Design and Construction Overview of the Biggest Coal Fired Power Plant in Thailand (BLCP Power Plant), Developed by Private Companies as IPP Business

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In Thailand, private IPP (Independent Power Producers) businesses are increasing and booming. Mitsubishi Heavy Industries, Ltd. (MHI) received under Mitsubishi Corporation an order from BLCP Power Limited for a power plant which will be Thailand's first large scale bituminous coal-fired power plant on a full turn-key (FTK) basis to conduct Engineering, Procurement and supply of equipment, and Construction including civil work. In this report, we would like to introduce our valuable experiences which successfully contributed to the accelerated completion of the project, jointly accomplished with the Owner. The report also includes various counter measures and considerations for IPP project which are not usually encountered in power plants for governments or authorities.

1. Introduction

Thailand, after overcoming the legacy of the fastest currency crisis in Southeast Asia, has maintained very steady economic growth by making the use of political stability, a plentiful labor force and the introduction of proactive foreign capital. The demand for electricity has shown steady growth along with economic growth and in addition to the development of facilities by the government-run public electricity corporation, private IPPs (Independent Power Producers) have become active. Mitsubishi Heavy Industries, Ltd. (MHI) received under Mitsubishi Corporation an order from BLCP Power Limited for a power plant which will be Thailand's first large scale bituminous coal-fired power plant on a full turn-key (FTK) basis to conduct Engineering, Procurement and supply of equipment, and Construction including civil work.

2. Project overview

The BLCP power plant is situated in the Map Ta Phut Industrial Estate which is located in Rayong Province in the southeast of Thailand. It takes about two and a half hours by car from the capital city Bangkok. The construction site is located on reclaimed land 3 km away from the eastern coastline of Map Ta Phut Port and is surrounded by sea, considering the entry of large coal ships. **Figure 1** shows the BLCP power plant construction site and **Fig. 2** is an overview of the power plant.

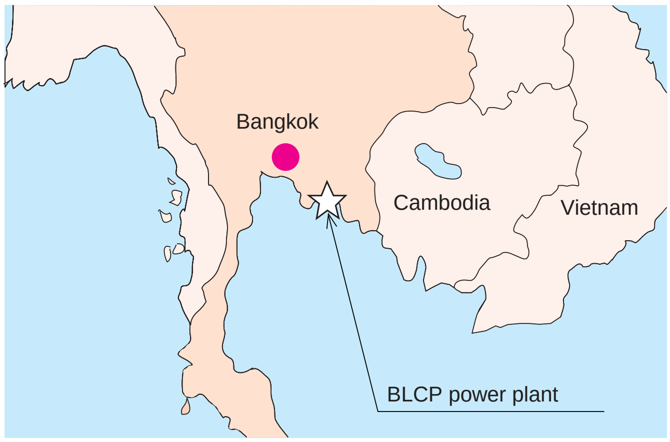

Fig. 1 Construction site of BLCP power plant

Fig. 2 Overview of the power plant

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Table 1 Major specifications of plant

Equipment		Specification
Plant	Rated output	717 MW (at Generator terminal)
	Steam condition	16.7 MPa (a) x 538°C (Turbine inlet)
	Fuel	Coal (Bituminous coal), Diesel oil (for start-up)
	Cooling system	Seawater cooling system
	Condenser vacuum	0.006931MPa (a)
	Feed water heater	8 stages (LP: 4 stages + deaerator + HP: 3 stages)
	Water treatment system	Low-phosphate treatment
Boiler	Type	Pulverized coal fired, forced circulation, single drum, radiant reheat type boiler (Maximum Continuous Rating: 2285 t/h)
Turbine	Type	Tandem-compound quadruple exhaust flow reheat regenerating condensing turbine 3000 min^{-1}, 35.4 inch last stage blade
Generator	Type	Water cooled generator
	Capacity	844 MVA
	Excitation system	Brushless excitation system
Substation	Type	GIS (Gas Insulated Switchgear)
Coal handling system	Type	Complete coal unloading facility, coal storage and transport system and conveyor system
Electrostatic Precipitator	Type	Fixed electrode system
Ash handling system	Type	Fly ash: vacuum transportation, Bottom ash: conveyor transportation
Flue Gas Desulfurization system	Type	Seawater desulfurization system

Table 2 Environmental limitations (at the stack outlet)

Item		Environmental limitations (7 % O_2, Dry, 1atm, 25 deg. C)
Nitrogen oxides (NO_x)	(ppm)	241
Sulfur dioxides (SO_2)	(ppm)	262
Carbon monoxide (CO)	(ppm)	94
Dust	(mg/m^3)	43

The power plant consists of two coal fired conventional plants, each composed of Boiler, Steam turbine, and Generator. The rated output per plant is 717 MW and the total power generation capacity of the two plants amounts to 1,434 MW. The coal used as fuel is bituminous coals produced in Australia and Indonesia, while diesel oil is used as the start-up fuel. MHI supplied all the equipment relating to power generation including the major BOP systems such as Coal unloading pier, Coal handling system, Electrostatic Precipitator, Ash handling system, and Flue Gas Desulfurization system and also ancillary facilities such as Water treatment system, Waste water treatment system, Circulating water system, and Ventilation and Air Conditioning system and Fire fighting systems.

In the design stage, 3D-CAD was employed for all the power plant systems including those above. In addition, the integrated control of the layout plan, detailed engineering, and interference checks were implemented not only for the power generation system but also for the BOP system. **Tables 1** and **2** show the specifications of the major systems and the environmental limitations respectively.

3. Outline of major power generating installation

3.1 Boiler

The boilers are forced circulation, exclusively coal-firing boilers designed and manufactured based on MHI's previous long experience. Performance-based design is adopted for the furnace and layout of the heat transfer surface fitting for the bituminous coal, while burner tilt mechanism to adjust the steam temperature is also installed to cope with the heat absorption differences in the furnace caused by the variation of coal properties. For the combustion facility, Mitsubishi vertical pulverizer fitted with MRS (Mitsubishi Rotary Separator), having good separation performance and high-fineness, is adopted. The CUF (Circular Ultra Firing) burner is selected and located in each corner of the furnace wall, which provides effective utilization of circular firing characteristics in the entire furnace. **Figure 3** shows a side view of the boiler.

Further, as an environmental measure, A-PM (Advanced-Pollution Minimum) burner with a good track record as a pulverized coal-firing burner, is adopted together with the in-furnace NOx reduction system (A-MACT), enabling low NOx operation for a wide range of coal properties. During the performance test, good boiler efficiency result was confirmed, which is higher than the design value.

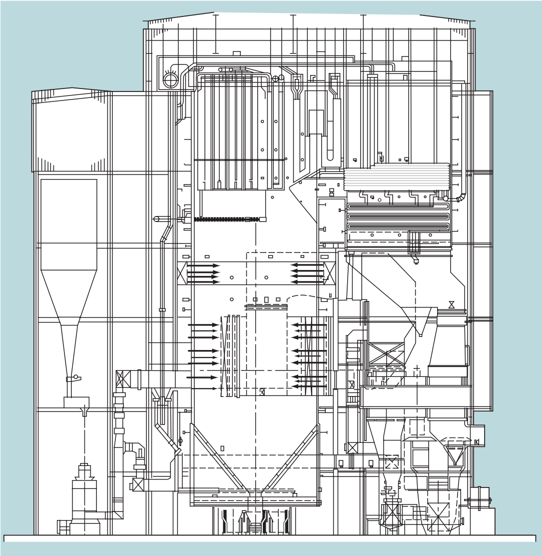

Fig. 3 Side view of boiler

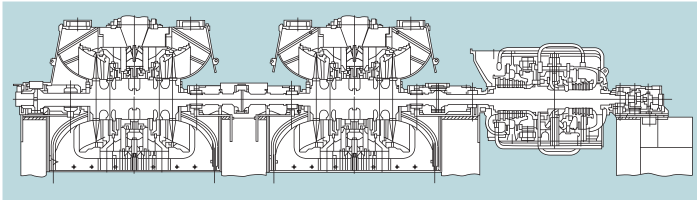

Fig. 4 Cross section of steam turbine

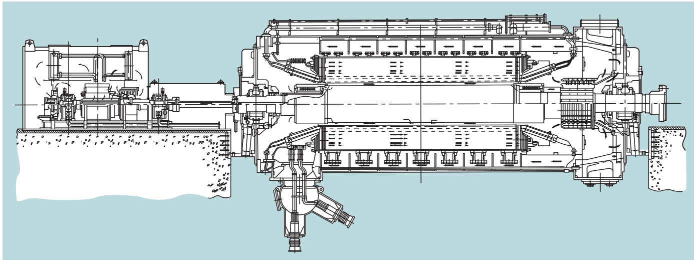

Fig. 5 Cross section of generator

3.2 Steam turbine

The turbine has a rated output of 717 MW and is the tandem compound type with a high-pressure (HP) / intermediate-pressure (IP) turbine casing and two low-pressure (LP) turbine casings connected by one shaft. The HP turbine and IP turbine are combined into one casing. The HP turbine is of single-flow design, consisting of one control stage and nine reaction stages. The IP turbine is also of single-flow design consisting of seven reaction stages, and arranged opposite to the HP turbine. The LP turbine is of double-flow, where each flow consists of seven reaction stages including the 35.4 inch ISB (Integral Shroud Blade) last stage blades. **Figure 4** shows a cross-sectional view of the turbine. The performance improvement is attained through the utilization of advanced fully three-dimensional designed reaction blades for all the reaction stages including the LP turbine last stage.

After operation started, various supervisory data including the shaft vibration were sufficiently lower than the allowable values and stable operation was observed. Further, during the performance test, the turbine achieved higher levels of efficiency that exceeded the design value.

3.3 Generator

For the type of Generator, a stator water cooling system is adopted to achieve the increased capacity of the generators. **Figure 5** shows a cross section of the generator. The capacity increase of the generator has been worked on since the 1980s targeting a tandem type 1,000 MW class generator. In this project, a structure which had already been verified with the 990 MVA generator for EGAT (Electricity Generating Authority of Thailand)(Note 1) is adopted. With regard to operating performance, it was confirmed from actual loading tests conducted at the site that the rotor shaft vibration, and coil temperature rise satisfied their planned values.

Note 1: Currently owned by RGCO (Ratchaburi Electricity Generating Co., Ltd.)

4. Characteristics of project

4.1 Permits and licenses from Authorities

As for the permits and licenses relating to the construction of infrastructures which tend to be omitted conventionally in public works in developing countries due to the governmental operating authority, we were required to obtain all the Thai legal permits and licenses concerning construction of power plants strictly in accordance with the respective laws and regulations. Of these, those which could only be applied for and obtained by the contractor, such as building permits for the power plant buildings were totally entrusted to the contractor and MHI also played a role. The application for a building permit to the Industrial Estate Authorities of Thailand ("IEAT") which had jurisdiction over the power plant site was an important issue. Its major objective was the establishment of safety of all structures (including foundations for the equipment) and buildings to be constructed on the site and no construction work could be started without this formal permit even after all the design work was completed. The importance of this approval was fully recognized from the start of the project by us. Dedicated engineers and coordinators were frequently dispatched to Thailand, even before start of the actual application process, to discuss with the officers with concerned details of the contents of the application procedure and the drawings and documents to be submitted. Further the fact that the design process had been scheduled to allow sufficient time before the start of construction and that the engineers and coordinators were stationed in Thailand to promote communication with the authorities contributed to the successful acquisition of over 80 approvals without causing any essential effect on the work process. Until the completion of the construction work, this permit continued to be a major issue of concern for not only the MHI engineers and those in charge of the work but also all the other concerned parties including the Owner.

4.2 Environmental Impact Assessment (EIA)

As this project was the first large-scale coal fired power plant in Thailand, a strict Environmental Impact Assessment (EIA) was introduced to minimize the possible environmental impact on the surrounding areas caused by the construction and operation of the power plant. The EIA covered not only conformity with the environmental quality standards in Thailand (wastewater, air quality and noise) but also various measures to mitigate the environmental load inherent in a large-scale thermal coal fired power plant. Some typical examples of these measures are described below:

(1) Compliance with various regulations through the construction period

In order to demonstrate compliance with the EIA during the construction period, fully implemented air quality observation inside and outside the site at regular intervals, wastewater quality control and monitoring, were conducted. Briefing sessions for outline of construction to community residents was organized and monitoring results were reported monthly to a committee established by the municipality. Typical measures implemented within the site are watering the temporary construction road for dust suppression, provision of a wheel cleaning system and controlling the speed of vehicles shuttling to and from the site, and provision of windbreak covers on construction material and equipment and on truck beds. Also, it was strictly enforced that wastewater generated during construction was first collected into multiple temporary water sedimentation basins located on the site and, after sedimentation and confirmation that the wastewater quality met the EIA standard requirement, it was finally discharged into the sea (**Fig. 6**).

Fig. 6 Sedimentation basin

(2) Use of impermeable sheets at the coal yard

In this project, the power plant was constructed on reclaimed land and the coal yard is located outdoors. Therefore, as it was thought that a large amount of rainwater falling on the coal yard would seep underground and finally flow out into the sea, the EIA specified impermeable sheets laid down over the entire area of the coal yard. Through the discussion with the Owner, HDPE (High Density PolyEthylene) sheet was laid on the entire area of the coal yard to prevent rainwater seepage to the soil. Further, to collect rainwater from the coal yard, a coal yard pond and a specific coal yard wastewater treatment system were constructed. Wastewater after treatment satisfying standard values in Thailand will be reused as water spray for the dust suppression at the coal yard.

(3) Measures for dust dispersion in the coal yard

A windbreak fence was built along the entire south side of the coal yard to prevent dust dispersion from the coal yard to the sea or other facilities. Further, by installing a wind meter in the vicinity of the coal yard, automatic control of watering based on the wind velocity was conducted. Implementation of intermittent watering by means of a chemical sprinkler vehicle (polymeric coating material), and compaction using a bulldozer for dust dispersal prevention were also conducted. The measures for dust dispersal prevention in relation to the coal handling facility are use of a covered conveyor, provision of a watering system in the Transfer towers and Screen house, and provision of dust collection facilities.

(4) Restrictions on discharge of condenser cooling water

The discharge system is designed based on the simulation results of "A three-dimensional modeling assessment of the cooling water discharge from the power plant" attached in the EIA so that the discharge velocity shall be 1.5 m/s or above in order to prevent the temperature rise more than 3℃ at any point in a radius of 500 m from the discharge point comparing with the ambient seawater temperature. Further, because of the adoption of the seawater desulfurization system, pH requirement (pH=7.0 or above) was additionally imposed along with the other general requirements at the discharge point (residual chloride concentration Cl: less than 1.0 ppm, discharged seawater temperature: 40℃ or less). The requirement of pH is relatively more stringent than the requirement in the other countries.

4.3 Application of tax exemption system by the Board of Investment of Thailand (BOI)

In general, a certain amount of custom duty is imposed on the equipment imported into Thailand. In this respect, as this project concerned the construction of public infrastructure, the tax exemption system of the Board of Investment of Thailand (BOI) was applied. However, this tax exemption benefit is no more than a basic principle and, in order to avoid the actual imposition of import duties and taxes at Customs, it was necessary for us to establish a perfect list of every equipment imported, to explain its non-availability in Thailand, and to obtain the particular approval of the Board of Investment prior to first importation of the equipment.

It was extremely difficult to prepare such a perfect list before the design was completed. As custom duties and taxes had to be borne by the contractor if the tax exemption was not contractually approved by the contractor's act or omission, we tried to establish a work system with all the necessary details, make the list, and prepared a huge volume of effective explanatory materials for submission to the authorities as soon as the Contract was put into effect. The completed list consisted of 2,000 items and the explanatory material was composed of 10 large files, each 8 cm thick. It took three full months for three specialized staff members to complete them. Even after the application, as in the case of the building permits, a number of explanations had to be given to the officers concerned. We hired an experienced customs agent to act for us in the application for and acquisition of approval and successfully obtained the right of tax exemption on all the applied items within two months from application.

4.4 Plan of seawater desulfurization system

This system is characterized by the reuse of a part of the cooling water (seawater) from the outlet of the condenser as an absorbent for desulfurization (**Figs. 7** & **8**). This is more advantageous compared with the lime/limestone gypsum process, as there is no need for additional absorbent or treatment of by-products, simplifying equipment and reducing the operating power consumption. However, the desulfurization performance largely depends on the seawater quality and therefore determining the seawater quality became one of the most important tasks for the design conditions. For this project, periodic analyses of the seawater in the surrounding ocean area took place through a year and the fluctuation ranges of the major parameters (alkalinity, pH, temperature) that affect the desulfurization performance were defined. The major equipment of the system consists of Absorber, BUF (Boost Up Fan), Seawater pump for desulfurization, Seawater treatment system and Oxidization system. For the exhaust gas, by adopting a partial desulfurization system (70% desulfurization, 30% bypassed), the flue gas temperature could increase more than EIA guideline by mixing with untreated flue gas and treated flue gas at the FGD outlet, satisfying SO_2 limitation. For the seawater system, approximately 20% of the seawater from the exit of the condenser is taken by Seawater pump and is fed into the absorber to be used for the desulfurization process in the absorber. As the seawater at the absorber exit had a low pH, it shall be aerated through the Seawater treatment system by oxidization and to recover the pH level to satisfy the EIA standard value (pH=7.0 or above). The system and equipment specifications were determined after various tests and simulations were conducted by the MHI Research and Development Center and other external research institutes.

Fig. 7 Seawater desulfurization system (absorber)

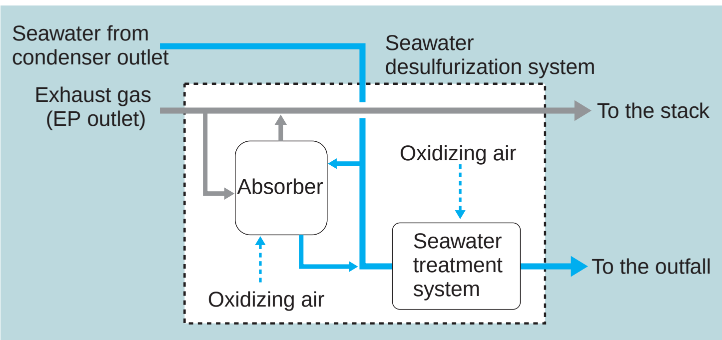

Fig. 8 Seawater desulfurization system (system flow diagram)

4.5 Design and construction of coal unloading pier

(1) Design of pier (mooring conditions in consideration of heavy storms)

The coal carriers to be moored are Cape-size vessels (170,000 DWT, DWT: dead weight tons) and Panamax-size vessels (70,000 DWT). In the event of heavy storms, they are not usually moored at the pier but are evacuated offshore. However, due to insufficient depth of the navigation channel, the vessels are to approach the pier during high tide and moored at the specified berthing place which is dredged 2 m deeper than the navigation channel. Therefore, in designing the pier it was necessary for us to include the maximum design wind velocity and the specified waves in discussing the mooring draft conditions, assuming a situation where a coal carrier would

Fig. 9 Coal unloading pier

encounter heavy storms during low tide and not be able to be moved offshore because of its deep draft. Normally, the maximum design wind velocity in a case like this is taken into consideration when designing a pier without a vessel moored. The wind velocity with rather high occurrence frequency (1/3 to 1/2 of the maximum design wind velocity) is used as the design wind velocity when a vessel is moored. Accordingly, the strength of this pier is substantially higher than that of others. Further study for simulating the dynamic behavior of moored vessel at berth in the above heavy storm conditions was conducted to evaluate safety during mooring and the stability of the pier structure.

(2) Construction of the pier

The pier has a concrete deck (30 m *W* x 346 m *L*) and a mooring dolphin supported by 326 steel pipe piles including battered piles, for which hardly any piling work could be performed during the summer monsoon season especially from July to September. In order to catch up with the construction schedule, we increased the number of piling vessels and introduced hollow precast concrete (PC) slabs as forms with the strength to support the concrete weight before the concrete hardened as a permanent part of the concrete deck section, thus having eliminated the time required for setting and removing the forms and shorings that would have been otherwise required in the conventional method. Further for the construction of the 60 m long trestle roadway connecting the plant site and the pier, large PC girders were prefabricated, carried onto and installed at the place. This contributed to an extensive reduction of the construction period in comparison with the usual case of cast-in place concrete.

(3) Environmental measures

In order to prevent coal dust discharge (conveyor and transfer tower) to the sea through the rain water, drain pits with sedimentation pit are provided on the pier. A large amount of rainwater drainage around the pier is first collected in the drain pits on the pier, then pumped up to the Coal yard pond in the coal yard, and finally treated in the Coal yard wastewater treatment system.

4.6 Local procurement management

In this project, since most of the equipment was procured in Thailand, a local procurement office was built in Thailand to conduct the process from placing orders to shipment of products smoothly. Experienced staff in material procurement design and quality control was employed in the office managed by the Vender Controller (VC). Also to improve the data transmission speed between Japan and the local procurement office and to improve the efficiency of procurement work in the office, special procurement system (FTK project support system) was developed through the Internet.

The local procurement office played a significant role throughout the construction period, which not only worked on delivery date control and management so that necessary materials could be obtained in time but also enabled prompt responses and quick material supply in the event of problems through the network of Thai suppliers which has been established by the VC. These efforts minimized the loss of schedule and cost, contributing greatly to maintaining the construction schedule.

4.7 Utilization of specialized local staff

Along with the expansion in functions of the local procurement office such as procurement control, document control (drawings and correspondence), personnel and labor control, and IT control (development, modification and maintenance of the document transfer system and various IT tools), the local staff working in the office had to naturally develop their ability from generalist to specialist. In this project, through the local works and the allocation of people in charge who were experienced in each field, efficient site works and services could be successfully facilitated.

5. Outline of construction work

As this project has a number of large equipment and systems, minimizing the assembling work on site was the most important key to shortening the construction schedule. Considering the efficiency and limitations of marine and inland transportation, each piece of equipment was maximized in knockdown size before shipment. Also, some of the equipment was preassembled at the ground level at construction site and lifted into place by a large crane.

As for local contractors of civil construction, considering that the construction work was large scale, two civil constructors are selected dividing the work into land construction work and sea construction work (coal unloading pier). The land construction work was awarded to Thai Nishimatsu Construction Co., Ltd. (TNC) whose subcontractors are two leading contractors in Thailand, Sino-Thai Engineering & Construction (STECON) and Italian-Thai Development (ITD) as well as a few other small-scale construction companies. Meanwhile, the sea construction work (coal unloading pier) was awarded to Toa Corporation (TOA) which had experiences in marine construction work with ITD as its subcontractor. The total amount of concrete for the land and sea construction work was 170,000 m^3.

As for the mechanical installation and electrical instrumentation work, Thai Jurong Engineering (TJEL) was selected as the local contractor, which could deal with all of the machinery, instrumentation and electric works. The total weights involved were 70,000 tons of mechanical equipment and 1,400 tons of electric equipment, and the total cable length was 1,960 km.

In Thailand, since there are a few contractors who are experts in the installation of coal fired power plants, a detailed installation instruction manual was necessary and prepared as a back-up support tool for construction work. This is referred to internally as "HEITAN (strategic logistic services)" activities. This instruction manual contained drawing numbers, drawing names, part numbers, part names, part quantities, and their weights which are necessary for the installation of each system. Thus, even if the person in charge was inexperienced in the system during the installation work, they could smoothly carry out the preparatory work (drawings, parts, tools, heavy equipment, workers, etc.) and could utilize this manual when giving installation instructions on site. Although it took a long time to prepare this instruction manual, it was highly regarded by those involved during the construction work and contributed effectively to the elimination of confusion and delays, and the observance of the quality and construction schedule.

For commissioning, the total period from Initial firing to Steam admission, Synchronization and final Turn over is 6 months. Since this period is relatively short for a 700 MW power station, commissioning staff participated in the design section from the early stages of the project to learn about the basic plan, design and operation concept of the plant and their requests and propositions in terms of commissioning activity was also fed back into the system design. Thus, mutual collaboration was established between the engineers and commissioning staffs, contributing to the realization of an efficient and trouble-free commissioning resulting in an accelerated completion of the project.

Further with regard to the Owner training, this was conducted at the same time as commissioning, providing comprehensive systematic instructions. The training program is established based on our extensive experiences with a complete review of not only the major machinery such as the Boiler and Turbine supplied by us but also other various equipment and systems supplied by different manufacturers.

6. Conclusion

In this project, our efforts were focused not only on overcoming the various problems and characteristics mentioned in Section 4 but also on promoting the "Implementation of visual control management for each activity." This was achieved by the establishment of our unique Project Management Tools (PMT) which were originally developed with the aim of the smooth management of overseas FTK projects, based on the lessons learned from large scale FTK projects. This enables us to conduct integrated management of the various tasks, such as Schedule control management, Drawing submission management, Outstanding issues management, Quality control management, Procurement management, and Risk management. The total number of each PMT established for this project is more than 30. These PMTs were constantly subject to review at appropriate times under the slogan of "more user-friendly and more effective" and thanks to the efforts of the people concerned, finally became a truly useful project management tool. Accordingly, we achieved good results especially for the risk management and delivery schedule management of equipment and systems which have been important issues for many years, contributing to the success of this project.

Finally, we would like to express our sincere gratitude to the Owner and all the parties involved in this project for their hard work which led to the successful completion of this project.


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