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Construction Technology and Management Practices for Nam Ngiep 1 Hydropower Plant in Lao PDR

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Abstract

The development and utilization of the hydropower plants is important in achieving the Sustainable Development Goals ("SDGs"). The Kansai Electric Power Co., Ltd ("Kansai") has been working to repower its existing hydropower plants and to develop hydropower plants in Japan and abroad. With this in consideration, Kansai, as a head shareholder, worked on the development of the Nam Ngiep 1 Hydropower Plant, playing an important role in the introduction of highly reliable equipment for the plant during planning and construction. This paper introduces the construction technologies and management practices for Nam Ngiep 1 Hydropower Plant.

Keywords: Nam ngiep 1; Affordable and clean energy (SDG 7); Electrical and mechanical; Hydropower project; Safety management

1. INTRODUCTION

The Nam Ngiep 1 Hydropower Plant is located approximately 145 km northeast of Vientiane, with two dams and power plants in the middle of the Nam Ngiep River, a tributary of the Mekong River. It consists of a main power station, which has a 273 MW capacity, and a re-regulation power station with an 18 MW capacity.

A Since signing the project development agreement with the Laos government in 2006, owner's engineers representing Kansai conducted various surveys and design projects, and engaged in discussion for the Power Purchase Agreement ("PPA"). During the construction period of about 5 years, civil engineers and electrical and mechanical ("E&M") engineers from Kansai were dispatched to manage construction at the site. Commercial operation commenced on September 5, 2019.

The specifications for the power plants are as shown in Table 1. The main power station exports electricity to neighboring Thailand. The re-regulation power station was built downstream from the main power station to regulate the water level downstream. The re-regulation power station supplies electricity for demand in Laos.

Table 1. Power plant specifications

Item		Main power station	Re-regulation power station
Power plant output		272.8 MW	17.6 MW
Turbines	Type	Vertical axis Francis turbine	Horizontal axis bulb turbine
	Number of units	2 units	1 unit
	Turbine output	140.5 MW per unit	18.79 MW
	Maximum turbine discharge	230 m^3/s	160 m^3/s
	Net head	130.94 m	12.73 m
Generators	Rated capacity	162 MVA	21.5 MVA
	Rated voltage	16.5 kV	11 kV
	Rated power factor	0.85	0.85
Main Transformers	Rated capacity	162 MVA	21.5 MVA
	Number of units	2 units	1 unit
	Voltage	16.5 kV / 230 kV	11 kV / 115 kV

During the planning phase, Kansai attempted to design an optimum equipment configuration with high reliability in order to realize stable and sustainable operation, considering the grid system requirements, local technical standards, and reduction for initial construction cost (CAPEX) and risk at the time of failure. During the construction phase, assembly and installation of E&M equipment was carried out in parallel with civil work to shorten the construction term, and the process was shortened safely.

This paper introduces examples of design, technology, and site management of the E&M facility of hydropower plants through activities of the Nam Ngiep 1 Hydropower project, with a focus on the main power station.

2. SPECIFICATION REVIEW, EQUIPMENT DESIGN

Technical considerations at the main power station are shown below.

2.1 Reliable equipment and optimal equipment configuration

2.1.1 Turbines

The turbine runner is a welding structure of cast material. 13Cr–4Ni with improved corrosion resistance is used for the turbine runner. Runner strength was evaluated using the Finite Element Method (“FEM”). It was then confirmed that the static strength was less than the allowable stress in two cases of maximum output at nominal condition and runaway speed. Fatigue strength was evaluated in each case of high cycle fatigue (maximum output) and low cycle fatigue (start / stop) with a safety factor of 2 times in the modified Goodman diagram.

The runner is guaranteed by the contractor against excessive pitting caused by cavitation. The guaranteed value for excessive pitting is defined as the following formula, in accordance with IEC 60609:

$$Volume = k1 \times D^2 \ cm^3 \quad [1]$$

$$Depth = k2 \times D^{0.4} \ mm \quad [2]$$

where,

k1: coefficient (20 – 100)

k2: coefficient (4 – 6)

D: runner diameter (m)

Kansai specified that the guarantee shall not exceed 20 x D^2 (cm^3) in volume and shall not exceed 4 x $D^{0.4}$ (mm) in depth for 8,000 operating hours, to the owner’s advantage.

It was confirmed that the critical cavitation coefficient measured in the model test had a sufficient margin for the plant cavitation coefficient.

2.1.2 Turbine auxiliaries (pressure oil supply system, water supply and drainage system)

(1) Pressure oil supply system

The pressure oil supply system is used for both inlet valve control and the speed governor control. One (1) pressure oil supply system set is installed for each unit. In consideration of maintenance, reliability, and economy, one (1) set of the system consists of a regular use pressure oil pump and a standby use pressure oil pump, as shown in Figure 1. The normal oil volume in the pressure oil tank is sufficient to operate the guide vane through three (3) strokes and the inlet valve through one (1) stroke without oil supply from the oil pumps. The capacity of the oil sump tank is sufficient to accommodate 110% of the total oil quantity of the pressure oil system (oil in pressure tank, sump tank, servomotors, piping, etc.).

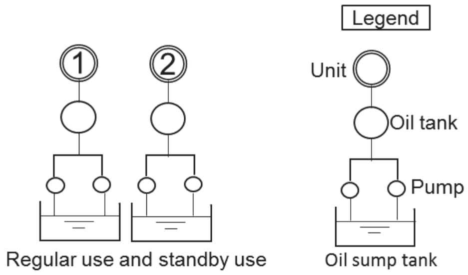

Figure 1. Pressure oil equipment

(2) Water supply system

The cooling water supply system is designed to supply water from draft tube, and is used for supplying cooling water to the thrust and guide bearings, and generator air cooler. Three (3) water pumps are installed for the cooling water supply systems as shown in Figure 2: one (1) for regular use for unit 1, one (1) for regular use for unit 2, and the third for common standby use.

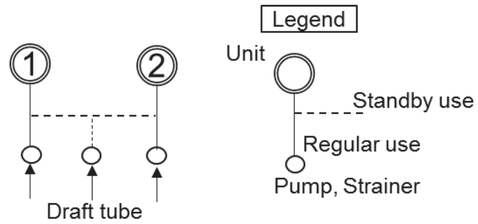

Figure 2. Water supply equipment

(3) Water drainage system

The water drainage system is designed to drain the water in the drainage pit to the tailrace. All station drainage passes through the oil separation pit with an oil leakage detector prior to draining into the drainage pit in the powerhouse so that oily water is not discharged to river. As shown in Figure 3, drainage is performed by two (2) submergible drainage pumps (one for regular use and the other one for standby use) and one jet pump for backup use to prevent inundation accidents when the power supply is lost.

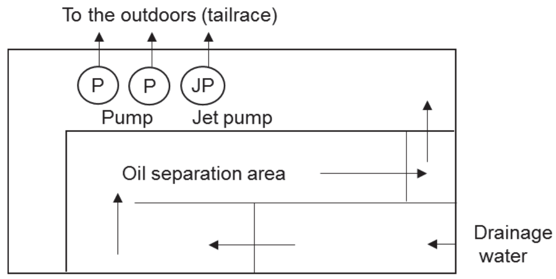

Figure 3. Schematic diagram of the drainage pit

2.1.3 Inlet valves

A contract engineer retained by the Laos government provided technical advice, including advice concerning elimination of the inlet valves, before signing a construction work contract with the contractor. Kansai then examined whether the inlet valves could be eliminated or not, in terms of economic efficiency and maintenance. If the inlet valve is eliminated, the following problems would occur:

- It would be difficult to stop the turbine completely due to water leakage from the guide vanes, as this power plant is high head.
- If water leakage continues from the guide vanes while the generator unit is in a status of shutdown, wasted power will be generated due to water leakage.
- If the turbine is rotating while the generator unit is in a status of shutdown, bearing wear will occur due to low rotation speed.

As per the results above, Kansai made the design choice to install an inlet valve for each unit. The inlet valves are equipped with counterweights to enable closing operation even if pressure oil is lost, ensuring safety and reliability. The capacity for the servomotors of the inlet valves and the counterweights was calculated on the following conditions:

- Opening Direction (1 case): Normal operation state
- Closing Direction (2 cases): Maximum full flow in the case of guide vane full opening, and normal operation state.

2.1.4 Generators

Three (3) phase synchronous generators are excited by a static exciter. Generator efficiency tests were conducted at the site. It was confirmed that the guaranteed generator efficiency was satisfied.

Resin bearings (PEEK) are used for the thrust bearings, so heat resistance is improved in comparison with white metal (WJ2). It is possible to eliminate the oil lifter at startup, improving maintainability, as resin bearings have a low coefficient of friction and excellent wear resistance.

2.2 Contribution to grid stability

Various operation modes and functions are equipped to meet requirements from the grid system. The Nam Ngiep 1 Power Plant has been realizing a high-level contribution to grid stability. Regarding balance of demand and supply, the maximum power output (MW) and annual average energy production potential (GWh) rates generated by the main power station against the power supply capacity in Thailand were approximately 0.95% and 0.79% in 2020.

2.2.1 Operation mode

Output control is performed by Thailand's National Control Center via SCADA system with Automatic Generation Control ("AGC") and Automatic Generation Voltage Control ("AGVC"). The operation modes are as shown in Table 2.

Table 2. Operation modes

Operation modes	Explanation
Generating Mode (GEN)	This mode is selected under normal condition.
Isolated Load Operation Mode (ISO)	When this mode is selected, the turbine generator units supply power only to the on-site load if the power plant is disconnected from the grid due to a grid accident. After recovery from the accident, this mode shifts to High Voltage Synchronization Mode.
High Voltage Synchronizing Mode (HV)	When a grid accident is recovered from and the operator presses the HV button, the circuit breaker on the high-voltage side of the main transformer is turned on again by the automatic synchronization device.
Black Start Mode (BL)	This mode is applied if the grid system blacks out and needs to be powered by the Nam Ngiep 1 Power Plant.
Line Charging Mode (CH)	This mode is applied if the grid system blacks out and needs to be supplied with voltage from the Nam Ngiep 1 Power Plant.

2.2.2 Requirements from the grid

Requirements from the grid system are specified in PPA as follows:

- Supply of Unit Reactive Power
- Unit Loading/Deloading Rate: average 1.2 MW/s in each case of:
  - load increase / decrease speed from no load to minimum output; and
  - load increase / decrease speed from minimum output to maximum output.
- Unit Primary Response: ± 6.2 MW in case of frequency deviation ± 0.3%
- Governor droop setting: 4%
- Operation time for each generating unit
  - Shutdown state to synchronize state: 240 sec
  - Unit at No-load, not excited state to complete shutdown: 720 sec
- Generation Stability Date
  - Inertia: $H \geq 3.9$ MW.s/MVA

3. CONSTRUCTION WORK

3.1 Process shortening

Outline for the construction process is shown in Figure 4. This clause describes the work that Hitachi Mitsubishi Hydro Corporation ("HM Hydro"), the E&M work contractor, derived in order to shorten the construction term.

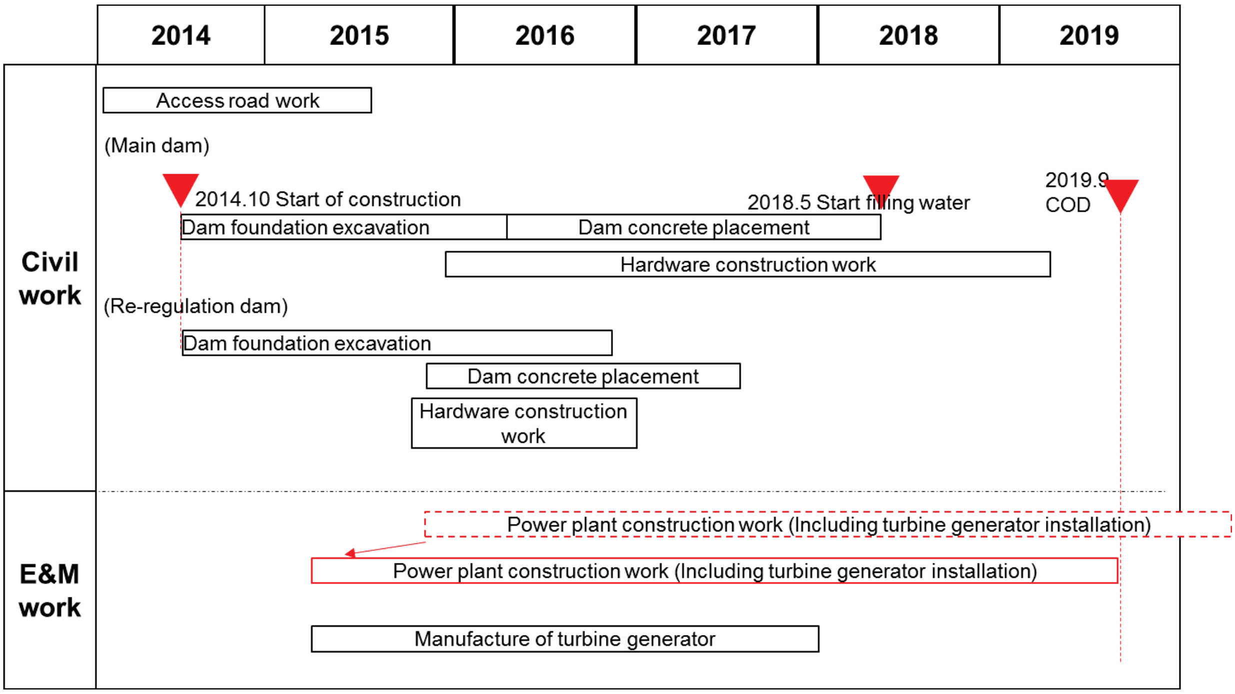

Figure 4. Outline for construction process

3.1.1 Ideas for installing E&M equipment

Normally, E&M work aside from embedding work is carried out after the civil work is completed. Assembly and installation of E&M equipment, however, was carried out in parallel with civil work to shorten the construction term. In parallel work, it was a concern that dust occurring from civil work would affect the quality of the electrical equipment. The electrical equipment was covered with sheets to protect it from dust during assembly. The stator, in particular, was assembled inside a temporary air-conditioned vinyl shelter in the powerhouse in order to ensure the designated quality, as shown in Figure 5.

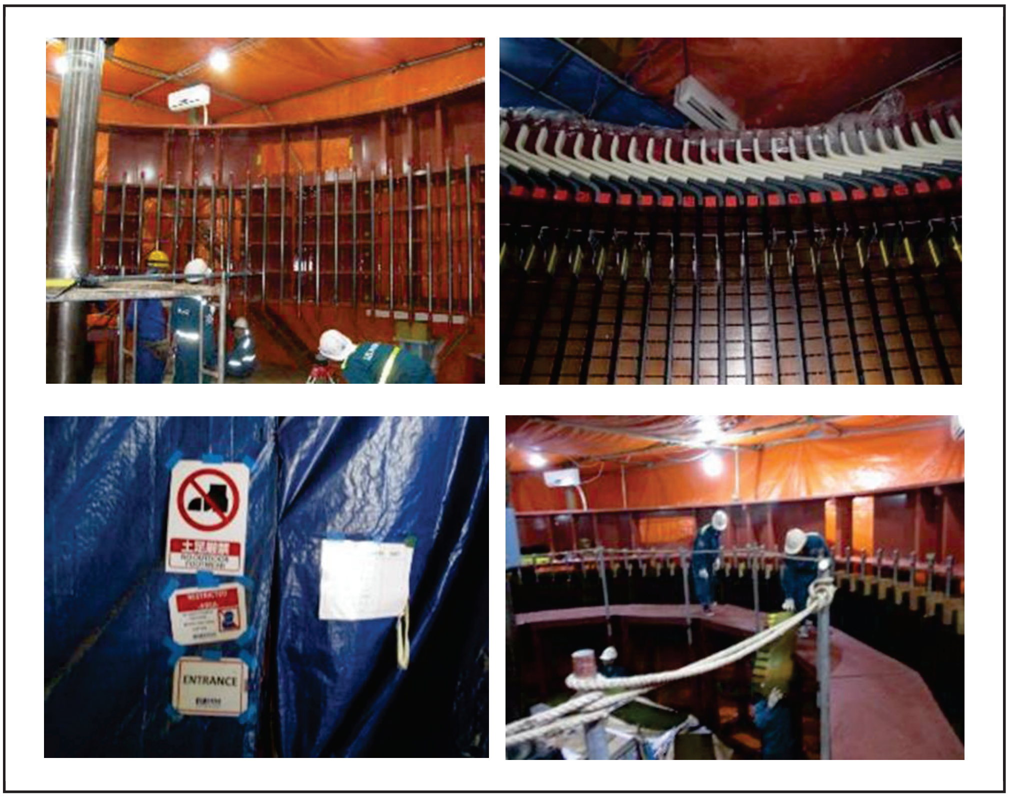

Figure 5. Assembling stator inside an air-conditioned vinyl shelter

3.1.2 Coordination between contractors through a detailed transportation schedule

The following transportation was undertaken at the peak of construction:

- (Civil Equipment) large truck for transportation of cement: App. 40 units / day
- (E&M Equipment) large trailer for transportation of large items: App. 15 units / day or more

The civil contractor and E&M contractor had a meeting to share the location of the truck and trailer, coordinating the transportation schedule every day so that the truck and trailer would not intersect on route, as the access road was narrow.

3.2 Safety management

The total number of E&M workers by month during the construction period is shown in Figure 6. Safety measures, such as monthly safety patrols, were implemented in accordance with the standards of Kansai. Additionally, HM Hydro prepared safety education and instruction materials in four languages (English, Lao, Vietnamese, and Chinese), according to the workers' nationalities.

The owner and contractors continued to enhance worker safety awareness by conducting safety education and safety patrols. In particular, safety patrols were conducted with teams that straddle departments and roles, reflecting opinions from various perspectives to realize a safer work environment.

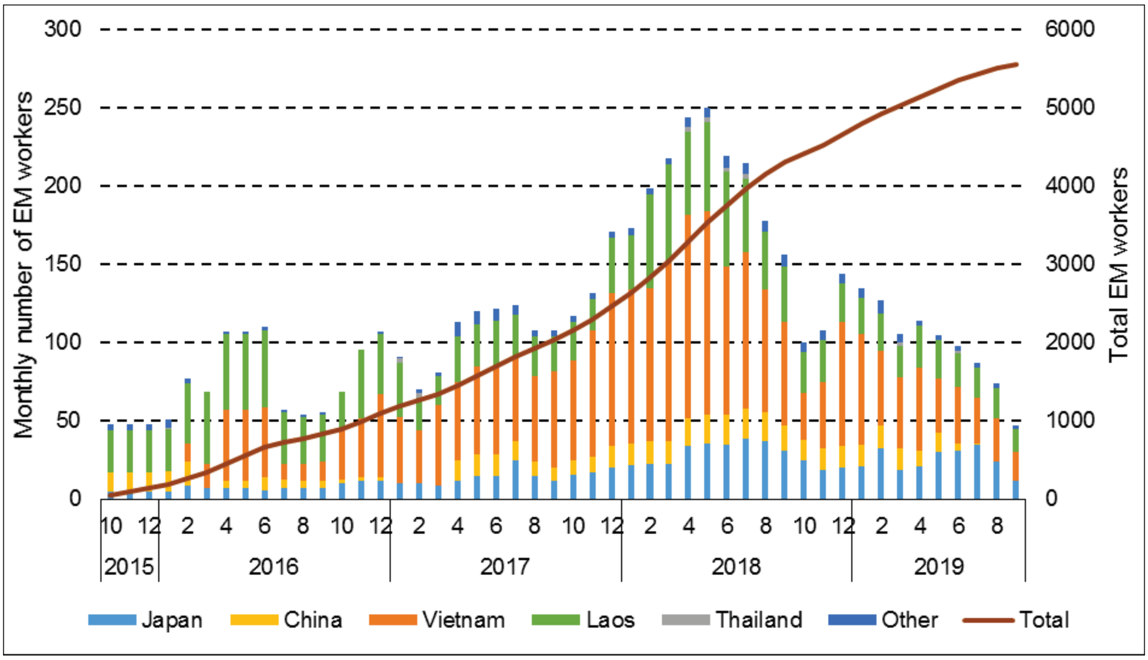

Figure 6. Monthly number of E&M workers (October 2015 to September 2019)

3.2.1 Regular safety education and safety patrols

The owner and contractors conducted various safety measures at the site. Typical examples are as follows:

- The contractor assigned a safety officer dedicated to safety and established an effective safety management system with related parties, including the owner.
- Joint safety patrols across specialized departments (Civil, E&M, Hydro-mechanical) were conducted every month.
- Safety patrols across a variety of roles (owner and contractor) were conducted every month.
- HM Hydro's own safety patrols were conducted twice a month.

4. CONCLUSIONS

In hydropower development project financing, it is necessary to design rational machines considering not only reduction of construction costs and operation and maintenance costs, but also reduction of risks. In addition, specifications must be determined based on the requirements of stakeholders such as grid operators, lenders and insurance companies.

In the development of the Nam Ngiep 1 Hydropower Plant, Kansai and HM Hydro worked to maintain high quality based on the design standards of Kansai and the quality control standards of HM Hydro, and also tried to reduce costs. As a result, a highly reliable and optimal equipment configuration was realized, enabling contribution to grid system stabilization. The owner and contractors thoroughly implemented safety measures on-site by working closely together and building safety management systems.

The above achievements are expected to be useful references for construction technology and management practices in hydropower development to ensure safety and high quality.

5. ACKNOWLEDGEMENTS

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