Irrigation Project to Contribute to the Greening of Deserts in Egypt

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OVERVIEW: In the Arab Republic of Egypt, since ancient times, the population has concentrated around the Nile River basin, which accounts for about 4% of the country's total area. The population increased rapidly during the 20th century, however, and in response the Egyptian government has embarked on large scale horizontal expansion projects since around the 1950's. Planning to increase habitable land a comprehensive scheme for developing desert areas was put into motion. In 1997, President Mubarak initiated a "20-year National Development Plan," according to which existing farmland would be increased to 4.75 million acres and the population distributed throughout the country by 2017, when the total population is expected to reach 80 million. The Toshka Development Plan, which represents the central theme of this project, involves converting some 225,000 ha of desert (roughly the same area as that of Metropolitan Tokyo) into farmland, and establishing three million persons as permanent residents in that area. The Toshka Plan also involves the construction of a total of 240 km of irrigation waterways and a huge pump station. In September 1997, the Ministry of Water Resources and Irrigation, Mechanical and Electrical Department, the Arab Republic of Egypt, put out a call for proposal-style bids for the design and construction of this pump station. Out of six groups that responded to the bid, the participating Hitachi Group was successful in receiving the order. Hitachi is in charge of mechanical and electrical systems design for the pump station, as well as supplying equipment, and thus will play an essential role in the pump station construction plan by taking advantage of its experience in the implementation of large-capacity high-lift pumps. One of the basic design elements is the effective use of space in the pump station.

INTRODUCTION

THE Mubarak Pump Station, which was named after the President of the Arab Republic of Egypt, is a massive pump station with a pumping capacity of 334 m^3/s and a required power of 240 MW. In order to accommodate the desert's flat land shape and the large variation of the water levels of Lake Nasser, Hitachi conducted repeated surveys and hydraulic model study before moving ahead with design, eventually establishing the site as an island type pump station rising high above the surface of the lake (see Fig. 1).

Fig. 2 shows the main pump station facilities.

The contract includes: (1) construction of a 6-km intake canal; (2) construction of the pump station; (3) construction of a discharge basin conduit; (4) construction of a discharge basin; (5) construction of a maintenance workshop; (6) construction of residences for the customer and an administrative building; (7) delivery and installation of required auxiliary facilities; (8) commissioning and handover; (9) training of the customer's staff; and (10) dispatch of operation engineers for a period of four years.

Here, we will discuss the main pump, synchronous motor, and control system delivered by Hitachi, Ltd.

MAIN PUMP

Features of the Main Pump

Table 1 shows the specifications of the main pump, and Fig. 3 is an external view of the pump at the time of factory assembly. This pump is operated using a variable speed control, so the shape of the water passage related to the pump performance had to offer high efficiency, high suction characteristic, and highly stable performance across the entire flow range, from low to high flow. To accommodate this requirement, Hitachi developed an optimum model based on 3D flow analyses and model-based tests.

In the impeller design, Hitachi improved the inlet

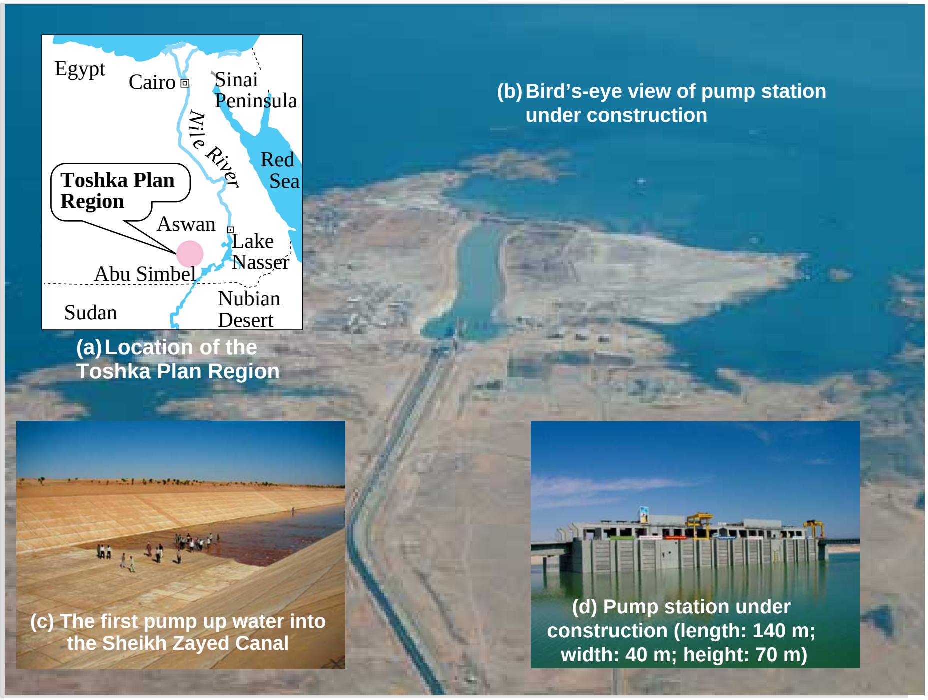


Fig. 1—Overview of the Mubarak Pump Station Construction Project.
The pump station was built on the shore of Lake Nasser. It is located about 280 km southeast of Aswan, and about 50 km northeast of the Abu Simbel Temple.

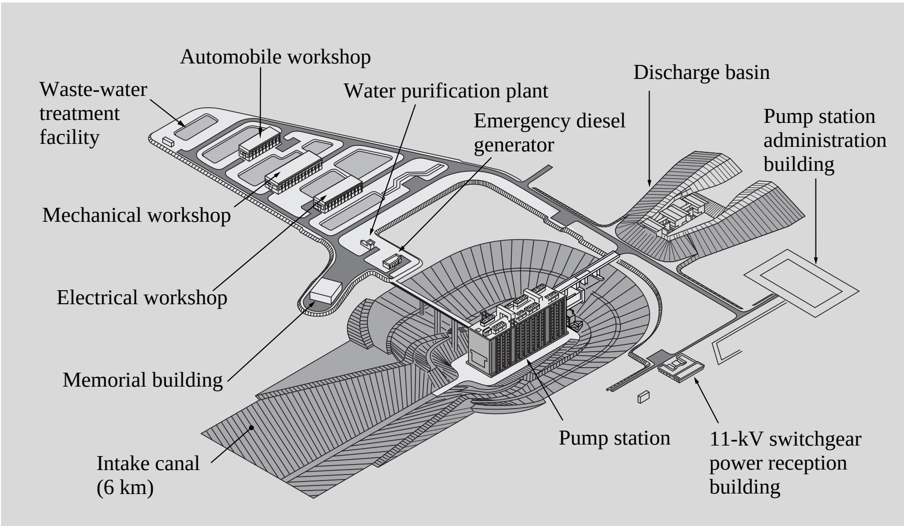


Fig. 2—Main Facilities of the Pump Station.
Facilities required for operation and maintenance have been built adjacent to the pump station. Management of the pump station is conducted based on independent operations by the customer.

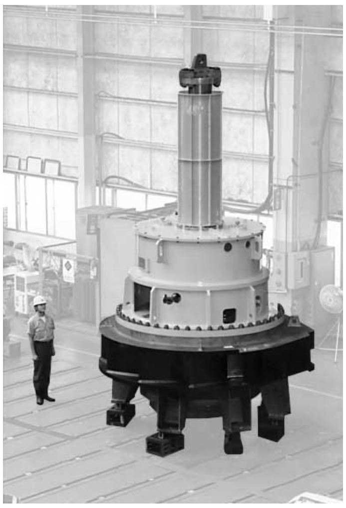


Fig. 3—Factory Assembly of Main Pump.
Assembled state of main pump before shipment. Fitting dimensions and assembly integrity were confirmed at the factory.

TABLE 1. Main Pump Specifications
At the Mubarak Pump Station, 21 large-capacity pumps are neatly arranged inside the station building. Basic specifications of the main pump are shown below.

Model	Vertical shaft, single suction centrifugal pump
Pump bore	2,400 × 1,800 (mm)
Discharge volume	16.7 m^3/s
Total head	57.1 m
Speed	210 – 300 min^{-1}
Drive motor	12,000-kW synchronous motor
Number of units	21

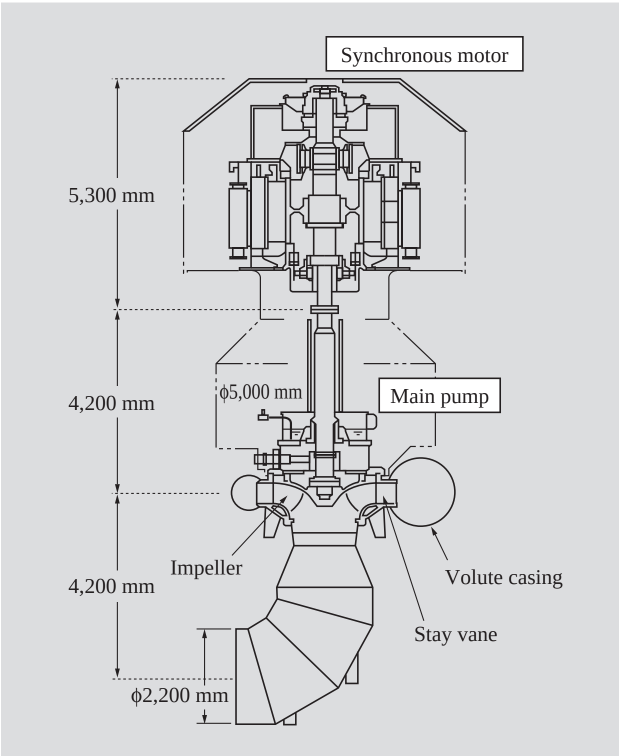


Fig. 4—Cross-section of Main Pump and Synchronous Motor.
The basic design of the pump station emphasized efficient use of space, with the main pump and synchronous motor located on separate floors for ease of maintenance.

angle of the blades, increasing the suction characteristic in the low flow range (which had been an issue in the past), and thus achieving increased efficiency.

Hitachi adopted a welded steel construction with few segments for the design of the stay vane and volute, with a view toward the production of the actual unit, and thus achieved its goal of reducing base costs while maintaining high efficiency and stable performance. A bend shape was selected for the stay vanes, to ensure optimum performance. In the production of the actual unit, a method was adopted for the bend-shaped segments by which the front and back edges of a thick plate were simply cut, after which the shape was completed using press processing.

The station uses a self-cooling method by which cooling water for the main pump bearing, shaft sealing water, cooling water for the synchronous motor bearing, and cooling water for the air cooler are drawn from the main pump discharge side, and then returned to the suction side. Using this method, the need for an independent cooling water pump and accompanying operation facilities are eliminated, contributing to the simplification of the station.

Assembly and Installation of the Main Pump

The volute casing for the main pump, which is of a welded steel structure, was manufactured in Cairo and transported to the site in parts, with the stay vane structure manufactured in Japan shipped separately from the external volute segment; the parts were welded together and machined at site, and then carried as a whole to the pump station. Rotating parts (including the impeller and shaft) and the casing cover were assembled inside a mechanical workshop located adjacent to the pump station, and carried to the pump station in one piece using a hoist.

Fig. 4 shows a cross-sectional view of the main pump and the synchronous motor.

SYNCHRONOUS MOTOR

Table 2 shows the specifications of the synchronous motor. Fig. 5 is an external view of the motor at the time of factory assembly.

In order to enable to combine with the variable speed drive equipment, Hitachi conducted repeated tests using a prototype motor to confirm its reliability. Following are the main features of this synchronous motor.

(1) Stator

In the past, frame designs were based on a round shape. This unit has a hexagonal frame, to reduce the number of man-hours required for manufacturing.

The motor is driven by a variable-speed drive, so in order to minimize torque ripple, two parallel coil connections were adopted at an electrical angle of 30˚ difference. The number of working man-hours was reduced by adopting a highly reliable one-shot varnish injection method.

(2) Rotor

The conventional method applied to rotor coils is the "edigewise" method, in which a continuous

TABLE 2. Main Specifications of Synchronous Motor
Motor speed is determined as required depending on output frequency from the variable speed drive equipment.

Rated power output	12,000 kW
Rated voltage	2,950 V
Rated current	1,369 A × 2
Rated power factor	0.88 (leading)
Speed	210 – 300 min^{-1}
Frequency	35 – 50 Hz
Number of poles	20
Protection	IP54

conductor is pulled and wound into shape. This rotor coils use a butt brazing method, in which the coil is wound using high-frequency brazer to a conductor that has been cut into specified lengths in advance. The centrifugal force on the rotor poles themselves is very small, so a bolt tightening method was used to simplify the assembly process.

(3) Bearing lubricant cooling

A heat pipe was used for cooling the lower guide bearing lubricant, and air cooling was adopted to reduce the amount of piping for bearing coolant water.

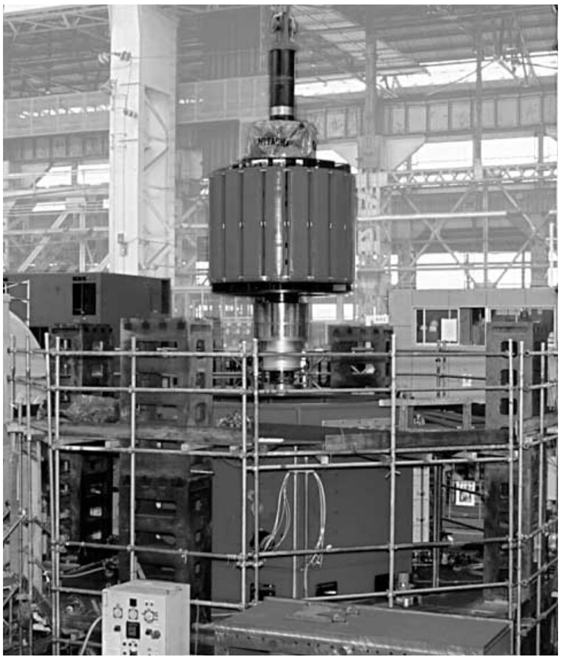


Fig. 5—Plant Assembly of Synchronous Motor.
Hoisting of synchronous motor rotor.

(4) AC exciter/rotating rectifier

In order to achieve brushless, variable-speed operation to enable maintenance-free running, Hitachi adopted an AC exciter that uses a wound rotor induction machine. Factory operation tests were conducted combining the synchronous motor, variable-speed drive, static exciter, AC exciter, and rotating rectifier, and obtained good results.

VARIABLE SPEED DRIVE EQUIPMENT AND OPERATION CONTROL/MONITORING SYSTEM

The pump operation water level on Lake Nasser changes throughout the year with levels ranging from 147 m to 178.5 m. To enable operations in keeping with these changes, Hitachi incorporated a load commutation inverter into the variable speed drive equipment, thus enabling operations from 70% to 100%.

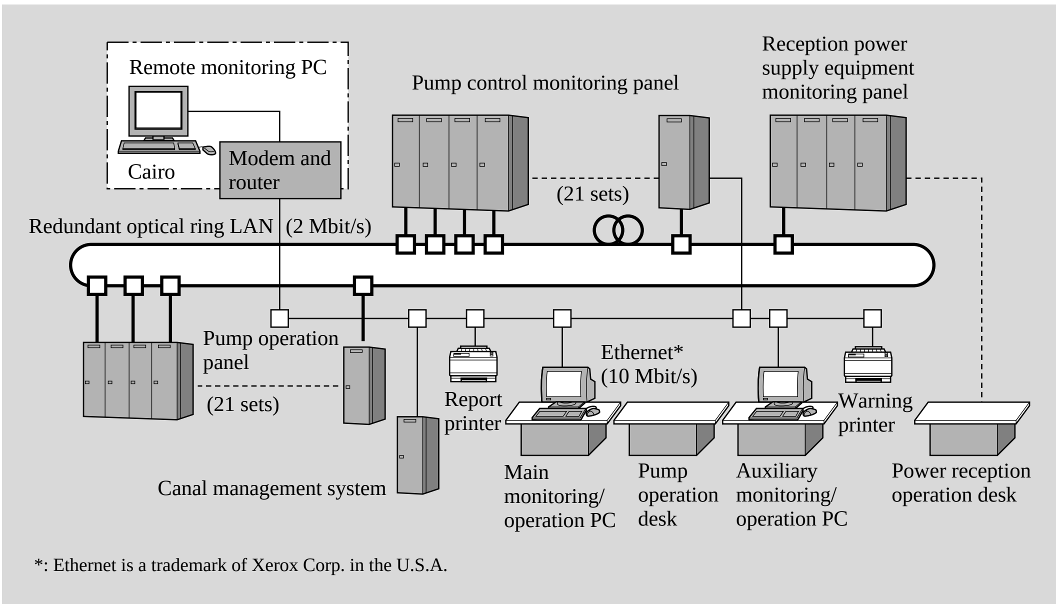
The required downstream water volume is sent from the canal management system to the operation control and monitoring system via a LAN (see Fig. 6). In this system, in order to achieve optimum operating conditions with minimum power consumption, the following system configuration was adopted, along with various control functions.

System Configuration

Because this pump station operates continuously 24 hours/day, Hitachi specifically selected devices that ensured high reliability.

Programmable logic controllers (PLCs) have been

Fig. 6—Mubarak Pump Station Operation Control and Monitoring System Configuration.
Optimum operating conditions and minimum power consumption are achieved through close links with river management systems.



installed for each of 21 pumps to enable independent operations. Redundant PLCs have also been implemented in the power receiving control and monitoring system to further increase reliability.

Two human interface (HMI) units have been installed to enable continuous 24-hour operation. An additional HMI unit has also been installed with connections via a phone line to enable remote monitoring of operating conditions at the Ministry of Water Resources and Irrigation, Mechanical and Electrical Department, located 1,000 km away in Cairo.

A redundant “optical ring LAN” was adopted as the PLC LAN to prevent noise from the inverter, and a standard LAN Ethernet was adopted for the HMI LAN.

A common PLC was installed for overall operation guidance and interlock management.

System Functions

Following are just a few of the functions adopted to ensure stable operation of the 21 pumps, and to lessen the burden on operators and maintenance personnel.

(1) Pump operation guidance functions; (2) automatic pump operation monitoring functions; (3) pump operation preparation monitoring functions; (4) inlet and outlet water level monitoring functions; (5) operation status and trend monitoring; (6) failure monitoring and notification functions; (7) energy management functions; and (8) daily / monthly report creation functions

The pump operation guidance functions enable operations in keeping with the water volumes required downstream, as well as a flexible response to changes in the water level of Lake Nasser. These functions also make it possible to provide the operators with information regarding which pump to start up and which to shut down, depending on factors such as optimum number of pumps running, operating speeds for maximum energy efficiency, and equalization of maintenance requirements.

The operation preparation functions display the status of complex preparatory tasks for each pump, and the failure monitoring functions identify locations in need of repair, so operation and maintenance can be conducted with ease (see Fig. 6).

CONCLUSIONS

Here, we have discussed features of the main devices used at the Mubarak Pump Station in Egypt.

Test operation of the first two pumps began in November 2002, followed by test operation and acceptance of all 21 pumps. All of the key equipment has been transported to the site, and initial targets have been successfully achieved. Meanwhile, construction of a 240-km waterway (based on a separate contract) is progressing smoothly. Settlement of the development region has also begun, and development is moving ahead steadily.

Hitachi, Ltd. will continue to promote research and development in the field of irrigation systems, and to contribute to the greening of deserts in Egypt.

REFERENCE

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