regional branches: Northern, Central, and Southern.

EDL also stated that routine inspections and simple maintenance tasks, such as daily/weekly checks and cleaning, are carried out by operators at each substation. Meanwhile, the regional maintenance staff are responsible for more detailed maintenance activities—such as monthly and annual insulation oil analysis and insulation resistance measurements—at substations within their respective jurisdictions.

b) Verification of Maintenance Procedures (Collection of Maintenance Manuals)

During the site visit, the project team requested a copy of EDL's transformer maintenance manual from the Power Plant and Transmission System Maintenance Center. However, the manual was not available at the time, and it was not possible to confirm the official procedures and rules established by EDL for transformer maintenance.

c) Verification of Maintenance Equipment in Possession

EDL's maintenance teams reportedly possess general transformer maintenance tools such as voltmeters, ammeters, oil pressure gauges, and insulation resistance testers.

When asked about specialized equipment such as vacuum gauges and insulating oil analyzers, it was found that EDL does not appear to have any vacuum gauges. As for oil analyzers, only one unit is available nationwide, located at the Vientiane Phonetong Substation. This analyzer is used to examine samples of insulating oil brought in from substations across the country on a regular basis.

The specific gas components that the analyzer can measure were not clarified during the interviews.

In any case, the fact that there is only one gas analysis unit in the entire country is clearly insufficient. Since it also appears that no vacuum gauges are owned, it is considered necessary for each regional maintenance branch to be equipped with at least one of each of these specialized devices.

5.1.3. Investigation (Nov–Dec 2023)

Following the investigation conducted during the June 2023 field visit, which was reported in the previous progress report, the activities carried out during the subsequent field visits in November to December 2023 are as follows:

(1) Collection and Translation of Transformer Failure Reports Prepared by EDL

A simplified translated version of the list of transformer failures since 2008—obtained from EDL's Power Plant and Transmission System Maintenance Center and originally written entirely in Lao—is presented in Table 4-1.

Table 5-1 Incident Record of 115/22 kV Transformer

Id	Substation/ Accident Date	TR and OLTC Specifications	Accident Events	Fault Triggers / Estimated Causes
1	Naxaithong SS 13/5/2008	TR: Shandong Dachi China Electric 30 MVA 2010 OLTC: SMS CMA7 CMIII-500Y/72.53-10193W	There was a short circuit inside the OLTC unit while changing the tap. The contact is loose, not tight and unable to receive current, causing short circuit such as Phase to Phase and Phase to Ground. The OLTC of the transformer #2 has burned. The Oil Surge Relay (OSR) protection system works to cut off the CB Trip Incoming 115 kV and 22 kV sections, but the transformer is damaged and cannot supply electricity.	Internal fault: OLTC - Deterioration of OLTC, or - Imperfection of OLTC maintenance
2	Thangon SS 13/7/2014	TR: DAIHEN Thailand Electric 30 MVA 2011 OLTC: MR. VIII350Y-76-10193WR	There was a short circuit while supplying power to the 22 kV Feeder. At that time, the 3 Phase network was still connected to the ground system causing a strong short circuit and causing a high current exceeding the short-circuit current value of the transformer to be received, causing damage to the coil of the transformer (because the point of short-circuit is only 50 m away from the transformer). There was a short circuit to the ground in all 3 phases of Feeder 8.3 and 8.1 because the private company changed the DS to 8.3 and 8.1 to be the same network, which the station side changed to Ground 8.1 and the OP put on the light 8.3, causing the fire due to access to 8.1 which is connected to the ground wire, so the protection system 8.3 and the protection system of the transformer 87T work but in it the transformer is damaged (burn).	External fault: 22 kV feeder - Imperfection of protection system
3	Nongdeung SS 4/2/2017	TR: Tranfro Thailand Electric 50 MVA 2012 OLTC: MR VIII350Y-76-10193WR	There was a short circuit at the 22 kV C-Bank set. Phase to Phase and Phase to Ground short circuits caused a strong short circuit and caused a high current exceeding the current value of the transformer to be received, causing the coil of the transformer to be damaged (burn). The 22 kV bushing burst (burned) because a cat entered the C-Bank unit causing a short circuit, causing the C-Bank protection system and the transformer working with Differential 87T to trip the CB end-to-end but damaging the transformer (burn).	External fault: C-bank (cat) - Imperfection of protection system
4	Thabok SS	TR: PROLEC INDO	There was a short circuit at 22 kV, which point is the connection between the coil of the transformer and the	Internal fault: 22 kV bushing, connection

	6/8/2017	TECH (India) 30 MVA 2013 OLTC: MR. MA-9 MII350Y-72.5/B-1019.3G	power cable. Sign: The coil of the transformer is made of gold wire and the sheath of the power cable is made of aluminum. This is one of the reasons that causes heat and short circuit. Another problem is the entry of the power cable header is not standard, as it should be, causing a much higher current than the short circuit current of the transformer to receive, causing the coil of the transformer to receive damage (burn). There was a short circuit on the 22 kV bushing due to a short circuit in the cabinet and caused the 87T differential protection system to operate the CB head-end trip but damaged the 22 kV transformer coil (burn).	point between 22 kV coil and power cable - Imperfection of design and/or manufacturing
5	Nam Ngum 5 26/6/2018	TR: Shandong TAIKAI China Electric 20 MVA 2011 OLTC: SMS SHM-III MII350Y-72.5/B-10193W	There was a short circuit fault at the 22 kV power control cabinet while supplying for the normal load, a short circuit occurred at the incoming 22 kV switch causing a high current exceeding the short circuit current value of the transformer to be received, causing the transformer coil to be damaged (burn). There was a fire incident in the 22 kV switchgear cabinet due to the bursting of the cable, causing the 110 V DC power system failure.	External fault: 22 kV switchgear cabinet - Deterioration of 22 kV switchgear, or - Imperfection of maintenance
6	Thanaleng SS 27/4/2018	TR: China TBEA Hengyang Electric 30 MVA 2004 OLTC SMS CMA9 CVIII - 350Y/63-10193W	There was a short circuit fault on the 22 kV grid outside the station, which caused the current to flow to the transformer coil and the transformer coil was damaged.	External fault: 22 kV feeder - Imperfection of protection system
7	Jiangxai SS 4/9/2019	TR: AREVA T&D India NAINA 30 MVA 2009 OLTC MR. MA-9 MII350Y-72.5/B-10193W	While supplying the electricity, supplying the normal load of the transformer, there was a transformer trip event by the protection system of the transformer: Relay 87T makes the transformer unable to supply electricity, through inspection and testing it was found that the coil of the 22 kV Phase B is burnt, the reason for the short circuit is occurring in the transformer itself, because the quality of the transformer may not be as good as it should be.	Internal fault: 22 kV coil - Imperfection of design and/or manufacturing
8	Khoksa'ad SS 6/8/2019	TR Shandong Dachi China Electric 22 MVA 2003 OLTC SMS CMA7 CMIII-500Y/72.53-10193W	There was a short circuit in the 22 kV grid outside the station: a phase to phase and phase to ground short circuit caused a very high current and the current flowed into the transformer. There was a short circuit event outside the grid such as Feeder 3 and caused the transformer to work with Differential 87T. It was able to trip the CB from the head-end, but it damaged the transformer (burned).	External fault: 22 kV feeder - Imperfection of protection system
9	Thalat SS 23/10/2019	TR: Shandong Dachi China Electric 30 MVA 2005 OLTC SMS CVIV-350Y/63-10193W	There was a short circuit in the 22 kV grid outside the station: a short circuit in phase to phase and phase to ground caused a very high current, the current flowed to the transformer, which is higher than the short circuit current value of the transformer to be received, causing the transformer coil to be damaged (burnt). Feeder 4 broke on the pole outside the station and fell on Feeder 5, resulting in a high fault current, the protection system works, but the Trip Coil of F4, F5 and Incoming 1 burned.	External fault: 22 kV feeder - Imperfection of protection system
10	Thaotan SS	TR DAIHEN Thailand	There was a 22 kV CB Incoming short circuit event in the station: there was a phase to ground short circuit,	External fault: 22 kV incoming circuit

	07/07/2021	Electric 30 MVA 2015 OLTC MR VIII350Y-76-10193WR	namely: Phase B, Phase C, causing a very high current, the current flowed to the transformer. This causes the windings of the transformer to be damaged. The protection system with "Function Over Current" and "Buchholz Relay" causes the front CB to trip out the front and back of the transformer but still causes the transformer to burn.	- Imperfection of protection system
11	Thanaleng SS 17/06/2022	TR: China TBEA Hengyang Electric 30 MVA 2004 OLTC: SMS CMA9 CVIII - 350Y/63-10193W	There was a short circuit fault on the 22 kV grid outside the station, which caused the current to flow to the transformer coil and the transformer coil was damaged.	External fault: 22 kV feeder - Imperfection of protection system
12	Nam Ou 1 15/09/2022	TR: Yunnan Tongbian 30 MVA 2014 OLTC: SMS CHM-III VCM III-500Y/72.5B-12233W	There was a short circuit fault on the 22 kV grid outside the station, which caused the current to flow to the transformer coil and the transformer coil was damaged.	External fault: 22 kV feeder - Imperfection of protection system
13	Sewnsouk 15/02/2023	TR: Tusco Trafo Thailand 30 MVA 2010 OLTC: MR VIII400Y-76-10191G	There was a short circuit fault on the 22 kV DS Main Bus section inside the station, causing a severe short circuit current to flow to the transformer coil and the transformer coil was damaged.	External fault: 22 kV main bus - Imperfection of protection system
14	Nathon SS 12/05/2023	TR: Shandong Taikai 20 MVA 2012 OLTC: SMS SHM-I CMIII-500Y/126B-10193W	There was a short circuit fault in the 115 kV section, the fuse bushing inside the transformer, seriously causing the Tertiary transformer coil and 22 kV, 115 kV transformer coil to be damaged, making the transformer unable to be used (burned coil).	External fault: 115 kV section - Imperfection of protection system
15	Phonsoung 15/05/2023	TR: Yunnan Transformer Electrical, China 2016 OLTC: SMS CMA7 CM2III-500Y/72.5B-12233W	There was a short circuit fault on the 22 kV grid (22/0.4 kV transformer) outside the station, which caused the current to flow to the transformer coil and the transformer coil was damaged.	External fault: 22/0.4 kV transformer - Imperfection of protection system

(Source: EDL Power Plant and Transmission System Maintenance Center; the rightmost column was added by the JICA Expert Team)

(2) Estimation and Analysis of Transformer Failure Causes

It is generally difficult to determine the exact cause of a transformer failure unless the transformer is disassembled by the manufacturer or specialists immediately after the incident. Therefore, in this investigation, the causes of the failures were estimated based on the sequence of events for each transformer listed in Table 4-1.

Triggering events for transformer failures can generally be classified into two categories: internal faults and external faults.

Internal faults refer to failures or degradation of internal components such as the transformer core, windings, insulating paper, or insulating oil.

External faults refer to grid-side incidents such as short circuits or ground faults, where fault currents enter the transformer from the outside.

The rightmost column of Table 4-1 provides the estimated triggering events and likely causes of each transformer failure based on the incident histories. According to the table, out of 15 transformer failures that occurred since 2008, only three were likely caused by internal faults of the transformer itself. In contrast, twelve were likely caused by external faults originating from the grid.

The following are the internal fault cases inferred from the records:

#1 Naxaithong SS (2008)

Failure due to degradation of the OLTC (On-Load Tap Changer) or insufficient OLTC maintenance.

#4 Thabok SS (2017)

Defective design or manufacturing—or insufficient maintenance—of the 22 kV bushing or the connection point between the 22 kV winding and power cable.

#7 Jiangxai SS (2019)

Possible design or manufacturing defect, or insufficient maintenance.

Although these three cases involve internal faults, each may have multiple contributing factors. Even if insufficient maintenance played a role, minor defects are often difficult to detect through routine maintenance. In other words, since only three internal faults have occurred in the past 15 years, it can be said that EDL's transformer maintenance systems and practices are functioning reasonably well.

On the other hand, among the 12 external fault cases, only one occurred on the 115 kV system, while the remaining 11 cases were caused by faults on the 22 kV system.

This indicates that the majority of transformer failures stem from insufficient or faulty protection on the 22 kV side. In other words, the likely causes include:

- Malfunction or misconfiguration of protective relays
- Incorrect protection settings
- Malfunction of circuit breakers or inadequate breaking capacity.

(3) Verification of Transformer Maintenance Procedures (Collection and Review of the Transformer Maintenance Manual)

The EDL Power Plant and Transmission System Maintenance Center provided the transformer maintenance manual (written entirely in Lao), which was then subjected to a simplified translation and content review.

The manual covers all essential aspects, including the importance of transformer maintenance, the maintenance system, maintenance schedules, methods and frequencies for each component, testing procedures, and reporting guidelines.

If maintenance is carried out in accordance with the procedures outlined in the manual, there appear to be no major issues.

(4) Preparation of the Investigation Report

The findings from the June 2023 field visit, as well as those from the current mission, have been compiled into a report (Attachment 1: Report_TR). A summary of the conclusions and recommendations is provided below.

[Recommendations]

The transformer maintenance manual and maintenance records provided by EDL were reviewed and found to be generally adequate in terms of content. The maintenance system appears to be well organized. Moreover, since the majority of transformer failures that have occurred over the past 15 years were due to grid-side (external) incidents, and only three internal failures were recorded during this period, it can be reasonably concluded that transformer maintenance itself has been conducted appropriately to a certain extent.

However, the fact that most transformer failures were caused by external factors on the grid side suggests there may be issues with the transformer protection systems, such as protective relays and circuit breakers.

Based on the above, the following recommendations are made to reduce transformer failures at EDL substations in the future:

1) Review of Transformer Protection Systems

Of the 15 transformer failures that occurred at EDL substations since 2008, 12 are presumed to have been caused by external faults on the grid side. Of those 12, 11 were due to incidents on the 22 kV side, with only one on the 115 kV side.

These failures are considered to have resulted from fault or ground currents on the 22 kV side entering the transformer and causing damage. In other words, there may be malfunctions or inadequacies in the transformer protection system—such as protective relay or circuit breaker failure, or short-circuit currents exceeding the breaking capacity of the breakers.

To prevent such incidents, it is necessary not only to regularly maintain and test protective relays and breakers, but also to review relay settings and recalculate fault currents and circuit breaker capacity whenever system expansions or new power sources (e.g., PV plants) are connected to the grid.

2) Transformer Maintenance System

i) EDL's transformer maintenance system—including its maintenance frequency and manuals—is generally well established. However, it is understood that only one insulating oil analysis device, which is a critical tool for transformer maintenance, is available, located at the Phonetong Substation in Vientiane.

To maintain transformers more efficiently and respond promptly to failures, it is recommended that maintenance equipment be appropriately allocated to all four regional branches. Additionally, training should be conducted to improve personnel proficiency in using this equipment and in transformer maintenance knowledge.

ii) In the event of future transformer failures, EDL should promptly invite engineers from the manufacturer to conduct as detailed an investigation as possible to determine the root cause. The findings and countermeasures should then be analyzed and shared across all EDL branches and substations to prevent recurrence of similar incidents.

5.1.4. Explanation of the Investigation Report to MEM and EDL

In June 2024, discussions were held with representatives from EDL's Power Plant and Transmission System Maintenance Center regarding the contents of the draft investigation report prepared during the previous visit. Although no major comments were received from EDL, they expressed some requests concerning inspection equipment. It was explained that related points had already been incorporated into the recommendations section of the report. Based on this discussion, minor revisions were made, and the report was finalized.

(Refer to Attachment 46 Att-1 Presentation.pdf)

On June 14, 2024, a presentation was held in a meeting room at EDL to explain the contents of the investigation report. The meeting was conducted in a hybrid format, combining in-person and remote participation. A total of approximately 20 participants from MEM, EDL, and the JICA expert team attended.

The explanation was conducted based on the presentation materials included in Attachment 7_Att-1 Presentation, which summarized the contents of the investigation report. The main points of the presentation are as follows:

<u>Structure of the Report</u>

Chapter 1: Overview

Purpose of the investigation, scope of work, etc.

Chapter 2: Classification of Transformer Failures

General categorization of transformer failure causes

Chapter 3: Transformer Failures at EDL Substations

Estimation of failure causes based on transformer failure records

Chapter 4: Preventive Measures for Transformer Failures

Common maintenance practices to prevent transformer failures

Chapter 5: Conclusions and Recommendations

General Classification of Transformer Failures

In general, transformer failure causes can be classified as follows:

1) Design deficiencies
2) Manufacturing defects
3) Equipment deficiencies
4) Operational and maintenance errors
5) Abnormal voltages
6) Natural aging
7) Natural disasters

In addition, triggering events of transformer failures can be broadly classified based on their origin into internal faults and external faults:

1) Internal Faults (e.g., windings, core, insulating paper, internal clamping structures, leads, insulating oil)
2) External Faults (e.g., tank, accessories, cooling system, on-load tap changers, etc.)

5.1.5. Estimation and Analysis of Transformer Failure Causes at EDL Substations

It is difficult to determine the exact cause of a transformer failure without disassembling the unit immediately after the incident with the help of the manufacturer or experts. Therefore, in this investigation, the likely causes were estimated based on the transformer failure reports shown in Figure 5-1.

As mentioned earlier, triggering events of transformer failures can generally be categorized into internal faults and external faults.

Internal faults refer to failures or degradation of internal components such as the transformer's core, windings, insulating paper, and insulating oil. External faults refer to cases where fault currents enter the transformer due to grid-side incidents such as short circuits or ground faults.

In the rightmost column of Table 4-2, the estimated triggering events and likely causes of each transformer failure were recorded based on the incident histories. According to this analysis, out of 15 transformer failures that occurred since 2008, only three are considered to have been caused by internal faults within the transformer itself, while twelve are believed to have resulted from external faults on the grid side.

The three internal fault cases may have involved multiple contributing factors. Even if insufficient maintenance was one of the causes, it is generally difficult to detect minor defects through routine maintenance. In other words, with only three internal failures occurring over the past 15 years, it can be said that EDL's transformer maintenance system and practices have functioned reasonably well.

On the other hand, among the 12 external fault cases, only one originated from the 115 kV system, while the remaining eleven were due to faults on the 22 kV side.

This suggests that the majority of transformer failures were caused by inadequate or faulty protection on the 22 kV side—such as malfunctions in protective relays, incorrect protection settings, or circuit breaker failures or insufficient breaking capacity.

5.1.6. General Preventive Measures for Transformer Failures

The following are general inspection and maintenance items for preventing transformer failures:

4.1 Detection of Internal Faults

4.1.1 Detection by Buchholz Relay

4.1.2 Pressure Relay

4.1.3 Pressure Relief Valve

4.1.4 Protective Relay

4.2 Diagnosis of Internal Faults

4.2.1 Electrical Testing

4.2.2 Insulating Oil Inspection

4.3 Internal Inspection

4.3.1 Internal Inspection by Lifting the Core

4.3.2 Internal Inspection through Overhaul

4.4 Internal Repairs

4.4.1 Repair of Windings

4.4.2 Repair of Core

4.4.3 Repair of Lead Wires and Off-Circuit Tap Changer

4.5 Repair of Aged Transformers

4.6 Other Transformer Failures and Repairs

5.1.7. Recommendations

The transformer maintenance manual and maintenance records provided by EDL were reviewed and found to be generally sufficient in content, indicating that the maintenance system is well organized. Moreover, since most of the transformer failures over the past 15 years were caused by grid-side (external) incidents, and only three internal failures occurred during this period, it can be reasonably concluded that transformer maintenance has been carried out appropriately to a certain extent.

However, the fact that the majority of failures were caused by external factors suggests potential issues in the transformer protection system, such as protective relays or circuit breakers.

Based on the above, the following recommendations are made to reduce transformer failures at EDL substations:

1) Review of Transformer Protection Systems

Since 2008, a total of 15 transformer failures have occurred at EDL substations. Of these, 12 cases are presumed to have been caused by external faults on the grid side. Among those, one originated from the 115 kV side, while the remaining 11 were all due to faults on the 22 kV side.

These incidents are believed to have occurred when short-circuit or ground fault currents from the 22 kV system entered the transformer and caused damage.

This implies the possibility of issues such as malfunctioning protective relays, incorrect relay settings, failure of circuit breakers, or fault currents exceeding the breaking capacity of the breakers.

To prevent such incidents, it is necessary not only to regularly maintain and test protective relays and breakers but also, whenever system upgrades or new power sources (such as PV plants) are connected to the grid, to review relay settings, recalculate fault currents, and confirm that breaker interrupting capacities are adequate.

2) Transformer Maintenance System

i) EDL's transformer maintenance structure, frequency, and manuals are generally well developed. However, it appears that only one insulating oil analysis device—a key tool for transformer maintenance—is available, located at the Phonetong Substation in Vientiane.

Therefore, to enable more efficient transformer maintenance and ensure a prompt response in the event of an incident, it is recommended to appropriately allocate transformer maintenance equipment to the four regional branches and conduct training to improve knowledge of equipment usage and maintenance techniques.

ii) In the event of future transformer failures, engineers from the manufacturer should be invited as quickly as possible to conduct a thorough investigation into the root cause. The results of the analysis and the proposed countermeasures should then be shared across all EDL branches and substations to prevent recurrence of similar incidents.

5.2. Power Outage Investigation in Saysettha Development Zone (SDZ)

5.2.1. Background

Around July 2021, frequent power outages occurred in the Special Economic Zone area in the northern part of Vientiane City. It was assumed that there were issues with the protection relay system and other components, and partial studies and recommendations for improvement were carried out.

5.2.2. Overview of SDZ

The Special Economic Zone was developed by Lao-China Joint Venture Investment Co., Ltd., established in 2010 with a capital structure of 75% from Yunnan Provincial Overseas Investment Co., Ltd. (a subsidiary of Yunnan Construction and Investment Group, China) and 25% from the Vientiane City Government.
The zone covers a total area of 1,149 hectares, with a planned investment of USD 5 billion. It hosts 75 registered companies, including two Japanese companies: HOYA Laos Co., Ltd. and Gas One Laos Co., Ltd.
(Source: JETRO Website – https://www.jetro.go.jp/world/asia/la/sezinfo/saysettha.html)

Figure 5-3 Saysettha Development Zone

5.2.3. Background of the Investigation

The impetus for this investigation was a consultation and information request received by the JICA Expert

Team through the JICA office from HOYA Laos Co., Ltd., a Japanese company operating in the Saysettha Development Zone (SDZ).

Summary of the Consultation

HOYA Laos Co., Ltd. has repeatedly submitted the following complaints and requests to EDL, but has not received any response and is seeking advice on how to prompt an investigation into the causes and implementation of countermeasures.

1) Frequent Power Outages During the Rainy Season

Power outages increase during the rainy season, disrupting production. While lightning-induced outages used to be frequent in countries like Thailand and Vietnam in the past, such incidents have decreased in recent years due to the implementation of lightning protection measures. They would like Laos to also enhance lightning protection and improve transmission quality.

2) Short Notice of Planned Power Outages

The company operates 24 hours a day, making recovery from power outages difficult. Even if notice is given a few days in advance, it is not enough to adjust operations, resulting in impacts on production volume. They are requesting that notification of planned outages be provided at least one month in advance so that production schedules can be adjusted accordingly.

(It is noted that the company manufactures disk substrates.)

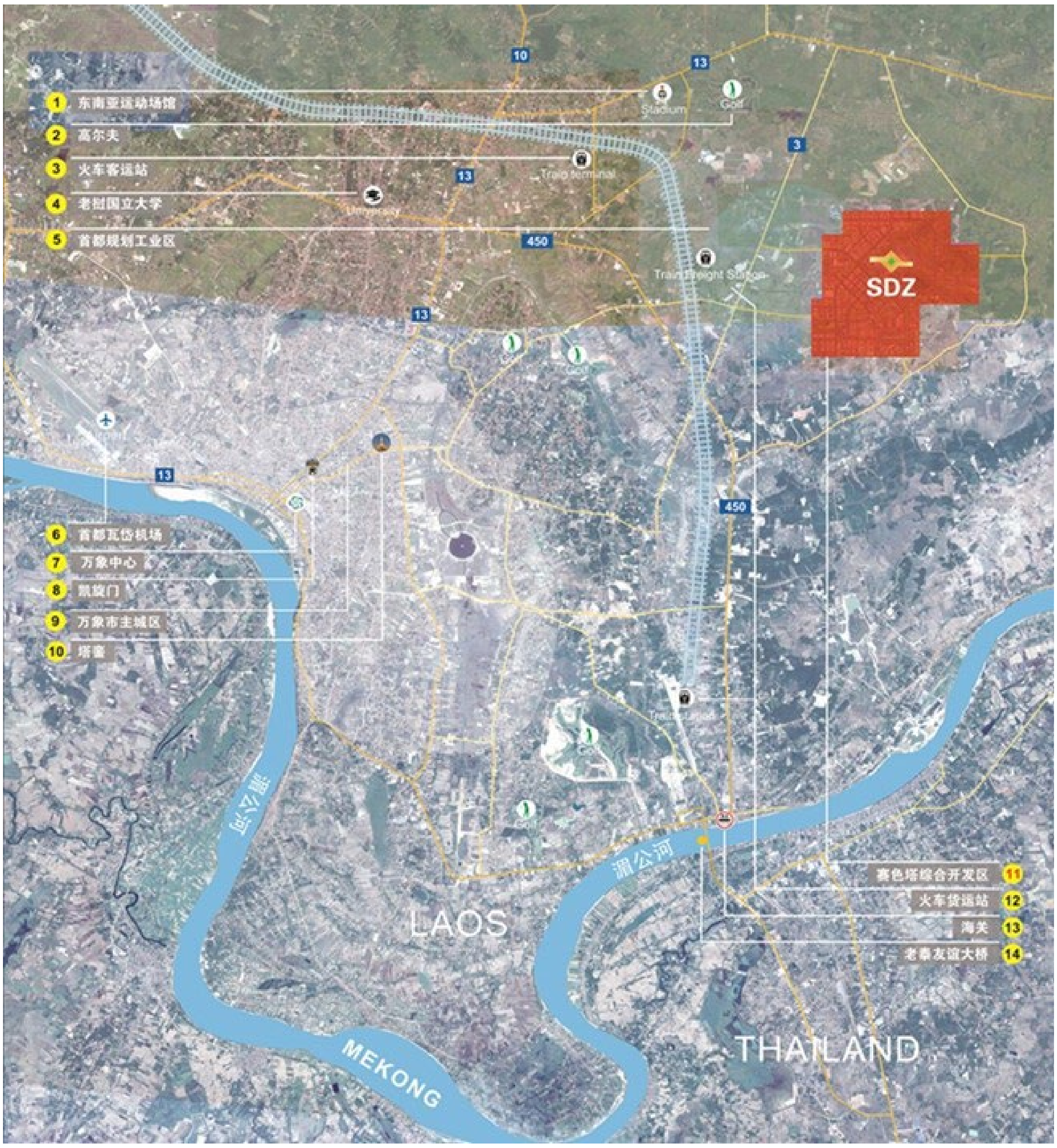


Figure 5-4 Map of Saysettha Development Zone

5.2.4. Power Supply System for SDZ

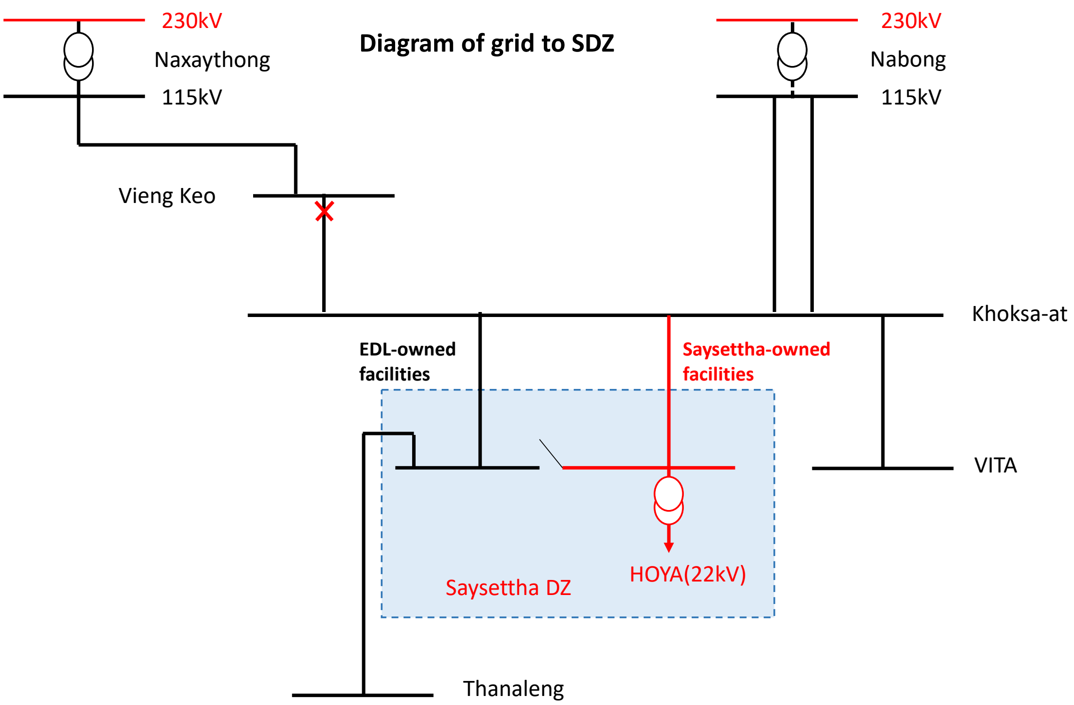


Figure 5-5 Power Supply System in Saysettha Development Zone

During the site visit to the C1 RCC on August 12, 2021, interviews were also conducted regarding this issue. According to the information obtained:

① **Power Supply to the SDZ**

- Power is supplied to the Saysettha Development Zone (SDZ) via two 115 kV transmission lines from the Khoksa-at Substation busbar. Electricity is stepped down to 22 kV through a transformer within the zone for supply to HOYA. Currently, the power source for the Khoksa-at Substation is the Nabong Substation, which supplies electricity through two 115 kV transmission lines.
- Although there is also a single 115 kV transmission line from Naxaython Substation via Vien Keo Substation connected to the 115 kV busbar at Khoksa-at Substation, the breaker at Vien Keo Substation is kept open to prevent overloading of the 115 kV Khoksa-at–Thanaleng transmission line (1 circuit).
- In the near future, there are plans to construct a new substation near the SDZ, and supply from this new substation is under consideration.

② **Estimated Causes of Outages**

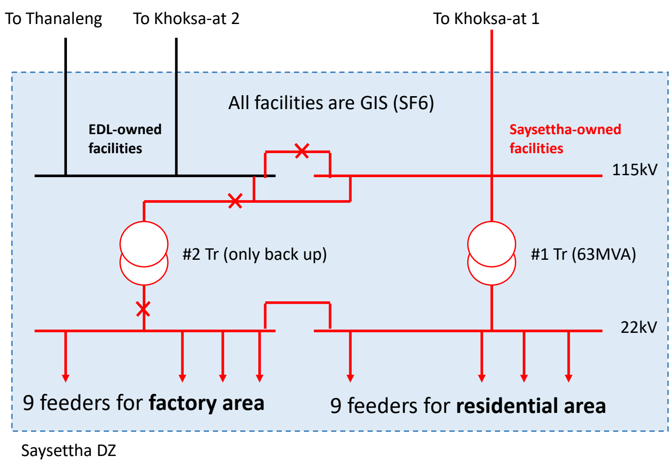
- Most power outages are believed to be caused by lightning strikes.
- A typical pattern for outages involving Khoksa-at Substation is that lightning strikes on various 230 kV transmission lines cause both circuits to trip. This then leads to overloading on other transmission lines, resulting in chain tripping by protection relays and ultimately a blackout.
- However, no staff member could provide an immediate explanation as to why both circuits always trip simultaneously due to lightning.
- Additionally, the distance from Khoksa-at Substation to the SDZ is only 2–3 km, which is quite short. The transmission line in that section is protected by a current differential relay. However, since many other 115 kV transmission lines still use distance relays, it was suggested that inappropriate settings on

those relays could lead to wide-area outages, including the SDZ.

- Although auto-reclosing relay systems are applied to the transmission lines, they appear not to be reclosing properly. However, no staff member could explain the cause.

On August 23, a site visit was conducted to the SDZ, and the following information was obtained from local engineers:

① **Power Equipment Configuration within the SDZ**



Transformer
- Indoor type
- Insulating oil is air-cooled (without forced circulation fans) — for capacity reduction
- Planned future configuration: 3-bank system (162 MVA)
- OLTC (17 taps) automatically controls to maintain constant primary voltage

Transmission Lines
- 115 kV overhead, 22 kV underground cable
- Protection scheme: Main – current differential; Backup – distance
- Auto-reclosing is functional
- 115 kV Thanaleng–SDZ: Owned by EDL (public)
- 115 kV Khoksa-at–SDZ Line 2: Owned by EDL (public)
- 115 kV Khoksa-at–SDZ Line 1: Owned by SDZ (private)

System Operation
- Of the two 115 kV transmission lines from Khoksa-at Substation, normally only Line 1 is used for receiving power; Line 2 is not used. (Reason: Policy prohibits simultaneous use of public and private transmission lines)
- When Line 1 experiences an outage, the Automatic Transfer Switch (ATS) detects the busbar voltage loss and automatically switches in the 115 kV bus tie 0.3 seconds later to restore power.

Figure 5-6 Configuration of Electrical Facilities in Saysettha Development Zone

② **Recent Power Outage Records**

- Since December 2019, no power outages have occurred due to incidents within the SDZ.
- Most recently, major outages occurred on July 6 and 9, 2021, due to troubles in the EDL system.

5.2.5. Issues and Future Considerations

The issues identified through this investigation and the proposed direction for future study and analysis are as follows:

(Issue 1) Despite the presence of two 115 kV incoming transmission lines, only one line—owned by SDZ (private transmission facility)—is used for regular power supply, due to ownership boundaries where one line is owned by EDL (public transmission facility) and the other by SDZ.

- While using a private line for general power supply or vice versa is understandably problematic from the perspective of electricity tariff calculations and contractual obligations, a more flexible interpretation may be worth considering.
- Transferring ownership of one line to the other party and aiming for dual-line operation should be explored.

(Issue 2) As with other cases, the use of distance relays as the protection scheme for the transmission lines appears to be a core problem.

- The recommended response is the same as described in Section 2.1.1.1, Issue 2.

(Issue 3) The root causes of outages are not being identified, and no records are kept.

- It is recommended to install fault recording devices such as oscillographs or PMUs to establish an environment in which the causes of incidents can be accurately analyzed.

Chapter 6 Implementation of Training to strengthen System Planning and Operation Capabilities

6.1. Technical Transfer of System Analysis

Power system analysis is essential for the core operations of both power system planning and power system operation departments. It is important to ensure that the preparation of data, analysis, and evaluation of results are properly applied to these operations.

Although Laos' power system sufficiently secures power supply for domestic demand, the long distances from power plants to demand centers and the inadequate development of transmission lines to match the rapid increase in generation capacity have resulted in transmission constraints due to stability concerns in certain areas. Furthermore, due to capacity limitations on cross-border transmission lines from the domestic grid to neighboring countries, surplus power cannot be sufficiently exported.

A lack of fundamental technical knowledge and experience at the Ministry of Energy and Mines (MEM) and Électricité du Laos (EDL) has also contributed to the inability to conduct stability assessments of the power system. Therefore, basic technical transfer was conducted on key aspects of power system analysis, including load flow analysis and fault current calculation.

From October to November 2021, data sets used by EDL for power system planning and operation were obtained. These included:

A 2030 peak demand rainy season power system model (PSS®E), and

2020 peak demand dry and rainy season models (DIgSILENT).

These models were analyzed to assess the structure of the power system and its operational status.

It was confirmed that the power system analysis models included not only the domestic grid but also the interconnected systems of neighboring countries.

In the PSS®E data, several configuration errors were identified, indicating that the dataset was not adequately prepared for conducting power system stability analysis.

For the DIgSILENT data, models for both the dry and rainy seasons were obtained, which confirmed that the operation of the power system differs depending on the season.

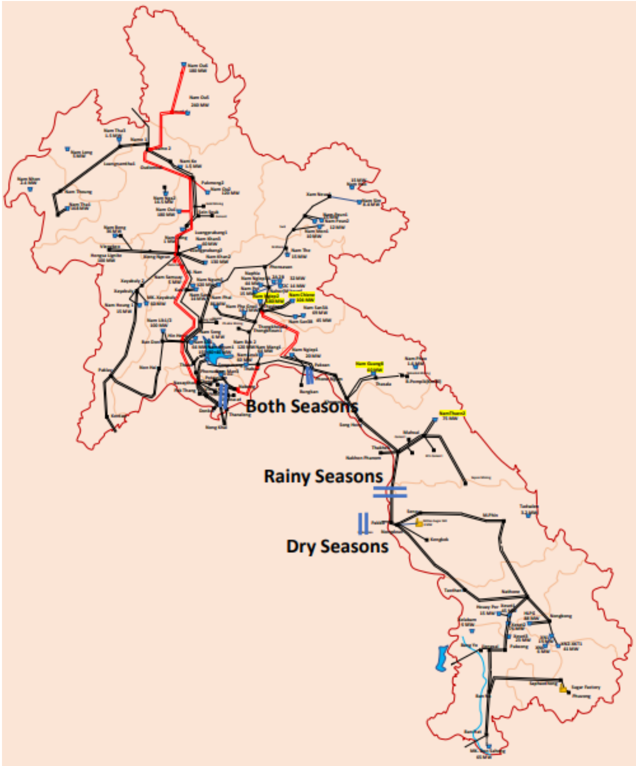


Figure 6-1 Grid Fragmentation Points in Rainy and Dry Seasons in Laos

- It was confirmed that the DIgSILENT data included the electrical parameters of generators (such as generator constants) and control-related information (such as output and voltage regulation), which are essential for power system stability analysis.
- Further analysis will be conducted on the DIgSILENT data inputs necessary for system stability assessment.
- When assessing the stability of the Lao power system, modeling the power systems of neighboring countries is also important. However, several areas in the neighboring systems appear to be inadequately modeled.
- Going forward, in order to conduct power system stability analysis, it is necessary to examine the modeling scope and equivalent network representations of neighboring countries' power systems.

The main activities conducted during the field mission from October to November 2021 were as follows:

- Acquisition of data necessary for power system analysis
- Assessment of operational methods for rainy and dry seasons
- Correction of currently available system data
- Review of the modeling scope for neighboring country power systems
- Review of future plans for Laos' national power system

In July 2023, EDL again shared PSS®E-based power system analysis data for Laos (file name: Wet_P_2030 Final.raw). Upon review, it was found that corrections were needed for values such as the impedance of transmission lines and transformers, as well as inconsistencies in the rated and maximum output capacities of generators and step-up transformer capacities. These issues were pointed out to EDL in August 2023.

To avoid errors in entering system analysis data, the following points should be kept in mind:

- Understanding of the per unit (PU) system

- Relationships between generator rated capacity, maximum output, and step-up transformer capacity
- Transmission line impedance:

It is necessary to be familiar with standard impedance per unit length for each voltage class and compare it with the impedance per unit length in the system analysis data.

- Transformer impedance:

When expressed on a machine base using the PU method, values typically range from approximately 6% to 18%. Therefore, it is recommended to express these values on a machine base in the analysis data.

The system analysis data obtained from EDL in December 2023 also showed several items that required correction. Continued review and revision of EDL's system analysis data is necessary.

Although EDL is updating the data periodically, basic input errors are still frequently observed. Therefore, ongoing technical transfer is needed regarding data input methods, analysis objectives, and methodologies.

It is essential that EDL acquires analytical skills necessary for system planning and operation, including data preparation, PU methodology, load flow and voltage calculations, fault current calculations, and stability analysis.

Given that the preparation of system analysis data, analytical techniques, and theoretical understanding requires a long-term effort, the establishment of a dedicated department or a research institute may also be considered to specialize in this work.

6.2. Capacity Building on Supply-Demand Operation Planning

n June 2022, a checklist was prepared and provided for the development of a supply-demand operation simulation model that incorporates reservoir operation.

Please fill out yellow, red, blue parts.

Power Plant	Located	Install Cap	Generator Unit Capacity (MW)								Turbinr	
Name	Region	MW	#1	#2	#3	#4	#5	#6	#7	#8	Type	Owner
Nam Khan 2	N	130	65	65							Francis	EDL-Gen
Nam Ou 6	N	180	60	60	60							Power China resources(85%), EDL-Gen(15%)
Nam Ou 5	N	240	80	80	80							Power China resources(85%), EDL-Gen(15%)
Nam Ou 2	N	120	40	40	40							Power China resources(85%), EDL-Gen(15%)
Nam Khan 3	N	60										
Nam Beng	N	36	12	12	12							China National Electrical EQUIPMENT Coporation(90%), EDL-Gen(10%)
Nam Tha 1	N	168										
Nam Ou 4	N	132										
Nam Ou [illegible]	[illegible]	[illegible]										
Nam Ng[illegible]	[illegible]	[illegible]										
Nam Phouan	N	45										
Nam Ngum 1	NC1	155	17.5	17.5	40	40	40				Francis	EDL-Gen
Nam Luek	NC1	60	30	30							Francis	EDL-Gen
Nam Mang 3	NC1	40	20	20							Pelton	EDL-Gen
Nam lik 1/2	NC1	100	50	50							Francis	China Water and Energy Corp.(CWE 90%), EDL-Gen(10%)
Nam Ngum 5	NC1	120	60	60							Francis	Power China resources(85%), EDL-Gen(15%)
Nam Ngipe 3A	NC1	44										
Nam Ngiep 2	NC1	180										
Nam Mang 1	NC1	64	21.3	21.3	21.3							Dongfang(75%), A&C(10.75%), EDL-Gen(10%), ???(4.25%)
Nam Song	NC1	6	3	3								EDL-Gen
Nam Ngum 1 (Extensien Phase 1)	NC1	80										
Nam Phai	NC1	86										
Nam PhaGnai	NC1	19.2										
Nam Ouv (Nam Aow)	NC1	15										
Nam Ngum 1 (Extensien Phase 2)	NC1	40										
Nam Ngum 4	NC1	240										
Nam Theun 2 (d)	C2	75										
Nam Gnoug 8	C2	60										
Xelanong 1	C2	70										
Nam Theun 1 (d)	C2	130										
Nam Hinboun	C2	30										
Houay Ho (d)	S	2.1	2.1								Pelton	Glow Co., Ltd.(67.25%), EDL-Gen(20%), Hemaray Land Development(12.75%)
Houaylamphanh Gnai	S	88	44	44							Pelton	EDL-Gen
Xeset 3	S	23										
Houay palai	S	30										
Houay Ho (e)	S	150	75	75							Francis	Glow Co., Ltd.(67.25%), EDL-Gen(20%), Hemaray Land Development(12.75%)

Figure 6-2 Checklist for Reservoir Operation Plan Confirmation

6.3. Capacity Building on Operational Planning

In 2022, in preparation for examining methods to adjust variable renewable energy sources based on the operational plans of reservoir-type hydropower plants, and in response to new demand trends such as digital mining and silicon mines, the operational plans of power plants were confirmed with EDL, and a supply-demand operation simulation model reflecting reservoir operation (PDPATII, developed by TEPCO) was created.

Workshops were held for DEPP and EDL to conduct technology transfer related to power development planning and supply-demand operation planning using the supply-demand operation simulation.

The Minister had instructed DEPP to fully understand the supply-demand balancing capacity of reservoirs when revising the National Power Development Plan (NPDP). However, at present, although the PDPATII simulation tool—donated by TEPCO 20 years ago—is available, it is not being effectively utilized. Similarly, although tools such as POLEXSO and DigSILENT have been provided by organizations including USAID, they are not being used proficiently.

As a result, the procedures for power development planning that incorporate supply-demand operation considerations have not been clearly established. Therefore, a training program on supply-demand simulation was conducted, based on the following attached materials:

Attachment 8

Attachment 9 Training_Demand_Supply(2).pdf

Attachment 10

The training schedule is shown in Table 6-1.

Table 6-1 Training Schedule for Supply-Demand Simulation

1st Workshop	October 12, 2022 (Wed)	Preparation for conducting the supply-demand simulation: installation and operation check of PDPATIII
2nd Workshop	October 13, 2022 (Thu)	Explanation and preparation of data required for the supply-demand simulation
3rd Workshop	October 17, 2022 (Mon)	Revision of demand data and hydropower data
Wrap-up	October 21, 2022	Based on Attachment 4: Supply-Demand Simulation Training (2)
	December 14, 2022	Participants were requested to organize the necessary data by the next session, particularly to prepare hourly data for demand and HPP (hydropower plant) inflow.

6.4. Explanation of Simulation on Reservoir Hydropower Regulation and Training on Supply-Demand Simulation

On Friday, June 9, 2023, a presentation was given to Mr. Soulivanh, Director of EDL Power System Planning & Control Department, and Mr. Chitpanya, Manager of Power System Planning Division, regarding the simulation results using the IRENA-provided FlexTool on the balancing capacity of reservoir-type hydropower plants (RES).

(Refer to Attachment 23 PDP_JICA_LaosGC Simulation_20230609.pdf)

In the simulation, the reservoir capacity was set to one month for each RES. As a result, the balancing capability of RES could be simulated. However, since the assumed reservoir capacity was a relatively large one-month value for all RES, the EDL was requested to submit actual values.

The 8,760-hour demand dataset used was from 2016 and considered outdated, so EDL agreed to provide updated demand data.

6.5. Case Study from Japan on System Connection

In the meeting on grid connection with EDL held on July 29, 2021, the JICA Expert Team confirmed the practical implementation of the Connection Code through interviews with EDL's system planning department. The following was revealed:

- The system planning department of EDL conducts work related to the connection of power generation facilities to the grid, such as grid impact studies, but is unable to do so adequately due to a lack of system analysis tools and staff with sufficient skills.
- As a result, they do not fully understand the technical requirements needed for the application form.

Given that EDL is aware of this issue, it was agreed that the next step would involve introducing case studies from Japan regarding system connection procedures for generation facilities, to deepen understanding of the required tasks.

A series of briefings and discussions were held to introduce Japan's (TEPCO Power Grid) practices for grid connection of generation facilities. These sessions helped deepen EDL's understanding of the procedures and reaffirmed the importance of developing standardized application forms.

An overview of the grid connection workflow and procedures for generation facilities at TEPCO Power Grid was presented in March 11, 2022. In addition, various standardized forms required from applicants during the grid connection assessment process were introduced.

Given EDL's strong interest in the form templates, the relevant data was shared.

EDL requested further explanations on the detailed procedures and technical criteria used during grid connection assessments. It was agreed to provide these explanations during the next mission.

Using Section III "Consideration of grid access facilities" of the document 20220630_ConnectionGuideline_ver3.pdf, the technical criteria for grid connection assessments at TEPCO PG were explained in June 24, 2022.

Using Section II "Business procedures of the grid access" from the same guideline document and the current Lao Grid Code, a comparative review and discussion were held on generation facility connection practices in Japan (TEPCO PG) and Laos in June 30, 2022.

It was confirmed that the Lao Grid Code describes the procedures in considerable detail, and is comparable in quality to the Japanese counterpart.

However, it was also confirmed that the current Lao Grid Code lacks standardized application forms necessary for practical operation. The importance of developing these forms was reaffirmed.

For reference, form templates used in TEPCO PG and the Thai Grid Code were shared with the Lao side.

- Presentation Materials:

Attachment 1 Outline of Generator Connection Business at TEPCO PG.pdf

Attachment 2 Appendix of Outline of Generator Connection Business at TEPCO PG.xls

Attachment 3 Generator Connection Guideline of TEPCO PG.pdf

6.6. Oscilloscope Training

On September 12, 2022, a training session on oscilloscopes was conducted for EDL employees at the 5th-floor conference room of the EDL headquarters. The training materials used were the attached document 14 "Overview of Automatic Fault Recorder and Measurement.pdf," which explained the basic mechanisms and roles of oscilloscopes. As an example of the equipment, the catalog of Kinkei Systems Co., Ltd. was presented. During the Q&A session, it was confirmed that the device is installed in a substation and receives three-phase inputs from CTs and VTs, that the fault locator function is not included, that not all functions listed in the catalog are standard but some are optional, and that while determining the exact cause of an accident is difficult, certain estimations are possible. Based on specific examples in the materials, it was explained that most accidents are caused by lightning, and a case where arc marks were confirmed during a site inspection was also introduced.

On Friday, June 2, 2023, we conducted a training session on the basics of oscilloscopes for EDL staff. The materials used were the attached document Attachment 26 202306 Automatic Fault Recorder(Pilot Project).pdf, which explained the basic functions and use cases of oscilloscopes. Additionally, at the request of EDL, we revisited the content of the training conducted in September 2022 and provided an overview of the device's features using the catalog from the manufacturer. During the Q&A session, there was discussion about whether installing multiple oscilloscope devices could improve the accuracy of accident analysis and accident point evaluation. We explained that by combining data from devices installed at both ends of a power line, it is possible to calculate the accident point impedance, which can lead to improved accuracy. Additionally, it was explained that the introduced devices do not have fault locator functionality but instead use recorded data for accident point estimation, support up to 64 analog inputs and 64 isolated digital inputs, and that in actual implementations, the number of inputs would be determined based on the scale of the substation, with either 8 or 4 lines being considered.

6.6.1. Training on Solar Output Forecasting

On Friday, June 2, 2023, based on the document Attachment 25 Training materials for PV output forecast_0602.pdf an overview of the solar power output prediction tool used at Tokyo Electric Power Company's Central Power Dispatch Center was presented. The content covered “how the prediction is used,” “methodology,” “the impact of each parameter,” and “examples from Tokyo Electric Power Company.” No discussion was held regarding the provision of the prediction tool. During the Q&A session, it was explained that output decreases are due to solar radiation settings, that generator location information also influences predictions, and that in Japan, the annual prediction cost amounts to 10 million yen.

Chapter 7 Electricity Regulator

7.1. Indicators of Output 3 "Enhance business systems, including monitoring of MEM and EDL"

The achievement of Output 3, "Enhance business systems, including monitoring of MEM and EDL" is shown below.

Table 7-1 Indicators of Output 3 Achieved

◎: Completely achieved
○: Generally achieved, but there are ongoing issues.

Results	Indicators	Status of Achievement
3. Strengthen business systems, including monitoring of MEM and EDL.	● Establish an internal audit system for MEM and EDL.	Achieved ◎
	● Propose the system of submitting the EDL self-safety plan and supply plan to the supervising authority.	<Current situation> It proposed the creation of an electricity regulatory agency and its functions to ensure transparency and efficiency in the electricity sector as a whole. The functions of the agency would be to advise the MEM from a professional standpoint in regulating electricity prices, granting business licenses, formulating, enforcing, and revising grid codes, mediating complaints and disputes in the electricity market, reviewing draft electricity development plans, and monitoring the progress of projects. The establishment of an electricity regulatory agency would require legal reform, and the MEM has established a cross-governmental working group to study the issue.
	● Establish an organization for future grid code revisions.	<Issues> Support for legal reform and the establishment of an electricity regulatory agency will be handed over to the Australian LASEP and the World Bank after the completion of this project.
	● Ensure that monitoring and command tasks are appropriately assigned.	

7.2. Overview of Regulatory Agency Study

The objective of this project is to support the revision of the Grid Code so that it can serve as a binding set of rules for all power system users in Laos—such as EDL, EDL-Gen, EDL-T, other transmission operators, independent power producers (IPPs), and large consumers. The revised Grid Code must be developed through a process that ensures consensus across the entire power sector.

In other countries, designated electricity regulatory bodies or their equivalents—such as OCCTO in Japan or EGAT in Thailand—take the lead in formulating and revising Grid Codes. These efforts typically involve approval by relevant government authorities and incorporate stakeholder consultations during the process.

However, in Laos, the institutions and functions necessary for such a process have not been adequately established. Therefore, the project first needed to initiate the institutional development. The "support for establishing a regulatory agency" began when it was recognized at the start of the project that such an agency (initially envisioned as a Grid Code Management Committee) would be essential.

Generally, a regulatory agency is not limited to managing the Grid Code—it oversees the regulation of the entire power sector. In Laos, since 2010, the market has gradually liberalized with the establishment of EDL-Gen (separated from EDL's generation department) and an increasing number of IPPs supplying electricity domestically. Furthermore, amendments to the Electricity Law in 2017 allowed entities other than EDL to enter the transmission business. With EDL-T, the national transmission system operator, set to begin full operations in 2024, the growing number of market participants has reaffirmed the need for an independent and robust electricity regulatory authority in parallel with this project.

In March 2022, under the leadership of Minister Dabbong, it was agreed that the regulatory agency would be established within the organizational structure of the Ministry of Energy and Mines (MEM). As a result, it has also become necessary to consider the reorganization of MEM to clarify the respective roles and coordination between the new agency and MEM's departments.

The main functions of the regulatory agency will include:

- Setting fair electricity tariffs
- Ensuring stable power supply
- Monitoring the use of power systems
- Protecting consumer interests

This initiative has drawn upon case studies of electricity regulatory bodies in neighboring countries such as Vietnam (ERAV), Thailand (ERC), and Cambodia (EAC), as well as those in advanced economies such as Germany (BNetzA), Australia (AER), and Japan (OCCTO and the E-Grid Code). It was ultimately determined that Vietnam's ERAV model, given its similarity in political structure and its early-stage development context, would be the most appropriate reference for Laos.

A concrete proposal was thus made to establish a new regulatory agency, the Electricity Regulatory Agency of Laos (ERAL), under MEM, with legal and operational independence. ERAL would be responsible for reviewing and evaluating transmission and distribution tariffs, formulating transparent electricity market rules, and overseeing the implementation and enforcement of the Grid Code. It would also play a role in increasing transparency in decision-making through stakeholder engagement and providing third-party assessments for power sector planning.

Although the current Grid Code was originally developed in 2013, it lacks legal enforceability. Therefore, alongside the establishment of ERAL, it must be legally empowered. ERAL, in cooperation with the Grid Code Committee (comprising EDL, generation companies, IPPs, etc.), will finalize and approve the Grid Code and ensure compliance by all stakeholders.

To realize this framework, an amendment to the Electricity Law will be required. The establishment of the new regulatory regime will proceed through a legal reform process involving the Lao Government and the National Assembly.

7.2.1. Grid Code Management Body

Between 2021 and 2022, the establishment of a Grid Code management organization was studied with reference to international case studies.

- Since the role of the regulatory authority directly influences the structure of Grid Code management, it is important to first discuss and examine the structure of the regulatory authority.
- From the perspective of ensuring transparency, the regulatory authority should ideally be an independent body. However, if established under a government ministry, it may be implemented more quickly.
- In Japan, the regulatory authority is under government jurisdiction and can only provide advice rather than make decisions. The Grid Code is governed by OCCTO, which sets overall policies, while transmission and distribution companies define the detailed content.
- In the Philippines, the Grid Code stipulates that all stakeholders must be members of the Grid Code management organization.
- In Thailand, there is an independent regulatory authority (ERC). A major challenge is how to unify the Grid Codes of various operators.
- During the local mission from February to March 2022, the concept of the regulatory authority and Grid Code management structure was presented to the directors of various departments using Attachment A5_Grid Code Proposal Organization, and their opinions were sought.

According to the view of the DPC Director on February 23, 2022, a model in which the regulatory authority is placed under MEM, similar to that of Japan or Vietnam (Figure 7-1), would be appropriate. It was also noted that five years had passed since the 2017 Electricity Law and that a legal amendment was in motion; therefore, the establishment of the regulatory authority and Grid Code management framework should be included in the new law. Similarly, on February 25, the DEPP Director also expressed support for Option 2.

Since the approach to Grid Code management is closely related to the functions of the regulatory authority, coordination with the Electricity Policy Advisor Project is essential. Going forward, the functions and structure of both the Grid Code management body and the regulatory authority will be reviewed and organized, a proposal will be drafted, and consultations with the Minister and each department will be conducted in parallel.

At the JCC meeting in December, DEM requested training related to Grid Code management.

7.2.2. Regulatory Commission

The structure of Grid Code management is closely linked to the functions of the regulatory authority. Therefore, a proposal was developed to clarify and organize the respective roles and structures of the Grid Code Management Body (Grid Code Committee) and the Regulatory Authority (Regulatory Commission).

An analysis of Grid Code management and regulation frameworks in various countries—Japan, Thailand, Vietnam, Malaysia, Saudi Arabia, the United Kingdom, the Philippines, and the United States (PJM)—along with recommendations for Laos, is documented in Attachment A5_Grid Code Proposal Organization.

Three types of models were identified:

Option 1: Establish a Grid Code Committee under an independent Regulatory Commission, as in the Philippines.

Option 2: Establish both entities under the Ministry of Industry or Energy, as seen in Japan and Vietnam.

Option 3: Define both through an Energy Industry Law, as in Thailand, where an independent Regulatory Commission has the authority to issue amendments and improvement orders.

In all models, the role of the regulatory authority and the framework for the Grid Code are clearly defined in electricity-related legislation. Therefore, it is essential for the country to first determine the formal positioning of the Grid Code Committee within its institutional framework.

Minister Dabbong and various department directors expressed that, from the standpoint of facilitating consensus and swift institutional development, Option 2 (as shown in Figure 7-1) is preferable. Based on this, it was instructed that a Department of Energy Regulatory Management (DERM) be established, using the current DEM (Department of Energy Management) as the foundation.

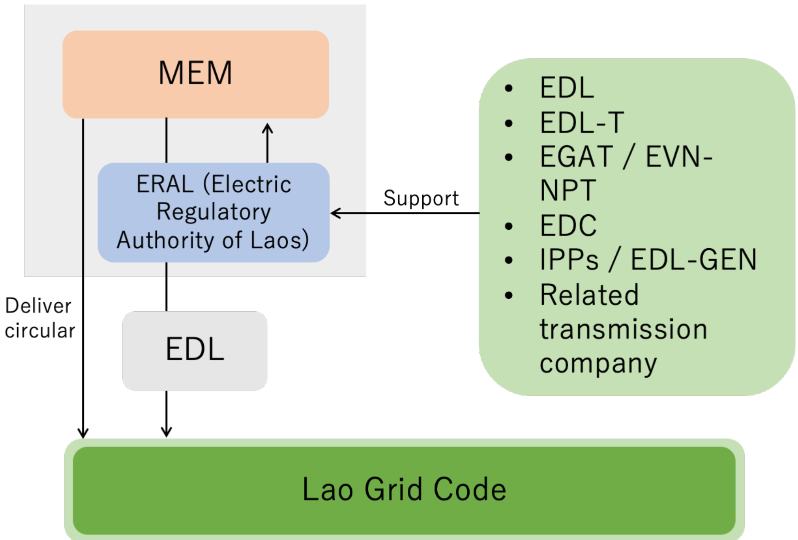


Figure 7-1 Revised Option 2 for Grid Code Committee Organization

In terms of legal revision, it is important to follow the proper procedures in accordance with the legal hierarchy. To amend the Grid Code, it is necessary first to establish a regulatory authority through legal amendments. Following that, a Grid Code Committee involving the regulatory authority must be formed.

Support will be provided to develop a draft to facilitate discussions in line with Lao legal procedures. Since Vietnam and Laos have similar political systems and legal frameworks, Vietnam's example will also serve as a useful reference.

7.3. Recommendations and Case Studies on Regulatory Agency

In July 2023, a report summarizing the recommendations for the regulatory agency was compiled. (Available in Japanese only.)

In September and December 2022, the following recommendations and case examples were presented.

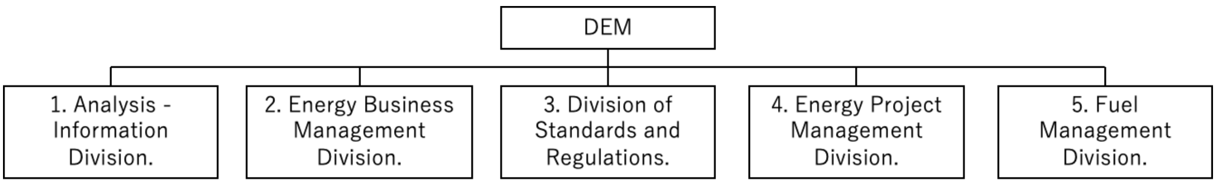
(For the explanations provided in 2022, refer to Attachment 4 and Attachment 4 .

For a detailed comparison with Thailand and Vietnam, refer to Attachment 16 .

1. Recommendation on Organizational Form and Tasks for ERAL (Energy Regulatory Authority of Laos)
2. The Case of Thailand
   1) EPPO
   2) ERC
3. The Case of Vietnam

Issues with the Current DEM Organizational Structure and Proposed Recommendations:

1. The functions of "High Voltage & Substation" and "Renewable Energy" are currently divided between the Division of Standards and Regulation and the Division of Energy Project Management, with responsibilities split between Design and Construction/Operation. It is recommended that the High Voltage division be unified to manage both design and construction/operation under a single department.
2. The Renewable Energy function should also be unified under a single department.
3. The Fuel Management Division, which oversees imported fuels, should expand its scope to include the management and safety control of coal, as well as future fuels such as ammonia and hydrogen.
4. On the user side, energy conservation should be integrated with related operations.
5. Regarding tariffs under DEPP (Department of Energy Policy and Planning), currently only retail tariffs are regulated; transmission tariffs should also be subject to regulatory oversight.
6. An independent asset evaluation unit should be established in connection with the unbundling of EDL and entities such as EDL-T.
7. International functions and the current Analysis-Information Division's general administrative role should be placed directly under the head of the regulatory authority.



(Source： Vientiane Capital, Dated: 27 Jan 2022)

Figure 7-2 Current Organization Structure of DEM

Table 7-2 Delineation of Survey and Evaluation for Design, Construction, and Operation

		DEM			DEPP	DPC
		DEM Energy Business Management Division	DEM Division of Standards and Regulations	DEM Energy Project Management Division		
Transmission & Substation	High voltage		Design	Construction / Operation	MOU / FS	CA
	Medium voltage	Design / Construction / Operation				
	Low voltage	Design / Construction / Operation				
User side (household)		Design / Construction / Operation				
Renewable energy			Design	Construction / Operation		

Note 1:

DPC = Department of Planned Cooperation

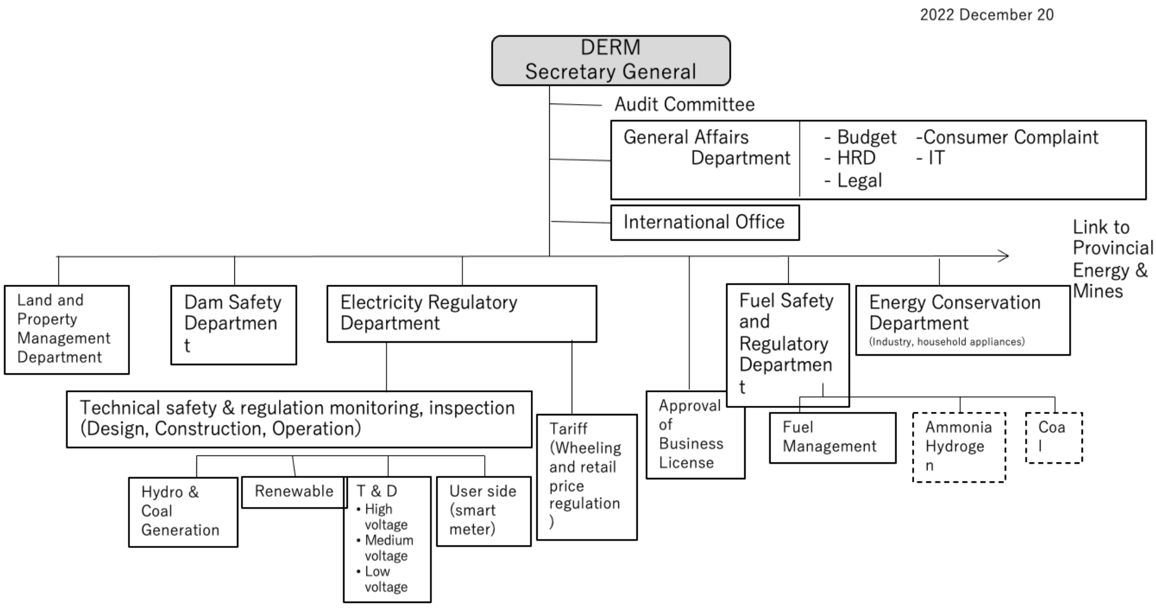
DEPP = Department of Energy Policy and Planning

DEB is responsible for F/S (Feasibility Study) approval.

CA = Concession Agreement

Note 2:

EDL is involved before project completion.



(Source：Hiroaki Nagayama, Kyoto University)

Figure 7-3 (Tentative) Organization Structure of DERM

Table 7-3 Current and Future Roles of Power Sector Regulator in Laos

	規制委員会の業務	ラオス DEM	ラオス DERM	ベトナム	タイ
		MEM	シングルバイヤー	強制プール	シングルバイヤー
1) 事業者規則	・新規事業者に対する事業ライセンスの発行	○(DEM)	○	○	○
	・発電事業者の発電レートの調整・決定（ヒートレートなど）	○	◎	△	○
	・配電会社のシステムロスの評価、系統ロスのガイドライン	○	◎		○
	・送配電託送料金規制	(No regulation)	◎	△	○
	・送電開発計画における送電資産の拡張・改修計画の承認	○(DEPP/DEM)	◎	△	○
	・グリッドコード、配電コード執行に係るその他ガイドラインの発行、技術・事業計画の査定		◎	○	○
2) 価格規制	・販売電力料金設定	○(DEPP)	○	△	○
	・使用時間料金（Time of use）		○		○
	・内部補助金の撤廃		○		△
3) 村落電化	・電化手法の評価		○		△
	・村落電化		○		△
4) 消費者保護	・必要なデータの提供			○	○
	・公聴会の開催と苦情処理	○(DOI/DEM)	○	○	○
5) 電力卸売市場	・電力事業者への市場参加ガイドライン			△	N/A
	・市場監視の枠組みの確立				○
	・価格決定のガイドライン（シングルプライスオークションなど）				N/A
	・市場モデルに見合った市場ルールの提示と市場ルールの欠陥の迅速な是正、紛争の調整			△	N/A
	・卸電力コストから電力料金への転嫁システム（パススルー）の調整				△
6) 省エネ、再エネを利用	・DSMの規制枠組み作成	○ (DEEP/EDL/DEM)	◎	△	○
7) 再生可能エネルギーの導入拡大	・再生可能エネルギーの買取/Fault ride though要件		◎		○
8) セクターアンバンドリングにかかる資産評価	・送電資産と副次送電資産の評価		○	△	○
9) メータリング	・MSP（Meter Service Provider）許可ガイドライン作成	○(DOI/DEM)	○		○
	・計測基準ガイドラインのトレーサビリティの作成	○(DOI/DEM)	○		○

1) Cabinet
2) Department of Inspection (DOI)
3) Department of Mining Management (DMM)
4) Department of Energy Management (DEM)
5) Department of Energy Business (DEB)
6) Department of Energy Industrial Safety Management (DEISM)
7) Department of Planning and Cooperation (DPC)
8) Department of Organization and Personnel (DOP)
9) Department of Geology and Minerals (DGM)
10) Department of Energy Policy and Planning (DEPP)
11) Department of Energy Efficiency and Promotion (DEEP)
12) Research Institute for Energy and Mines (RIEM)

(Source：H. Nagayama, Kyoto University)

Table 7-4 (Reference): Future Functional Roles of Electricity Regulator in Laos

	規制委員会の業務	ラオス DEM	ラオス（DERM）（目標）	(参考) ベトナム ERAV	(参考) タイ	(参考) VIETNAM-ERAV 首相決定258/2005/QD-TTgの事項
		Single buyer	Single buyer→ Wholesale competition?	Wholesale competition	Single buyer	和訳
1）事業者規則	・新規事業者に対する事業ライセンスの発行	○(DEM)	○	○	○	第2条5項）電力市場への組織的および個人的参加者の活動ライセンスの更新、修正、補足および取り消しを評価する。
	・発電事業者の発電レートの調整・決定（ヒートレートなど）	○	◎	△	○	第2条3項d）【規制の公布のための大臣（工商省MOIT）への提出】発電価格帯、電力卸売価格帯を評価する。
	・配電会社のシステムロスの評価、系統ロスのガイドライン	○	◎		○	
	・送配電託送料金規制	(No regulation)	◎	△	○	第2条3項e）【規制の公布のための大臣（工商省MOIT）への提出】送電料金、配電料金、電力市場参加料金、配送料金の市場換算、規制料金、付帯サービスの利用料金およびその他の料金、電力市場の運営に係る料金を評価する。
	・送電開発計画における送電資産の拡張・改修計画の承認	○(DEPP/DEM)	◎	△	○	第2条8項c）合理的なレベルの冗長性、最小の生産及び運営コストである電力システムにおいて、安全で信頼性の高い運営及び長期的な需要と供給のバランスを確保するために、電力プロジェクトと送電網の投資と開発を奨励または制限するためのソリューションを提案する；
	・グリッドコード、配電コード執行に係るその他ガイドラインの発行、技術・事業計画の査定		◎	○	○	第2条8項e）需要と供給のバランスを確保するために、承認された計画に従って年間開発投資を必要とする電力プロジェクトと送電網への投資のリストを発表する；
2）価格規制	・販売電力料金設定	○ (DEPP)	○	△	○	第2条2項）大臣（工商省MOIT）が検討し、首相が公式に決定するために、電力小売価格表を策定し提出する。 第2条7項）小売料金、価格帯、その他の料金に関連するタスクの実施:
	・使用時間料金（Time of use）		○		○	
	・内部補助金の撤廃		○		△	
3）村落電化	・電化手法の評価		○		△	
	・村落電化		○		△	
4）消費者保護	・必要なデータの提供			○	○	第2条14項）規制に従って電力市場の規制と運営活動をまとめた年次報告書を作成する。 第2条18項）電力会社に対して生産および事業活動に関連する資料および情報の提供を要求する。
	・公聴会の開催と苦情処理	○ (DOI/DEM)	○	○	○	第2条9項）競争規則に従って、市場参加者間の競争活動を規制する。電力市場における苦情や紛争を解決する。電力市場の透明性と競争的な運営活動を確保するために、電力会社の合併または分割に関する計画を関係当局に提案する。

At the MEM consultation meeting on December 17, 2024 (jointly organized by USAID, LASEP, and JICA), the World Bank–MEM briefing session on the regulatory agency held on February 5, 2025, and the JCC meeting on March 4, 2025, the following recommendations regarding the regulatory agency were presented:

- Although ERAL (Electricity Regulatory Agency of Laos) will be placed under the Ministry of Energy and Mines (MEM), it must be granted legal independence.
- Its main roles include optimizing electricity tariffs, evaluating project costs, reviewing power system planning documents such as the NPDP and NTDP, protecting consumers, and establishing and enforcing grid usage rules.
- In its initial phase, the regulatory agency should aim for a structure similar to Vietnam's ERAV, with phased expansion of the organization foreseen.
- The existing Grid Code, formulated in 2013, lacks legal enforcement. With the establishment of ERAL, it will be necessary to reissue the Grid Code as a formal regulation through a ministerial notification by the MEM Minister, and require all grid users to comply.
- The proposed ERAL organization would consist of divisions such as tariff, technical safety and monitoring, international cooperation, legal affairs, data management, and consumer protection, and would be directly involved in overseeing the operations of both EDL and EDL-T.
- In order to proceed with legal revision, relevant institutions (such as the Ministry of Justice, the Prime Minister's Office, and the National Assembly) must be involved in a step-by-step process from drafting to review and approval.

(Attachment)

Attachment 50　Nagayama Dec 17_ver 3

Attachment 51　Nagayama Feb 5th

Attachment 52　Regulator_V2.pptx

Attachment 66　Laos(EN)_0207.docx

7.4. Submission of the Draft Amendment to the Law

On May 15, 2025, a consultation meeting on the amendment of the Electricity Law was held by the Department of Energy Management (DEM), with support from LASEP. The JICA expert team submitted comments to DEM, suggesting that the legal provisions concerning the Grid Code should follow the same format as those for the Lao Electric Power Technical Standards.

Chapter 8 Pilot Projects

8.1. Selection of Pilot Projects

The JICA Expert Team initially proposed the introduction of an overload protection device that continuously limits generator output as a pilot project. However, due to the following reasons—(i) an overload protection system had already been applied in 2020, (ii) the generators were not equipped with interfaces to receive AGC (Automatic Generation Control) signals, and (iii) many hydropower generators lacked sufficient continuous output control capability—it was determined that the project's original feature, i.e., continuous generator output adjustment based on the degree of equipment overload, could not be realized.

Consequently, on August 19, 2021, it was agreed with the counterpart to reconsider a project that would similarly contribute to grid stabilization, particularly in the Vientiane metropolitan area.

As a result of the review, it was concluded that installing fault recorders (oscillograph data recorders) that can record the characteristics of grid faults and diagnose the appropriateness of protection relay operations based on fault behavior would be effective. This would help identify the causes of frequent outages caused by lightning and improper relay operation, thereby contributing to the stabilization of the grid around Vientiane. On November 2, EDL and the JICA Expert Team agreed to install grid fault automatic recording devices (oscillograph data recorders) at substations around Vientiane. At the JCC meeting in December of the same year, it was approved as a pilot project to install such oscilloscopes at four substations to record grid fault events.

In addition, at the JCC meeting, the introduction of a power demand forecasting system based on meteorological data to predict generation from renewable energy sources was proposed and approved.

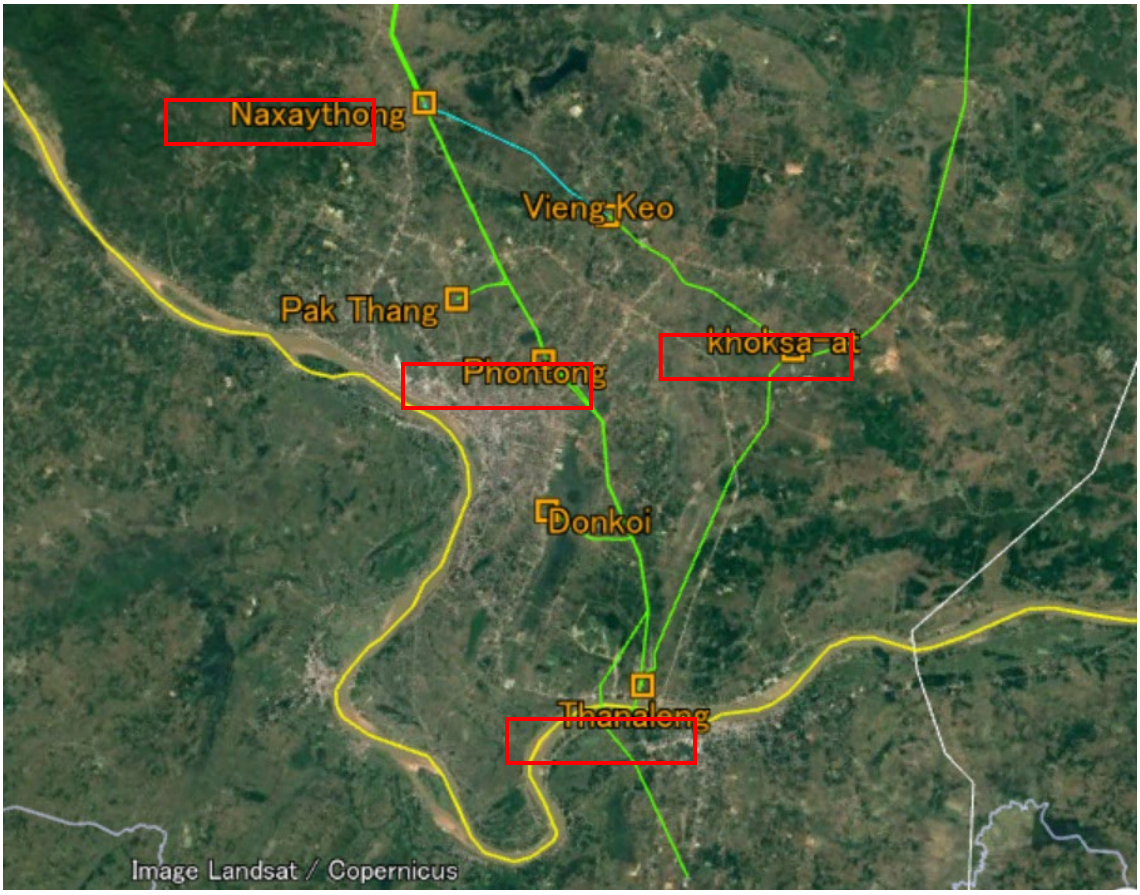
8.2. Field Survey Reports on Pilot Projects

(1) Objective

In preparation for implementing the pilot project, a site survey of substations within Vientiane Capital was conducted jointly with EDL counterparts. The purpose was to assess the feasibility of installing the proposed equipment and to review the operational status of protection relays at the substations.

Based on their importance in supplying electricity to Vientiane Capital and their relevance to interconnection with Thailand, four substations—Phonetong, Thanaleng, Khoksa-at, and Naxaithong—were selected for the site survey through consultation with EDL.

Figure 8-4 shows the locations of the four substations surveyed.



(Source: JICA Expert Team)

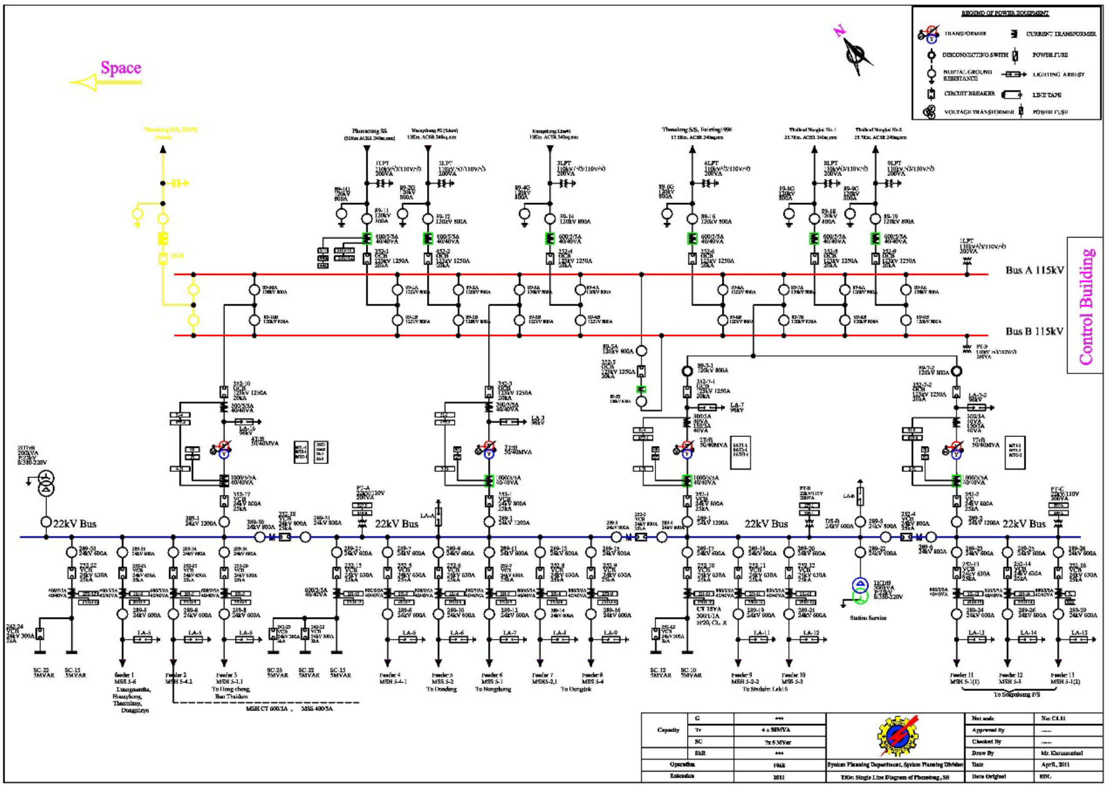
Figure 8-1 Map of On-site Surveyed Substation Locations

(2) Survey Details

(1) 115/22 kV Phonetong Substation

The Phonetong Substation is located in the center of Vientiane Capital and has a total 115 kV transformer capacity of 200 MVA (4 units of 50 MVA each), making it the largest substation in Laos at the 115 kV level.

Figure 8-5 shows the single-line diagram of the Phonetong Substation.



(Source: EDL)

Figure 8-2 Single Line Diagram of Phonetong Substation

Table 8-1 shows the list of transmission line protection relays (Main/Backup) targeted in the pilot project at the Phonetong Substation.

Table 8-1 Transmission Line Protection Relays at Phonetong Substation

No.	Transmission Line Bays		Function	Type
1	Parkthang	Main	21	ABB REL 670
		Back Up	50/51, 27, 59 & 79	Multilin F650
2	Naxaythong #1	Main	21	ABB REL 670
		Back Up	21	ABB REL 670
3	Naxaythong #2	Main	21	ABB REL 670
		Back Up	50/51, 27, 59 & 79	Multilin F650
4	Naxaythong #3	Main	21	ABB REL 670
		Back Up	50/51, 27, 59 & 79	Multilin F650
5	Donekoy	Main	21	ABB REL 670
		Back Up	50/51, 27, 59 & 79	Multilin F650
6	Nongkai #1	Main	21	ABB REL 670
		Back Up	50/51, 27, 59 & 79	Multilin F650
7	Nongkai #2	Main	21	ABB REL 670
		Back Up	50/51, 27, 59 & 79	Multilin F650

(note) 21: Distance protection
27: Undervoltage protection
50/51: Over current/Earth fault relays
59: Overvoltage protection
79: AC reclosing relay/ auto-reclose

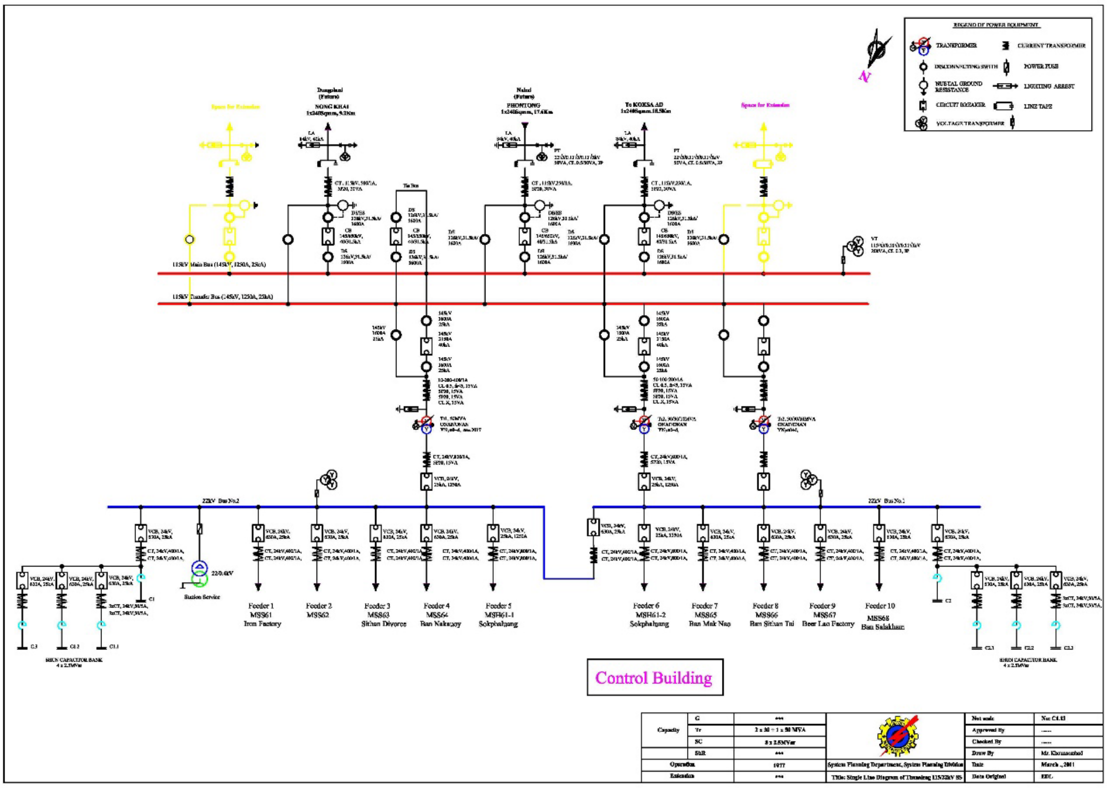
As shown in Table 8-1, among the seven transmission lines connected to the Phonetong Substation, all except for Line #1 connected to the Naxaithong Substation adopt the standard EDL configuration: distance relays for main protection and overcurrent relays for backup protection. For Line #1 to Naxaithong Substation, a distance relay is also used for backup protection. When the reason for this was inquired about at the substation, the detailed background was unclear, but it was suggested that this might be due to the replacement of a failed backup relay with a spare distance relay, which has remained in place since.

It was also confirmed that the device to be introduced under the pilot project can be installed in the control room of the substation.

(2) 115/22 kV Thanaleng Substation

The Thanaleng Substation is located in the southern part of Vientiane Capital, near the Thai border along the Mekong River. It is connected to EGAT's Nong Khai Substation in Thailand via a 115 kV transmission line and is used for measuring the amount of imported and exported electricity.

Figure 8-6 shows the single-line diagram of the Thanaleng Substation.



(Source: EDL)

Figure 8-3 Single Line Diagram of Thanaleng Substation

Table 8-2 Transmission Line Protection Relays at Thanaleng Substation

No.	Transmission Line Bays		Function	Type
1	Nongkhai #1	Main	21	ABB REL 511
		Back Up	50/51, 27, 59 & 79	Multilin F650
2	Donkoi #1	Main	21	ABB REL 511
		Back Up	50/51, 27, 59 & 79	Multilin F650
3	Xaisettha #1	Main	21	ABB REL 511
		Back Up	50/51, 27, 59 & 79	Multilin F650

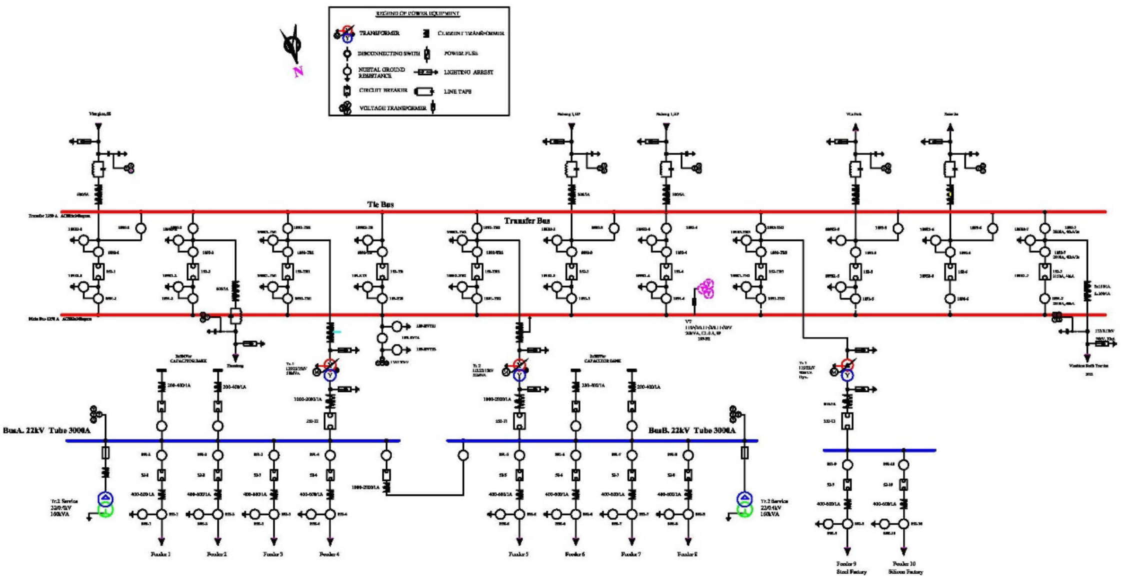
(note) 21: Distance protection
27: Undervoltage protection
50/51: Over current/Earth fault relays
59: Overvoltage protection
79: AC reclosing relay/ auto-reclose

As shown in Table 8-2, all three transmission lines connected to the Thanaleng Substation employ distance relays for main protection and overcurrent relays for backup protection, in accordance with current EDL regulations. It was also confirmed that the device to be introduced under the pilot project can be installed in the substation's control room.

(3) 115/22 kV Khoksa-at Substation

The Khoksa-at Substation is located in the northeastern part of Vientiane Capital and serves as a critical substation for supplying electricity to nearby industrial zones and the railway.

Figure 8-7 shows the single-line diagram of the Khoksa-at Substation.



(Source: EDL)

Figure 8-4 Single Line Diagram of Khoksa-at Substation

Table 8-3 shows the list of transmission line protection relays (Main/Backup) targeted in the pilot project at the Khoksa-at Substation.

Table 8-3　Transmission Line Protection Relays at Khoksa-at Substation

No.	Transmission Line Bays		Function	Type
1	Naboung #1	Main	21	ABB REL 511
		Back Up	-	-
2	Naboung #2	Main	21	SIEMENS 7SA611
		Back Up	67/67N, 50BF	ABB REF 630
3	Viengkeo #1	Main	21	ABB REL 511
		Back Up	-	-
4	VITA Park #1	Main	21	ABB REL 650
		Back Up	-	-
5	Xaisettha #1	Main	21	ABB RED 670
		Back Up	-	-
6	Xaisettha #2 (Tanaleng)	Main	21	ABB REL 511
		Back Up	-	-
7	Railway Station #1	Main	87L	CYG PRS-753
		Back Up	21	CYG PRS-753

（note）　21: Distance protection
50/51: Over current/Earth fault relays
67/67N Directional Overcurrent Protection
87: Differential protection

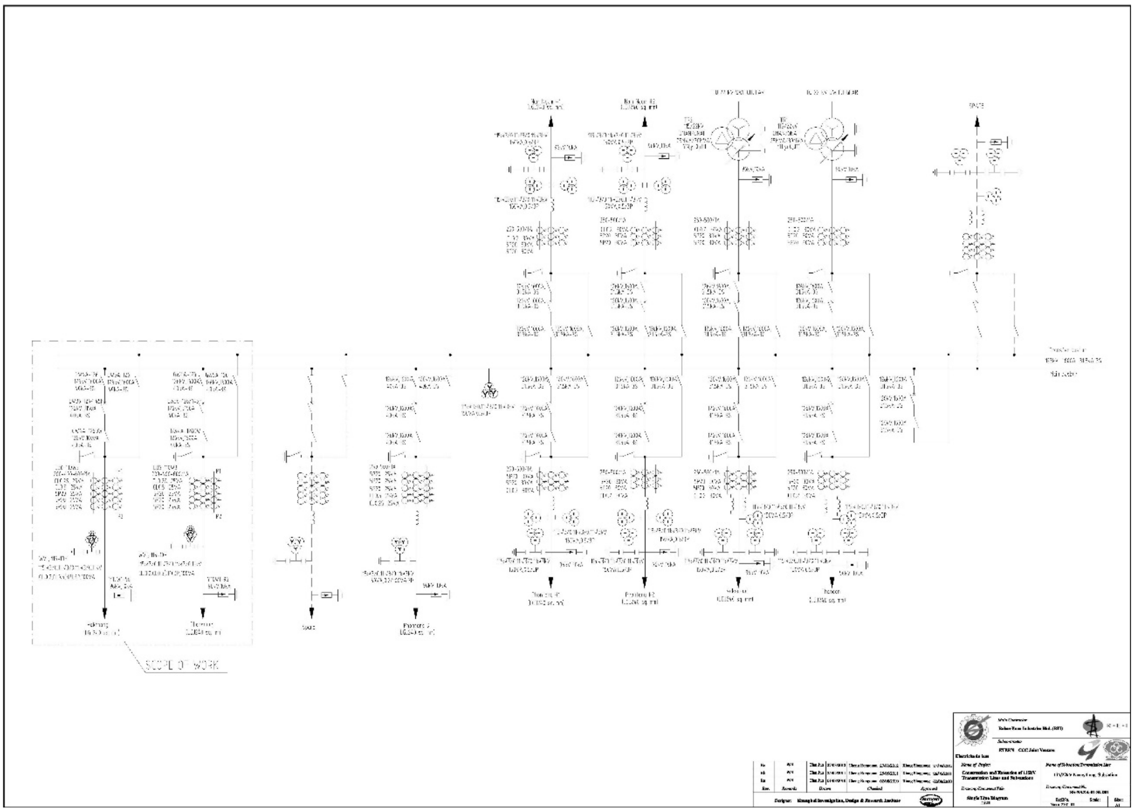
As shown in Table 8-3, among the seven transmission lines connected to the Khoksa-at Substation, Line #7, which supplies power to the railway, uses a current differential relay for main protection and a distance relay for backup protection. This configuration is based on the requirements of the railway company receiving the supply.

For the remaining lines, except for Line #2 to the Naboun Substation, only distance relays for main protection are installed, and no backup protection is provided. When asked about the reason at the substation, it was explained that this has been the case since the substation began operation in 2005, and the details are unknown.

It was also confirmed that the device to be introduced under the pilot project can be installed in the substation's control room.

(4) 220/115 kV Naxaithong Substation

The Naxaithong Substation is located in the northwestern part of Vientiane Capital. It is a key substation that collects electricity from hydropower plants in northern Laos via 220 kV transmission lines, steps the voltage down to 115 kV, and supplies power to Vientiane Capital, the area with the highest demand.
Figure 8-8 shows the single-line diagram of the 115 kV section of the Naxaithong Substation.



(Source: EDL)

Figure 8-5 Single Line Diagram of Naxaithong Substation (115 kV section)

Table 8-4 shows the list of transmission line protection relays (Main/Backup) targeted in the pilot project at the Naxaithong Substation.

Table 8-4 Transmission Line Protection Relays at Naxaithong Substation

No.	Transmission Line Bays		Function	Type
1	Hin Heup #1 (220 kV)	Main	87L, 27, 59, 27	ABB RED 670
		Back Up	21	ABB REL 670
2	Hin Heup #2 (220 kV)	Main	87L, 27, 59, 27	ABB RED 670
		Back Up	21	ABB REL 670
3	Sengsavang #1	Main	21	ABB REL 511
		Back Up	50/51, 27, 59 & 79	GE Multilin F650
4	Sengsavang #2	Main	21	ABB REL 511
		Back Up	50/51, 27, 59 & 79	GE Multilin F650
5	Phonesoung	Main	21	MICOM
		Back Up	50/51, 50N/51N	MICOM
6	Pakthang #1	Main	21	MICOM
		Back Up	50/51, 50N/51N	MICOM
7	Phontong #1	Main	21	ABB REL 670
		Back Up	50/51, 27, 59 & 79	ABB REL 670
8	Phontong #2	Main	21	ABB REL 511
		Back Up	50/51, 27, 59 & 79	GE Multilin F650
9	Phontong #3	Main	21	ABB REL 511
		Back Up	50/51, 27, 59 & 79	GE Multilin F650
10	Viengkeo #1	Main	21	ABB REL 511
		Back Up	50/51, 27, 59 & 79	GE Multilin F650
11	Tha Ngone (Thasavang) #1	Main	21	ABB REL 511
		Back Up	50/51, 27, 59 & 79	GE Multilin F650

(note) 21: Distance protection
27: Undervoltage protection
50/51: Over current/Earth fault relays
59: Overvoltage protection
67/67N Directional Overcurrent Protection
79: AC reclosing relay/ auto-reclose
87: Differential protection

As shown in Table 8-4, at the Naxaithong Substation, all 220 kV transmission lines are equipped with current differential relays for main protection and distance relays for backup protection, in accordance with EDL regulations. Similarly, all 115 kV transmission lines are equipped with distance relays for main protection and overcurrent relays for backup protection.

It was also confirmed that the device to be introduced under the pilot project can be installed in the substation's control room.

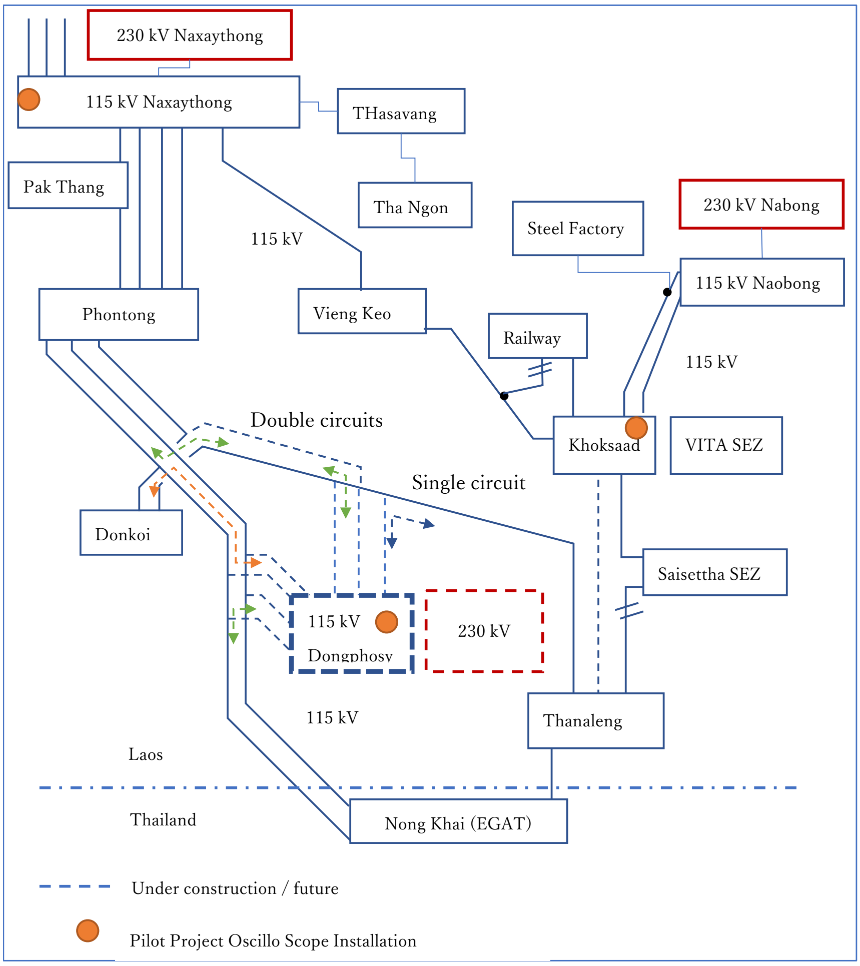


Figure 8-6 Locations of Oscillograph Data Recorders Installed for Pilot Project

8.3. Installation of Oscillograph Data Recorders

In this pilot project, oscillograph data recorders (hereinafter referred to as "recorders") were introduced to record the characteristics of grid faults and to assess the appropriateness of protection relay operations based on the nature of each fault. In parallel, training was conducted on how to interpret and utilize the recorded data. The installation of recorders at four substations around Vientiane was approved at the JCC meeting held in December 2021.

Subsequently, during the procurement process, quotations obtained from the contractor revealed that both an increase in equipment costs and a reduction in project scope were necessary compared to the original plan. As a result, in 2022, an agreement was reached with the counterpart to limit the installation of recorders to three substations within Vientiane City (Naxaithong, Khoksa-at, and Dongphosy substations), and this revised plan was officially approved by JICA on September 20, 2022.

The key steps in the implementation process are as follows:

- May 29 – June 10, 2023
  - Conducted site surveys at the three target substations with the selected contractor, Takaoka Engineering Co., Ltd.
  - Held discussions with EDL regarding technical specifications, installation schedules, and substation outage plans.
  - Discussed customs duty exemption procedures with JICA and the Ministry of Energy and Mines (MEM).

- September 25 – October 7, 2023
  - Conducted a second round of site surveys at the target substations.
  - Finalized technical specifications, installation schedules, and outage plans with EDL.
  - Finalized exemption procedures with JICA and MEM.
- June – October 2023
  - Confirmed final technical specifications, installation schedules, and outage plans with EDL and obtained formal consent.
  - Reviewed the exemption documentation to be submitted by MEM to the Ministry of Planning and Investment (MPI) and the Ministry of Finance (MOF).
- November 2023
  - Conducted technical training for EDL on the effective use of the recorders, based on the document "Attachment 40　202311 Automatic Fault Recorder(Pilot Project).en_r2b.pptx"
  - Provided explanations on fault location estimation using single-end installation of recorders and clarified the differences from dedicated fault location detection devices, as requested by EDL in May 2023.
- May 2023 – January 2024
  - Reviewed and approved technical documents, including drawings and specifications of the recorders.
- January 2024
  - Visited the factory of Kinkei System Co., Ltd., the manufacturer of the recorders, and attended the factory acceptance test.
- May 2024
  - Delivered the recorders to the Naxaithong, Khoksa-at, and Dongphosy substations.
- August 2024
  - Completed installation and acceptance inspections, and held a handover ceremony on August 6.
  - The ceremony was attended by Director General of DEM, Mr. Phetsavanh RATTANATHONGSAY, Deputy Managing Director of EDL, Mr. Sine INTHAVONG, Deputy Director General of DEPP, Mr. Souliya PHOTHITAY, Director of Department of Power System Planning & Control, Mr. Soulivanh THAMMAVONG, and Deputy Chief Representative of JICA Laos Office, Mr. Noriyuki.
  - The recorders were officially handed over to EDL, with a one-year defect liability period stipulated.
- Attachment
  - Attachment 34
  - Attachment 35　MPI_form.pdf
  - Attachment 36
  - Attachment 37

8.4. Issues and Future Utilization

The fault recording devices (oscilloscopes) installed under this pilot project have also been introduced at nearly all transmission substations of TEPCO Power Grid in Japan. They are used for investigating the causes of transmission line faults, evaluating the appropriateness of protection system operations, and diagnosing system malfunctions, thereby contributing to the maintenance and improvement of power system reliability.

In 2024, the oscilloscopes installed at three substations within Vientiane City under this project successfully recorded the actual behavior of protection relays during fault events (including inappropriate operations). This confirmed the effectiveness of the devices in evaluating relay settings and diagnosing protection system malfunctions.

However, as the current installation is limited to a small area, accurately identifying fault locations and enabling comprehensive diagnosis of protection relays across the entire system requires further action. It is therefore important to standardize the installation of oscilloscopes at the time of new substation construction and to expand their deployment throughout the network. This is expected to make a significant contribution to further improving the reliability of the power system in Laos.

8.5. Pilot Project Equipment List

The list of equipment provided to the EDL for this pilot project is shown in Table 8-5. Oscilloscope units (FR Panel) were installed at three substations (Naxaythong, Khoksaat, and Dongphosy), and GPS antennas were installed to receive signals from artificial satellites and obtain high-precision time information.

Table 8-5 Pilot Project Equipment List

No.	Name of Item	Qty	Specification and Accessories	Date
Location: Naxaythong Substation				
1	FR Panel (Sr. no. 2310304004)	1 set	Set of FR Panel including all its internal equipment and accessories: - 1 x AMT-7000-05 (Sr. no. 2310304001) - 3 x Auxiliary relays LY4-D - 1 x Surge arrester SP3000[E1] - 1 x Noise filter RSAN-2010 - 1 x Power switch BH-H3003-WS-LDP - 1 x HIPC LAN Port - 8 x VT test terminals TS-101 - Terminals and internal wirings	August 6^{th} 2024
2	GPS antenna	1 unit	GPA-014B	August 6^{th} 2024
3	GPS pole	1 set	Set of SUS304 ground mounted GPS pole with earthing wires.	August 6^{th} 2024
4	Monitoring PC	1 unit	Dell Latitude 3540 with the following specifications: - CPU: i5-1335U - Chipset: RPL-U - RAM: 1 x 16GB DDR4 3200MT/s - SSD: M.2 2230 Class 35 NVMe 512GB - iGPU: Iris Xe Accessories packet (adapter, charger, etc.)	August 6^{th} 2024
5	Cables and terminals	1 set	Cables to existing panels: - 8 x CT clamp and cable sets for CTs - 8 x CVVS 4c-3.5mm^2 for VTs - 6 x CVVS 15c-2mm^2 for DI - 2 x CVVS 8c-2mm^2 for DI - 5 x CVVS 4c-2mm^2 for DI - 1 x coaxial cable for GPS Antenna - 1 x CV 2c-3.5mm^2 for power supply - 1 x Cat 5 Ethernet cable for networking Terminal blocks, MCBs and other components in the existing panels	August 6^{th} 2024
6	Other	1 set	- 1 x Base cover - 1 x PC's Ethernet cable - 8 x Test plugs (with case) - 200 x Ferrule terminals - 2 x Power supply fuses with alarm - 32 x Short pieces - Etc.	August 6^{th} 2024

No.	Name of Item	Qty	Specification and Accessories	Date
Location: Khoksaat Substation				
1	FR Panel (Sr. no. 2310304005)	1 set	Set of FR Panel including all its internal equipment and accessories: - 1 x AMT-7000-05 (Sr. no. 2310304002) - 11 x Auxiliary relays LY4-D - 1 x Surge arrester SP3000[E1] - 1 x Noise filter RSAN-2010 - 1 x Power switch BH-H3003-WS-LDP - 1 x HIPC LAN Port - 7 x VT test terminals TS-101 - Terminals and internal wirings	August 6th 2024
2	GPS antenna	1 unit	GPA-014B	August 6th 2024
3	GPS pole	1 set	Set of SUS304 wall mounted GPS pole.	August 6th 2024
4	Monitoring PC	1 unit	Dell Latitude 3540 with the following specifications: - CPU: i5-1335U - Chipset: RPL-U - RAM: 1 x 16GB DDR4 3200MT/s - SSD: M.2 2230 Class 35 NVMe 512GB - iGPU: Iris Xe Accessories packet (adapter, charger, etc.)	August 6th 2024
5	Cables and terminals	1 set	Cables to existing panels: - 7 x CT clamp and cable sets for CTs - 7 x CVVS 4c-3.5mm^2 for VTs - 7 x CVVS 15c-2mm^2 for DI - 2 x CVVS 8c-2mm^2 for DI - 1 x CVVS 4c-2mm^2 for DI - 1 x coaxial cable for GPS Antenna - 1 x CV 2c-3.5mm^2 for power supply - 1 x Cat 5 Ethernet cable for networking Terminal blocks, MCBs and other components in the existing panels	August 6th 2024
5	Other	1 set	- 1 x Base cover - 1 x PC's Ethernet cable - 7 x Test plugs (with case) - 200 x Ferrule terminals - 2 x Power supply fuses with alarm - 32 x Short pieces - Etc.	August 6th 2024

No.	Name of Item	Qty	Specification and Accessories	Date
Location: Dongphosy Substation				
1	FR Panel (Sr. no. 2310304006)	1 set	Set of FR Panel including all its internal equipment and accessories: - 1 x AMT-7000-05 (Sr. no. 2310304003) - 15 x Auxiliary relays LY4-D - 1 x Surge arrester SP3000[E1] - 1 x Noise filter RSAN-2010 - 1 x Power switch BH-H3003-WS-LDP - 1 x HIPC LAN Port - 4 x VT test terminal TS-101 - Terminals and internal wirings	August 6th 2024
2	GPS antenna	1 unit	GPA-014B	August 6th 2024
3	Monitoring PC	1 unit	Dell Latitude 3540 with the following specifications: - CPU: i5-1335U - Chipset: RPL-U - RAM: 1 x 16GB DDR4 3200MT/s - SSD: M.2 2230 Class 35 NVMe 512GB - iGPU: Iris Xe Accessories packet (adapter, charger, etc.)	August 6th 2024
4	Cables and terminals	1 set	Cables to existing panels: - 4 x CT clamp and cable sets for CTs - 4 x CVVS 4c-3.5mm^2 for VTs - 4 x CVVS 15c-2mm^2 for DI - 5 x CVVS 4c-2mm^2 for DI - 1 x coaxial cable for GPS Antenna - 1 x CV 2c-3.5mm^2 for power supply - 1 x Cat 5 Ethernet cable for networking Terminal blocks, MCBs and other components in the existing panels	August 6th 2024
5	Other	1 set	- 1 x Base cover - 1 x PC's Ethernet cable - 4 x Test plugs (with case) - 200 x Ferrule terminals - 2 x Power supply fuses with alarm - 16 x Short pieces - Etc.	August 6th 2024

No.	Name of Item	Qty	Specification and Accessories	Date
Common for all substations: Software (CDs)				
1	Data Manager	3	1 CD for each substation Also has been installed in the Monitoring PC	August 6th 2024
2	Advanced Waveform Analysis	3	1 CD for each substation Also has been installed in the Monitoring PC	August 6th 2024
3	IEC61850 Logical Node Mapping	3	1 CD for each substation Also has been installed in the Monitoring PC	August 6th 2024
Common for all substations: Manual				
1	AMT-7000-5 Manual (English)	1	Also submitted with soft copy	August 6th 2024
2	Data Manager Software Manual (English)	1	Also submitted with soft copy	August 6th 2024
3	Advanced Waveform Analysis Software Manual (English)	1	Also submitted with soft copy	August 6th 2024
4	IEC61850 Logical Node Mapping Software Manual (English)	1	Also submitted with soft copy	August 6th 2024
5	Data Manager Software Manual (Laos)	1	Also submitted with soft copy Only for certain necessary parts, discussed and agreed upon with EdL.	August 6th 2024
6	Advanced Waveform Analysis Software Manual (Laos)	1	Also submitted with soft copy Only for certain necessary parts, discussed and agreed upon with EdL.	August 6th 2024

Attachment

Attachment 1	Outline of Generator Connection Business at TEPCO PG.pdf
Attachment 2	Appendix of Outline of Generator Connection Business at TEPCO PG.xls
Attachment 3	Generator Connection Guideline of TEPCO PG.pdf
Attachment 4	GridCodeCommittee.docx
Attachment 5	Nagayama0311.pptx
Attachment 6	GC_Thailand_Recommendation_to_EDL.pdf
Attachment 7	FRT.pdf
Attachment 8	Training_Demand_Supply(1).pdf
Attachment 9	Training_Demand_Supply(2).pdf
Attachment 10	Training_Demand_Supply(3).pdf
Attachment 11	Request_Fault_Analysis.pdf
Attachment 12	Initial consideration of transformer damage.pdf
Attachment 13	Questionnaire for the 3rdmeeting with NCCProject.pdf
Attachment 14	Overview of Automatic Fault Recorder and Measurement.pdf
Attachment 15	Some considerations about planning criteria.pdf
Attachment 16	Regulators_Vietnam_Thailand.pdf
Attachment 17	Suggestion for the Next Step.pdf
Attachment 18	20230530_GC upgrade_Scheduling&Dispatch.pdf
Attachment 19	20230609_GC upgrade_WrapUp.pdf
Attachment 20	20230530_GC upgrade_S&D_App.pdf
Attachment 21	Meeting June_07_shared (By USAID).pdf
Attachment 22	20230718_NCC_Situations_V1.pdf
Attachment 23	PDP_JICA_LaosGC Simulation_20230609.pdf
Attachment 24	EDLMeeting_09Jun2023_Distribution_Minejima_r2.pdf
Attachment 25	Training materials for PV output forecast_0602.pdf
Attachment 26	202306 Automatic Fault Recorder(Pilot Project).pdf
Attachment 27	Understanding_Distribution_30May2023_Minejima_r2.pdf
Attachment 28	202307_Regulator.pdf
Attachment 29	20231128_Planning_Rures_Japan_V1.pdf
Attachment 30	Questions to Vietnam_ver３.pdf
Attachment 31	20230922_GC upgrade_policy_fixed_d.pdf
Attachment 32	20230928_GC upgrade_Small Meeting_fixed_d.pdf
Attachment 33	Frequency Control Code Draft_p.pdf
Attachment 34	EDL_MOM_Pilot.pdf
Attachment 35	MPI_form.pdf

Attachment 36 MOF_form.pdf

Attachment 37 Drawings_Pilot.pdf

Attachment 38 EDLMeeting_12Sep2023_Distribution_Minejima.pdf

Attachment 39 EDLMeeting_29Nov2023_Distribution_Minejima.pdf

Attachment 40 202311 Automatic Fault Recorder(Pilot Project).en_r2b.pptx

Attachment 41 EDL_Hearing_Tarif.pdf

Attachment 42 N0493-Researching report on the new electricity selling price structure for the period 2024-2028.pdf

Attachment 43 20240301_GC upgrade_Data Collection_r4_d.pdf

Attachment 44 ①202406xx_GC upgrade_Review of Inverter Based Connection_ENver2_0531.pdf

Attachment 45 ②Lao Grid Code Update Report_GridSTART (DRAFT_1_28_21_r1).pdf

Attachment 46 Att-1 Presentation.pdf

Attachment 47 20240610 NRCC_V1.pdf

Attachment 48 2024-03-20 Memo_Third_Countries.pdf

Attachment 49 Nam Ou Management and Monitoring Control Center_V0.docx

Attachment 50 Nagayama Dec 17_ver 3

Attachment 51 Nagayama Feb 5th

Attachment 52 Regulator_V2.pptx

Attachment 53 JCC_Project_Outline_V4.pptx

Attachment 54 JCC_Part3_Power System Operation_r1.pdf

Attachment 55 Part4_Generator connection_ver4.pdf

Attachment 56 Roadmap for manual development_v1.pdf

Attachment 57 MOM of JCC for Grid Code_V4.docx

Attachment 58 20211215_JCC_Power_Quality_V3

Attachment 59 20211215_JCC_ConnectionCode_ver1_e

Attachment 60 20211215_Nagayama_Organization

Attachment 61 ບົດບັນທຶກ JCC 15.12.2021

Attachment 62 Interview Surveys.docx

Attachment 63 20250228_GC upgrade_Draft_Connection_Code_ver3.1.pdf

Attachment 64 20250304_JCC_Part3_Power System Operation.pdf

Attachment 65 Draft Procedure for Developing Electricity Plan.docx

Attachment 66 Laos(EN)_0207.docx

Attachment 67 Planning_Procedures.pptx

Attachment 68 20240909_GC upgrade_Balancing Planning & Scheduling_d.pdf

Attachment 69 20240904_GC upgrade_Draft_Connection_Code_ver3.pdf

Attachment 70 20240903_Part of System Planning (Chapter4)_V3.pptx

Attachment 71 EDLMeeting_09Sep2024_Distribution_Minejima_0908.pptx

Attachment 72	202409 Automatic Fault Recorder(Pilot Project)r3.1.pptx
Attachment 73	01-2_Lao_Grid Code_(Operation Code)_Manual_r4.1.0.docx
Attachment 74	01-c_Lao Grid Code (Operation Code)_Comparison_r4.1.1.docx
Attachment 75	02-1_Guideline_Frequency Control_Attachment (GC)_r1.0.0.docx
Attachment 76	02-2_Guideline_Frequency Control_Attachment (Mnl)_r1.0.1.docx
Attachment 77	02-c_Guideline_Frequency Control_Comparison_r1.0.0.pdf
Attachment 78	Revised Lao Grid Code