Status of Full Turn-Key Construction of Advanced Combined-Cycle Power Plants in Mexico

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In the export business of power generation plants, mainly full turnkey contracts dominate in which all aspects of work from planning, design, manufacture, procurement, construction, trial operation, and delivery of the plant to the customer are covered. Mitsubishi Heavy Industries, Ltd. (MHI) have received orders for five combined-cycle power plants using the latest M501F gas turbines, to be installed at five different sites in Mexico to cater the rapidly increasing demand for electric power. Two of the five plants have been completed and delivered to the customer as scheduled. In both the plants, up-rated M501F gas turbines with higher performance levels than conventional one have been adopted for the first time. Both the plants are currently operating at higher efficiency and reliability, thus meeting the ultimate requirement of the customer.

1. Introduction

MHI has already delivered many electric power plants such as conventional thermal, hydraulic, and geothermal power plants to customers in Mexico. In order to cope-up with the recent increasing demand for electric power, many gas turbine based combined-cycle power plants have been planned in Mexico because of its higher efficiency, short construction period, and comparatively lower cost. MHI have received five orders of these type of plants for different sites (**Table 1**). Of these, four plants which received the order under the contract of full turnkey have the configuration of two M501F gas turbines and one steam turbine, a so-called two-on-one configuration (**Fig. 1**). The first plant was built at Chihuahua under a BLT (Built, Lease, and Transfer) agreement (an agreement under which a private investor builds the plant, then leases it to the Commission Federal de Electricidad (CFE), and finally transfers it to CFE at the end of a specified leasing period). The other plants were built for IPPs (Independent Power Producers).

2. Electric power demand in Mexico

Reflecting favorable macro-economical conditions in Mexico, it is anticipated that total electric power generation capacity, which was 36 000 MW at the end of 1999, will rise to 56 000 MW in 2008. As a result, it is expected that additional demand for new power plants will be for 22 000 MW in total capacity, including compensation for the lost capacity due to disposing of old plants in this period. In order to control the

Table 1 Combined-cycle plants in Mexico ordered from MHI

Power plant	Chihuahua	Tuxpan 2	Altamila 2	Tuxpan 3 & 4	Champeche
Contract	FTK	FTK	FTK	FTK	CIF
Project	BLT	IPP	IPP	IPP	IPP
Customer	CFE	MC / KEP	MC / EDF	Union Fenosa	Trans Alta
Start of commercial operation (planned)	May 24, 2001	Dec. 15, 2001	May 1, 2002	May 30, 2003	Nov. 1, 2002
Configuration	2 on1	2 on1	2 on1	2 on1	1 on1
Output	450 MW	495 MW	498 MW	996 MW	260 MW
Cooling system	Air-cooled condenser	Sea water cooled condenser	Wet type cooling tower	Sea water cooled condenser	Wet type cooling tower
Fuel	Gas/Oil	Gas/Oil	Gas/Oil	Gas	Gas/Oil

Note) FTK: Full Turn Key, CIF: Cost Insurance Freight
MC: Mitsubishi Corporation KEP: Kyushu Electric Power Co., Inc.

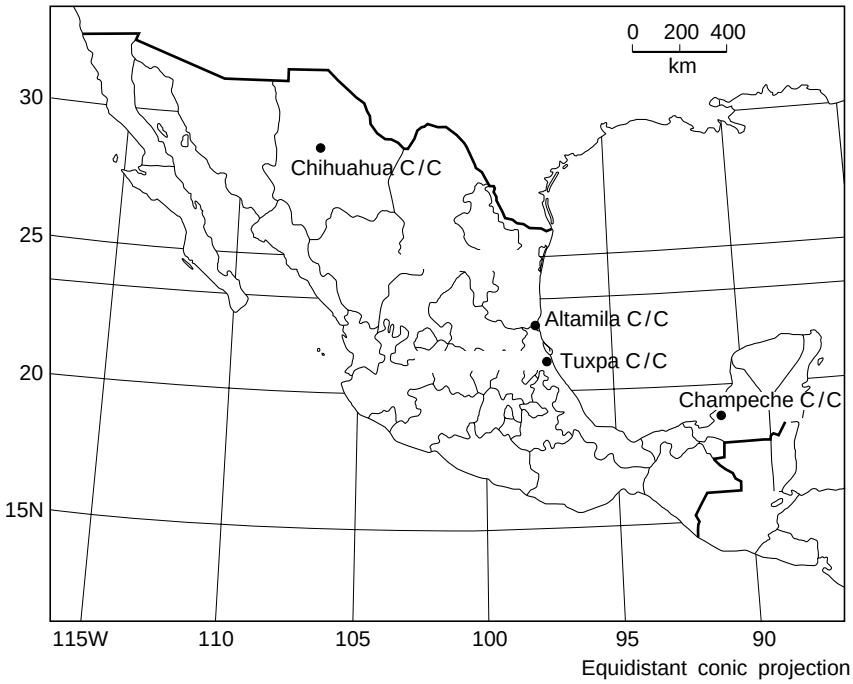


Fig. 1 Combined-cycle power plants delivered by MHI in Mexico
This figure shows the locations of the combined- cycle power plants for which MHI has received orders.

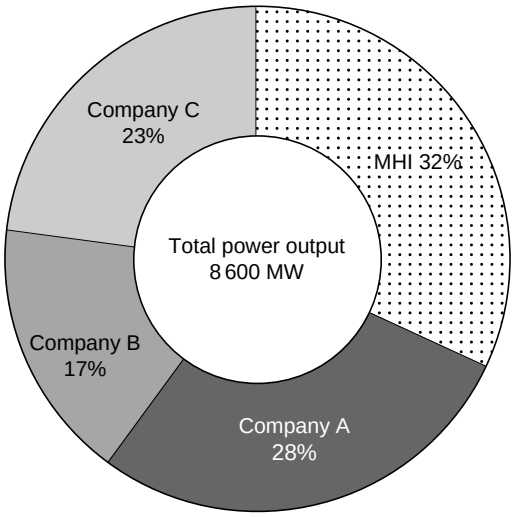


Fig. 2 Output share of combined-cycle power plants delivered by principal manufactures (MHI has a share of 32%.)

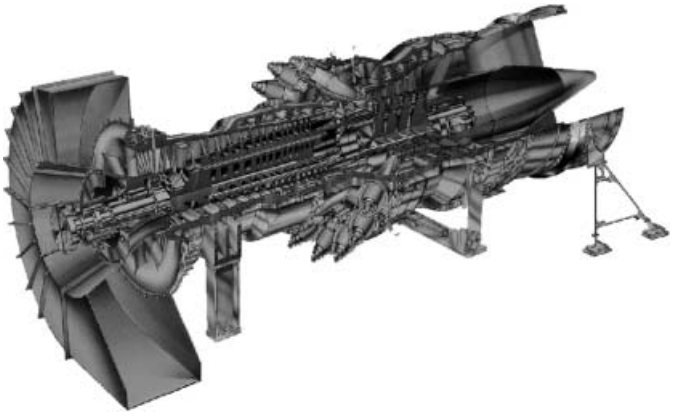


Fig. 3 M501F gas turbine
Up-rated M501F gas turbines are used in all combined-cycle power plants delivered by MHI in Mexico.

amount of foreign loans and improve the extent of the national debt, the Mexican government has established a policy of actively encouraging the introduction of private investment, including from foreign countries such as Japan, in the development of infrastructure improvement projects. Accordingly, the government has revised the Electricity Public Service Law in 1992 so as to accelerate the introduction of such investment into the electric power sector, which is on top priority, in order to cope-up with the expected increase in demand for electric power. The Tuxpan No.2 plant is the fifth combined-cycle plant contracted for a Mexican IPP. All four previous plants for IPPs were failed to be delivered as scheduled. On the other hand, the Tuxpan No.2 plant delivered by MHI was the first plant to begin commercial operation on schedule. The total generating capacity of combined-cycle plants currently in operation and under construction is about 8 600 MW, and the capacity of the plants contracted by MHI is one third of that total capacity (**Fig. 2**).

3. M501F gas turbine

All the plants described in this report are with the latest uprated M501F gas turbines (**Fig. 3**). The M501F gas turbine is a gas turbine that has been developed applying the latest aerodynamic, combustion, cooling, and material technologies. The turbine also incorporates many features of the basic structures that have proved so successful up through the series D

Fig. 4 Chihuahua Plant

Fig. 5 Tuxpan No. 2 Plant

turbine engine, including the use of stacked disk type rotors, cannular-type combustor, four-stage turbine, cold end drive, turbine air cooling by external cooler, and tangential struts. The above said features have been applied consistently in the previous series and have been sufficiently verified through commercial use. There are sufficient operational experience with M501F gas turbines as number of them have been delivered to power companies in Japan . In order to cater to the recent requirements for increased capacity and efficiency, the latest uprated M501F gas turbines adopted in the plants and described in this report have 6% higher air flow and 50°C higher combustion temperature than original M501F turbines. In other words, they have an increased converted plant output of 18% and an improved relative efficiency of 5%. The combustor and turbine blades used in this gas turbine, however, utilize the same design and materials as the latest 50 Hz model M701F, which has an increased combustion temperature of 50°C, just as in the case of M501F with already proven reliability.

To withstand the 50°C increase in the combustion temperature, MGA2400 alloyed steel has been adopted for the blades and MGA1400 alloyed steel for the vanes, because of their durability and added strength at higher temperature ranges. In addition, TBC (Thermal Barrier Coating) has been partially applied to the blade surfaces in order to reduce the surface temperatures of the blades and vanes. Furthermore, the latest in various cooling technologies have been adopted to cool the first stage blades, such as the use of shower head cooling, film cooling, and pin fin cooling. Rotor-cooling air bled from the compressor is cooled by an external cooler. Heat recovered by the cooler is used to pre-heat the fuel thereby helping to improve the thermal efficiency. The combustor is a multi-nozzle type premix dual fuel combustor, designed to maintain stable operation at each load and guaranteed levels of NOx emissions in any combined-cycle plant.

4. Outline of Chihuahua plant

The Chihuahua combined-cycle power plant (**Fig. 4**) is a plant leased to the CFE under a BLT agreement. The plant officially began commercial operation with a ceremony held on May 24, 2001, attended by the president of Mexico. The Chihuahua plant is located in Chihuahua city in the northern part of Mexico. This plant is built on a elevated land at an altitude of 1 480 m and a distinguishing feature of this plant is its use of air-cooled condenser. In order to compensate for the reduced output of the gas turbines that occurs under conditions of high atmospheric temperature, the plant is equipped with an evaporative cooler for power augmentation, to meet the increased power demand in summer. The configuration of the plant follows a two-on-one system consisting of two sets of gas turbine/HRSG (Heat Recovery Steam Generators) connected to one steam turbine. Both the gas turbines and steam turbine are installed indoors in accordance with the requirements of CFE.

5. Outline of Tuxpan No.2 plant

The Tuxpan No.2 plant (**Fig. 5**) is a 495 MW combined-cycle plant built in the Tuxpan area (about 250 km north-east from Mexico City), State of Veracruz, Mexico by EAT (Electricidad Agula de Tuxpan), a local Mexican joint venture of Mitsubishi Corporation and Kyushu Electric Power Co., Inc., under a BOO (build, own and operate) agreement to sell electric power to CFE for 25 years. This project was the first IPP project in which a Japanese enterprise has carried out plant operation, management, and procurement, as well as full investment. In particular, Kyushu Electric Power Co., Inc. have invested

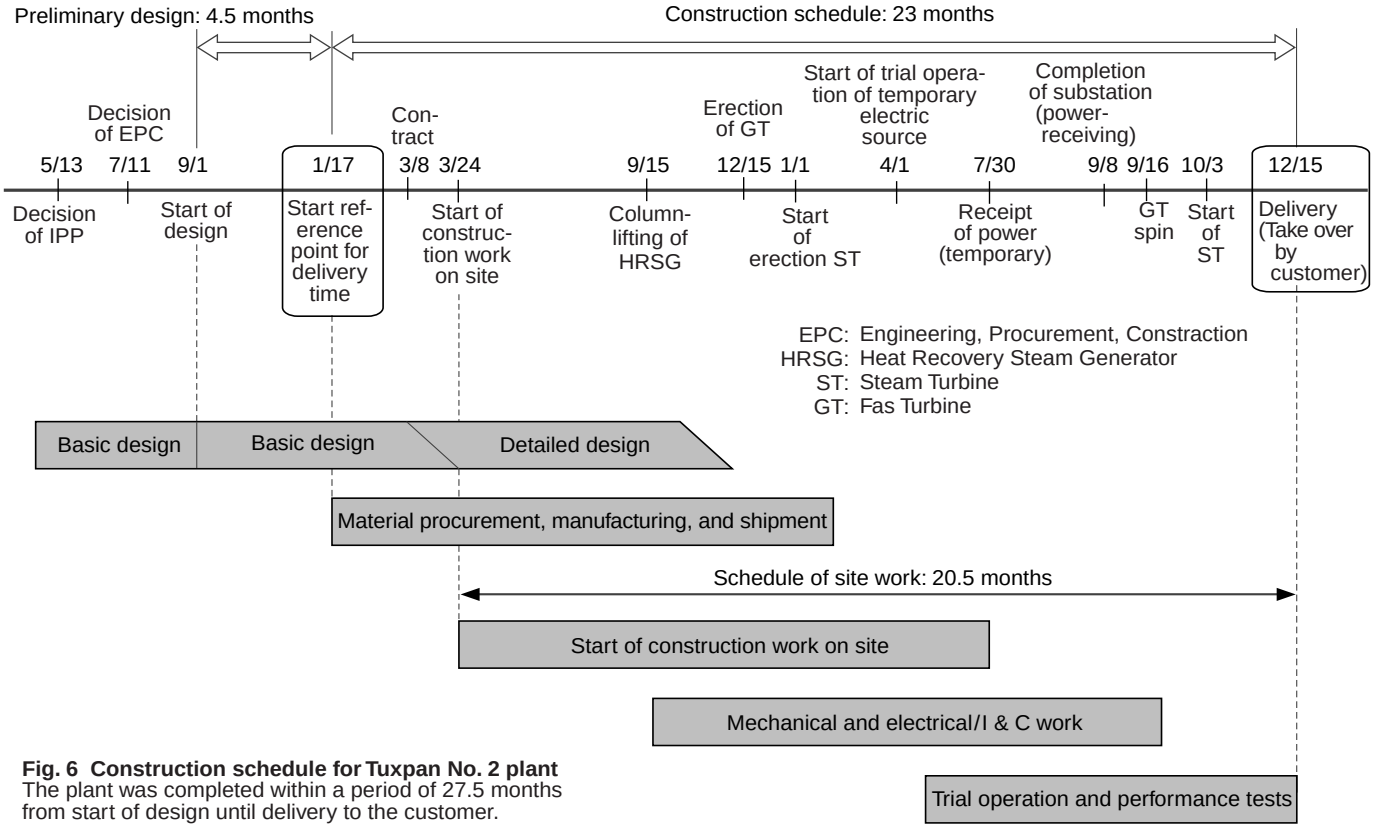


Fig. 6 Construction schedule for Tuxpan No. 2 plant
The plant was completed within a period of 27.5 months from start of design until delivery to the customer.

30% in the capital venture and is also responsible for actual O & M (Operation and Maintenance), i.e., this project was the first case of an overseas IPP project being carried out by the company. MHI was able to receive the order because its offer unit power price sold to CFE, which was evaluated to be least expensive among the offers made by participants in the bid. A major key to this success was in determining how best to reduce the construction costs while maintaining the guaranteed output and efficiency of the plant without adversely affecting the reliability, thereby effectively reducing the unit power price. Because of IPP plant, this plant differs from the Chihuahua plant in one notable aspect, in which the specifications are functional thereby allowing the seller to optimize the system satisfying the basic requirements of CFE. This difference contributed to reduce the total cost of the plant. For instance, the gas turbines and steam turbine are installed outdoors, thereby eliminating the need for a building for these turbines. Further, the plant is arranged so that mobile cranes can readily disassemble major equipment.

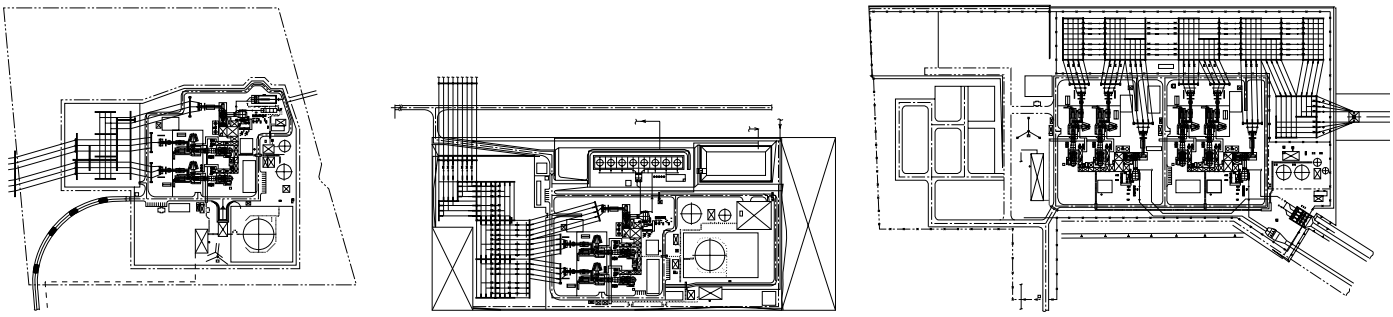
Fig. 6 shows the construction schedule for the Tuxpan plant. As can be seen from the schedule, the plant was completed in only 27.5 months from the start of the design process till completion and delivery. A thorough study was performed during the design stage itself for below ground work such as buried piping and wiring, trenches, piling construction of foundation, which are usually the greatest bottleneck at full turnkey job sites. As a result, the underground work could be completely finished prior to the erection of the equipment above ground, thereby minimizing the repeated work above and below ground after erection as far as possible. This design concept has also been applied to the Altamila No.2 and Tuxpan Nos.3 and 4 plants, which are undergoing either trial operation or construction at present.

6. Common power blocks

In order to reduce the costs of IPP projects in Mexico, the power blocks were planned with a common, standardized design, which can be followed for other plants also. This has made it possible to maintain the construction schedules and signifcant reduction in manpower and other costs related to the procurement of material. Since there was no need to redo designs and basic construction work, the plants could be completed within a short period, while maintaining high quality. **Fig. 7** shows the common power blocks at the Tuxpan No.2, the Tuxpan Nos.3 and 4, and the Altamila No.2 plants.

7. Maintenance and support system

If the design engineers of MHI can monitor the operational status of these gas turbine plants 24 hours a day at their office in Japan, they can offer advice to the operators on site immediately whenever any irregularities or problems occur or noted. This can contribute significantly in improving the reliability



(a) Tuxpan No. 2 (b) Altamila No. 2 (c) Tuxpan Nos. 3 and 4

Fig. 7 Common power blocks
The power blocks are designed based on a common, standardized design in order to help maintain construction schedules and significantly reduce manpower and others costs associated with the procurement of materials.

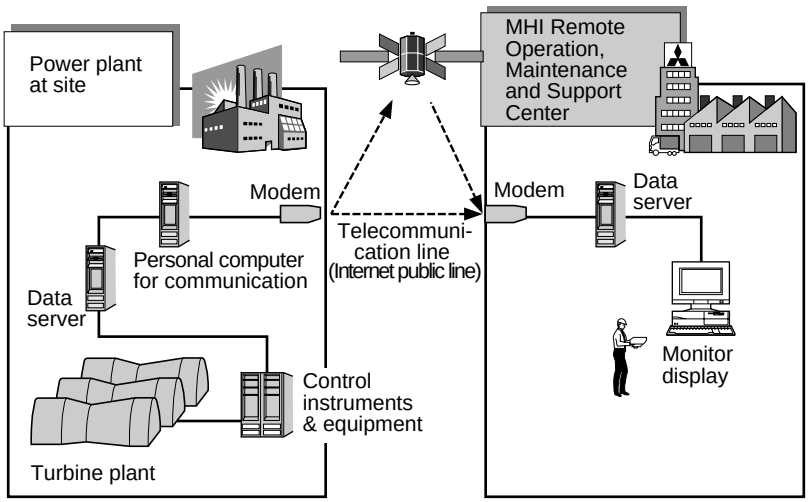


Fig. 8 Remote monitoring system
Monitoring the operation status of these gas turbine plants 24 hours per day, the design engineers of MHI can advice operators on site immediately whenever any irregularities occur.

of each plant and their respective systems.

Accordingly, a remote operational maintenance and support system is provided at the Maintenance and Support Center in Takasago Machinery Works to monitor data that is continuously being observed from the site via Internet. This enables the Center to support customers in monitoring the operational status of each plant, prepare maintenance schedules, and clarify the causes of any problems that might arise (**Fig. 8**).

8. Conclusion

Both the Chihuahua power plant and Tuxpan power plant built in Mexico as full turnkey projects are demonstrating their performance as expected, ensuring high reliability and economy using the latest technologies in combined-cycle plants. It is felt that the combined-cycle power plants designed, built, and set up by MHI will contribute greatly to the establishment of reliable and stable power sources in Mexico.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