TECHNICAL DIARY- Offshore

220MW Barge Mounted Power Plant

This barge was built in 2000 Hyundai. It was set up with four LM6000 gas turbines providing 46 MW each and one 50 MW steam turbine. Chillers are installed to cool down the air intake to enhance the performance of the turbines, especially in warm climates.
The turbines have an average of 36000 total working hours since new.
The turbines have been serviced under a Long term service contract from the OEM.

There are three generator step-up transformers on the barge transforming the power up 220 KV. Two transformers have a capacity of 120 MVA each and the third one has a capacity of 70 MVA.

The barge operates on both diesel or natural gas.
The turbines consume 220,000 x 8,500 BTU/KW = 1,870,000,000 BTU per hour.
Divided by 1,000,000 = 1,870 MMBTU x 2,80 USD = 5,236 USD / per hour

5,236 USD / 220,000 kw = 2,4 US cents KW

There are many factors that influence the price.
Availability of the turbines, air temperature, humidity, quality of gas etc.

The operating and maintenance costs for the barge would be 0.7 US cent per KW.
For continuous operation a crew of 16 people would be needed to operate the barge.

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A. OTSG

Once Through Steam Generators also called OTSG are supplied by IST, Canada. These are the steam generators, which generate steam for power generation in steam turbine. The heat in the exhaust gases from Gas Turbines is transferred to feed water to generate steam at two pressures, HP & LP. The OTSG are drum less boilers having tube bundles where steam is generated. Feed water is supplied to OTSG through feed water pumps after treating the water in Condensate Polishing Unit. Suppling DM water to condenser hot well fulfils the additional makeup requirement. The exhaust gases after giving their heat to feed water are let off to atmosphere through stack. The OTSG has a dry running capability up to 560◦C.

General Specification:

Manufacture	: INNOVATIVE STEAM TECHNOLOGIES
Type	: ONCE THROUGH STEAM GENERATOR
Make No.	:
Number of boilers	: 4
Working Pr in psig / kg/cm2 (g)	: HP - 865 / 59.62 & LP - 68.3 / 4.71
Design pr in psig / kg/cm2 (g).	: HP - 953 / 65.71 & LP - 103 / 7.10
Hydraulic test pressure in psig / kg/cm2(g)	: HP - 1884 / 129.87 & LP - 384 / 26.47
Flue Gases	: Gas Turbine exhaust flue gas
Capacity in lb/hr / kg/hr.	: HP - 107600/48806.5 & LP - 35570/16134.28
Design dry running gas temperature	: 986 F
Maximum operating gas temperature	: 856 F

B. BARGE

The Function of Barge is to contain and deliver 1(one) combined cycle barge mounted floating power plant of nominal net capacity 220 MW, consisting of 4(four) Once Through Steam Generator (OSTG), 1(one) steam turbine generator (STG), 4(four) combustion gas turbine generators and auxiliary equipment condensers, chilling system for air intake and the remaining balance of plant. The basic design is to include the barge and the connections to the mooring system, together with the power plant equipment.

The Design data of the barge

a) Barge size (length x wide x depth) : 106m x 55.2m x 6m
b) Barge draft for towing : 2.4 m (Normal operation 3.4m)
c) Total barge weight : 13,900tonnes

(barge itself including steam turbine hall, control building and above deck foundations: approximate 6,000 tonnes)

Stability

a) The barge is designed to comply with the intact stability regulation of US 46 CFR Chapter I, Section 174.015 for river and harbor service.
b) The barge is designed to comply with the one compartment damage stability regulations of US 46 CFR Chapter I, Section 172.065. The Barge shall comply with a wind heeling moment as defined in CFR Chapter I, Section 174.055
c) The Barge is designed to comply with IMO International Convention on Load Lines

Barge Access

Four(4) ramps are designed to access the barge from shore,
one(1) main ramp 6m wide
one(1) ramp 4.5m and
two(2) auxiliary ramps 3.5m wide respectively.

Barge Ventilation

Below deck spaces are ventilated according to the recommended practices of SNAME T&R 4~16 “Calculation Merchant Ship Heating, Ventilation and Air Condition Design”.

Fans are sized to limit the temperature rise in the ventilated spaces to be less than 5^{o}C and to
Provide sufficient ventilation air to ensure noxious fumes are below accepted occupational
Safety regulation levels.

C. CHILLERS

Chillers are used to cool Gas Turbine intake air and enhancing the output of each Gas Turbine by 7 to 10 MW approximately. The chillers operate on Vapour Compression Cycle. Chilled water is circulated through evaporator where it rejects heat to refrigerant HFC134a and become chilled. This chilled water again picks up heat from gas turbine intake air-cooling them. The boiled refrigerant is than compressor. The heat added to the refrigerant in evaporator and compressor is that rejected in condenser, cooled by sea water. The motor is hermetically sealed. Lube Oil and motor windings are cooled by refrigerant. Therefore heat from a low temperature source is rejected to high temperature source.

Design criteria

1) Site condition
   GT chiller coil required cooling capacity : 1200 USRT x 2 sets

2) GT chiller cooling coil design condition
   - Inlet air condition (Ambient) 37 ◦ DB / 75 % RH
   - Outlet air condition (GT inlet air) 7.22 ◦ DB / 95 % RH
   - GT inlet air flow rate 128.9 kg/s
   - Chilled water supply / return temp. 5 ◦c / 13.8 ◦c
   - Chilled water flow rate: 826 m³/h

Chilled water system consists with the following equipment,

Group 1.

Equipment No.	Name	Q"ty	Remarks
1. GT-1	Combustion air chilling coil #1	1 set	100%
2. GT-2	Combustion air chilling coil #2	1 set	100%
3. CS-M-CH01-1A	Centrifugal Chiller #1A	1 set	50%
4. CS-M-CH01-1B	Centrifugal Chiller #1B	1 set	50%
5. CS-M-CH01-2A	Centrifugal Chiller #2A	1 set	50%
6. CS-M-CH01-2B	Centrifugal Chiller #2B	1 set	50%
7. CS-M-PP01-1A	Chilled water Circul. P/P #1A	1 set	50%
8. CS-M-PP01-1B	Chilled water Circul. P/P #1B	1 set	50%
9. CS-M-PP01-2A	Chilled water Circul. P/P #2A	1 set	50%
10. CS-M-PP01-2B	Chilled water Circul. P/P #2B	1 set	50%

Group 2.

Equipment No.	Name	Q"ty	Remarks
1. GT-3	Combustion air chilling coil #3	1 set	100%
2. GT-4	Combustion air chilling coil #4	1 set	100%
3. CS-M-CH01-3A	Centrifugal Chiller #3A	1 set	50%
4. CS-M-CH01-3B	Centrifugal Chiller #3B	1 set	50%
5. CS-M-CH01-4A	Centrifugal Chiller #4A	1 set	50%
6. CS-M-CH01-4B	Centrifugal Chiller #4B	1 set	50%
7. CS-M-PP01-3A	Chilled water Circul. P/P #3A	1 set	50%
8. CS-M-PP01-3B	Chilled water Circul. P/P #3B	1 set	50%
9. CS-M-PP01-4A	Chilled water Circul. P/P #4A	1 set	50%
10.CS-M-PP01-4B	Chilled water Circul. P/P #4B	1 set	50%

Details of Chiller:

Name Plate Details:

Type:	Centrifugal
Make:	Carrier, USA
Refrigerant Used:	R 134a
Quantity of Refrigerant charge:	1270 Kg
No. of chillers:	8
Capacity:	1210 USRT each
Motor:	Hermetically Sealed
Rated Power:	808 KW
Design Chilled water temperature:	5°c
Delta T across evaporator:	8.8°c
Chilled water flow rate:	415.77 m3/hr
Design Sea water inlet temperature:	29°c
Delta T across condenser:	6 °c
Condenser sea water flow rate:	739 m3/hr
No of tubes in evaporator:	976
Evaporator tube diameter:	19.05 mm
Evaporator heat transfer area:	228 m2
Evaporator tube material:	Copper
Chilled water:	DM water
Evaporator fouling factor:	0.00008806 m2.deg.c/W
LMTD across evaporator:	7.13
Evaporator approach:	> 1°c
No of tubes in condenser:	1170
Condenser tube diameter:	19.05 mm
Condenser heat transfer area:	257 m2
Condenser tube material:	Titanium

Condenser fouling factor:	0.00008806 m2.deg.c/W
LMTD across evaporator:	3.08
Condenser approach:	1 to 2 ºc
Coefficient of Performance (COP):	5.2
Energy Efficiency:	0.192
Main motor:	6,600 V, 50 Hz, and 3 Ph
Aux. Power:	415 V, 50 Hz, 3 Ph

D. AIR COMPRESSOR

The plant instrument air and service air requirement are met through screw type air compressors located in barge below deck compartments. There are 3 X 100 % compressors installed, having one instrument air receiver and one service air receiver. The instrument air is passes through 2 X 100 % desiccant type dryers which dries the air for use in instruments. The compressors are water cooled. To meets the equipment preservation air requirement and service air requirement we have a onshore air compressors which is run when the plant is under shutdown. The air is routed through the driers in barge to fulfil the requirement.

Specifications

Type	rotary screw Oil free,
Make	Water cooled screw type
Serial no	TS 1703
Manufacturer	Ingersoll Rand
Quantity	3 sets
Capacity	12.7Nm3/min
Pressure	8.64 bar g
Motor	120.4 kw/set
Compressor package data	
Capacity	18 m^3/min
Rated operating pressure	8.5 bar g
Max discharge pressure	8.7 bar g
Gross mass	3250 Kg
Total package amperes	218/209
Voltage	380/415 V
Phase/hertz	3/50
Serial no	TS1701000126

E. GAS TURBINE

Gas Turbines are the main power generating units located on barge top deck. These are LM6000PC machines, which uses Natural Gas as fuel for continuous operation. . These engines are aero derivative engines manufactured by GE. There are four GT each of 46.68 MW capacity. These machines are twin shaft engines. LP shaft is connected to generator at cold end through a reduction gear box. HP shaft is a freewheeling type shaft and its speed is proportional to load. LP shaft has LP compressor and LP turbine mounted on it. HP shaft has HP compressor and HP turbine mounted on it.

Inlet air to gas turbines are filtered in the filter house which has conical filters. Instrument air is used to clean the filters of dust accumulation. The air is then used for generator compartment pressurization, combustion and ventilation. The air is cooled by chilled water supplied from chillers pass through heat exchanger. The air than passes through drift eliminator and coalescer before going to engine after removing the moisture. The condensate generated in cooling process is used form DM water production in DM plant. The air energy is raised through compression and used for combustion. After expansion in turbine the exhaust gases are diverted to OTSG where its heat energy is utilized in generating steam. The turbine has water injection for Nox control.

Gas turbine lube oil system

A) Lube oil facility for gas turbine is installed on auxiliary package.

B) The system consists of four major sections.
- Gas turbine lube oil unit
- On-engine mounted supply and scavenge pump
- Lube oil cooler unit
- Air/oil separator module

Generator and gearbox lube oil system

The lube oil system consists of two major sections
- Shaft driven main lube oil pump integrated on the reduction gearbox.
- Lube oil module including electric motor driven lube oil pump, twin water-cooled lube oil coolers, filters, and lube oil tank.

Hydraulic starting system

The main component of the system is as follows:
- Motor driven main hydraulic starting oil pump with hydraulic control
- Motor driven clutch cooling oil pump

- High and low pressure regulating valves
- Hydraulic starting oil tank
- Supply and return filters
- Hydraulic starter
- Hydraulic starting oil cooler

Air intake and exhaust gas system

Gas turbine inlet air is drawn through this filter house, and is led to the gas turbine inlet through the air silencer and an inlet scroll assembly

Water washing system

The main components consisting system are as follows:

- Solution and rinse water tank
- AC motor driven pump
- Water wash filter
- Off-line water wash spray manifold (on-engine)
- On-line water wash spray manifold (on-engine)

Fire protection system

The fire protection system consists of CO2 bottle skid, related valves, pipe and Instrumentation.

- The CO2 is supplied to two places as follows,
- Gas turbine enclosure
- Generator rear bearing enclosure

Generator

A) The generator uses open air-cooled, synchronous type, and totally enclosed type.

B) The generator will be able to handle all load situations in a satisfactory manner at both maximum and minimum ambient temperature. The generator consists of the following components:

(1) Rotor
(2) Stator
(3) Exciter
(4) Cooling system
(5) Frame & enclosure.

General specification

GT Type Aero-derivative -LM 6000 PC
Make GE
Power 46,688 kw/GT
Revolution 3600 rpm

Compressor

Type	:	Axial
Stage	:	LPC-5 / HPC-14
Compression Ratio	:	LPC - 2.4:1 / HPC - 12.5:1

Combustor

No of combustor	:	1 per GT
No of nozzle	:	30/combustor
Combustor type	:	Annular Sequential
Ignition type	:	Electrical igniter

Inlet Air System

Make	:	Donaldson
Filter elements	:	Static Cylindrical and conical
No. Of elements	:	224 pairs (2 * 16 columns * 7 rows)

Air Flow	**Initial clean sys.**	**Initial clean filter**	**pressure drop**
GT Combustion	130 kg/sec	93 mm W g	18.5 mm W g
GT Ventilation	25 kg/sec	57	
Generator cooling And ventilation	1390cuM/min	42 mm W g	31.5 mm W g
Generator bearing Pressurising air	30 cu. M/min	50 mm W g	

Filter efficiency:

- Sodium removal efficiency : 99.98%
- Chloride removal efficiency: 99.98%
- Moisture removal efficiency: 99.5% on 50 micro droplet

SPRINT System

The term “SPRINT” (**SPR**ay **INT**ercooling) is a technological advancement that has been developed by GE Industrial Aero Derivative Gas Turbines (GE-IAD) to enhance the output performance of the LM6000 Gas Turbine. The addition of GE‟s proprietary Sprint technology increases the output by 9% at ISO and by more than 20% on 90° F (32°C) days. The effectiveness of the system becomes more pronounced as ambient temperatures rise.

The SPRINT system begins a mist injection process once the turbine reaches full load operation; no enhancement benefits are achieved at part load for either power augmentation or decreased heat rate.

The SPRINT cooling technology lowers the high-pressure compressor (HPC) inlet temperature (T2.5), which in turn effectively lowers the HPC compressor discharge temperature (T3).

ISO-International Standards Organization

- Ambient temperature 59 F (15 C)
- Barometric pressure 14.6% (101.4 kPa)
- Relative humidity 60%
- Elevation sea level
- Inlet and exhaust losses-none
- Emission controls-none

The system consists of two multi-nozzle inter stage mist injection systems

1) The low-pressure compressor (LPC) mist injection system consists of a single row of 23 nozzles located in the inlet of the LPC.
2) The high-pressure compressor (HPC) manifold is split into two (2) separate manifolds (inner / outer) consisting of two rows of 12 nozzles each for a combined total of 24 nozzles. The HPC manifolds are located in the compressor front frame support housing between the LPC and HPC.

Only one manifold will be operational at a given time. Which manifold is energized is dependent on the inlet air temperature. Inlet air temperatures of ≥ 48°F enables the LPC SOV valve to be opened when the system is enabled. When temperature drop below 48°F the LPC manifold will be de-energized and HPC manifold energized. If the temperature continues to drop, at 41°F both HPC and LPC will be de- energized. As temperatures increase from below 41°F the HPC manifold will be reenergized at 43°F increasing and at 50°F increasing the LPC manifold will be reenergized and HPC manifold de-energized.

Air extracted from the engine 8th stage HPC bleed air extraction port is utilized to atomize & pressurize the system By using the SPRINT spray inter-cooling system, the compressor pressure ratio can be increased and additional air can be directed through the compressor to increase the gas turbine characteristics

Specifications

Pump Type	:	Vertical Multi Stage Centrifugal Pump
Material	:	Stainless Steel
Catalogue No	:	3SVDK15SCP
Pressure	:	P SI 360 max
Temperature	:	250 F Max
Manufacturer	:	Goulds Pumps , ITT , G&L Services SSV
Flow Range	:	1 1 to 75 gpm
Pump Efficiency	:	65%
Motor Power	:	3/4 HP

Filter

Type : Duplex

Manufacturer : Indufil BV, Netherland

Year : 2007

Skid Mounted Equipment

Demineralised water is supplied to the SPRINT system from DM plant. It is supplied at a rate of 10-gpm minimum to 30 gpm maximum and at pressures 0-65 psig. After interface connection, it flows through a Y-type strainer, a normally open ball valve to a centrifugal pump . The centrifugal pump is driven by motor rated at 10 HP. After the pump, the demineralised water pressure is monitored by pressure switch LOW PSL-62227 which activates pressure alarm LOW PAL- 62227 in the event the water pressure falls below 75 psig. Pressure gauge PI-62229 scaled 0-400 psig displays pump discharge pressure .The demineralised water then flows through a flow meter, solenoid actuated block valve, and enters a duplex filter that filters the water to 20 microns absolute. Pressure differential switch HIGH PDSH-62233 monitors the differential pressure across the filters and activates an alarm should the differential pressure increase to 10 psid. Pressure differential indicator PDI-62232 provides a visual display of the differential pressure across the filter.

LPC SPRINT – 17 gpm (64 L/Min)

HPC SPRINT – 13 gpm (50 L/Min), 6.5 gpm (25 L/Min)per manifold

System Pressurization Air

Air for atomizing and pressurizing the SPRINT system is extracted from the 8th stage HPC at engine. The air is supplied at 630 scfm (18 SCMM) and 150 psia (1034 KPaG) through an orifice. The air flow is divided into two separate flow one for LP SPRINT and the other for HP SPRINT.

System purge air is used to purge demineralized water from the system for approximately two minutes immediately after SPRINT shutdown. This is conducted to prevent corrosion and the possibility of ice formation. System purge air is provided from the customer‟s connection at 80-120 psig, dry filtered to 5 microns absolute.

Fuel Injection System

Type: Gas Fuel System with Nox Injection

The LM6000 PC fuel system includes fuel manifolds, flexible fuel hoses, and 30 fuel Nozzles. The minimum temperature of the gas fuel supplied to the gas turbine shall be 50°F (27.8°C) greater than the saturated vapour temperature of the gas supply pressure. The temperature of the gas fuel should not exceed 300°F (148.8°C) at the gas manifold inlet

F. STEAM TURBINE

Steam Turbine expands the steam generated from all the OTSG to generate power. HP and LP steam generated from all 4 OTSG by utilizing the heat in exhaust flue gases, is directed to common header. Steam from HP and LP headers are injected in the steam turbine through control valves. LP steam is injected at 29th stage of the turbine. The steam gets expanded over the reaction blades and after utilization of work is dumped into the axial flow deaerator cum condenser. The steam gets condensed in the condenser and feed water from condenser hot well is directed back to the OTSG through boiler feed pumps. Condensate polishing unit purifies the feed water before it enters the OTSG. Steam jet air ejector and vacuum pump are used to generate and maintain vacuum in the condenser. The two-pole Generator uses air cooling for the rotor winding and the stator winding. The losses in the remaining generator components, such as iron losses, windage losses, and stray losses, are also dissipated through air.

The AC exciter is provided to supply the field current to the rotor winding of the generator.

The brushless Exciter system is consists of three phase main exciter (AC exciter), Rotary Rectifier (R-RF), Pilot Exciter (permanent magnetic generator) and AVR (Automatic Voltage Regulator).The turbine is an axialflow, single casing construction with approx. 50% of reaction.

TURBINE BYPASS SYSTEM

There are four bypass stations in the Tanir Bavi (GEL, Kakinada) power plant. Two of them are HP bypass stations and other two LP bypass stations.

Each HP and LP bypass stations are connected to HP and LP steam line of two OTSG (once-through steam generator).

The bypass stations functions are described below.

Each bypass stations consisting of:

One steam shut off valve per bypass

One steam pressure control valve per bypass

One water injection control valve per bypass

One steam assisting/preheating per bypass

HP steam by-pass valve

Inlet Steam Pressure	60.0	bar a
Inlet Steam Temperature	419	°C
Inlet Steam Flow	82.6	t /h
Outlet Steam Pressure	5.0	bar a
Outlet Steam Temperature app.	162	°C
Cooling Water	Feed water	

LP steam by-pass valve

Inlet Steam Pressure	5.8	bara
Inlet Steam Temperature	240	°C
Inlet Steam Flow	30.6	t /h
Outlet Steam Pressure	3.0	bar a
Outlet Steam Temperature app.	143	°C
Cooling Water	Feed water	

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STEAM TURBINE GENERATOR

1	**Type**	K 9 V	
a	Manufacturer		ABB generation
b	Type		GTL 1200 GC
c	Number of poles (Pair)		2(1)
d	Protection class		54
e	Characteristic generator curve no.		TT/1 , TT/4
f	Rated apparent power at design conditions	MVA	64.7
g	Rated power factor (lagging)	cos phi	0.85
h	Rated voltage	kV	11
i	Voltage variation range at full load	%	+5 to -5
j	Rated current	A	3396
k	Rated frequency	Hz	50
l	Rated speed	rpm	3000
m	Efficiency at 100% base load and power factor 0.8	%	98.48
n	Stator winding - cooling medium	-	Air
o	Max. outlet temperature of cooling medium	°C	80
p	Rotor winding - cooling medium	-	Air
q	Max. outlet temperature of cooling medium	0C	85
r	Pressure of cooling medium	bar (g)	-
s	Synchronous reactance saturated, Xq	%	

G. FEEDWATER SYSTEM

The function of the feedwater system is to provide boiler feedwater to the followings;

Feeding of the HP and LP feedwater

Feeding feedwater to the attemperator sprays for the HP and LP by-pass system.

The feedwater system design flow is based on the heat balance for the MCR condition including spray water for Steam Turbine by-pass operation.

The HP/LP feedwater pumps are sized with 10% margin on head

loss. **Boiler Feed Pump**

Type	horizontal centrifugal pump
Serial no	99042871
Number of pumps	6
Model no	80*65SS 14M
Capacity (HP/LP)	HP 54 M^3/hr. LP 17 M^3/hr
Speed	2980 rpm
Design temperature	41◦c
Fluid handled	feed water
TDH(HP/LP)	957 M/ 267 M
Power(BHP)	206.85 Kw
HTP	152.48 bar g
Weight	5190 kg
Make	HYOSUNG-EBARA CO ltd
Oil	AWT-32

Motor

Type	3D squirrel cage induction motor
Frame	400
Power	240 Kw
Poles	2
Voltage	6600 V
Current	24.9 A
Frequency	50 Hz
Code letter	F
Rating	S1
Efficiency	93.5%
cos D	0.900
Insulation class	F
Amb temperature	50◦C
Temp rise	70◦C
Space heater	1D, 240 V, 238 W
Bearing (DE/NDE)	NU217MC4+6217C4
Total weight	2800 Kg
Serial no	00525RMHO28004

Manufacturing date	2000, 06
Make	HYUNDAI

Ammonia/ Hydrazine dosing

Ammonia solution tank

Type	vertical cylindrical
Capacity	300 L

Hydrazine solution tank

Type	vertical cylindrical
Capacity	300 L

Ammonia dosing pump

Type	metering pump
Capacity	5.0 L/hr @ 20.7 bar g
Make	LIQUID DYNAMICS
M.A.W.P	3000 bar at 100◦C
MIN.D. metal temp	20 F
Serial no	024477
Seal material	E.MAX 170 F MIM -50 F
Membrane material	E.MAX 170 F MIM -50 F
Recommended refill pressure	2400 Psi

Agitator

Model	8641-99
Power	0.25 HP
Voltage	240 V
FLA	2.4
INS class	F
Enc	TEFC
Frame	56C
Duty	continuous
Speed	960 rpm
Frequency	50 Hz
SF	1.0
Max Ambient	50◦C
Bearing	6023

H. CLOSED COOLING WATER SYSTEM

The function of the circulating water system is to provide cooling water to the main condenser to condense turbine exhaust steam for reuse in the turbine cycle and to the closed cooling water coolers including G/T inlet air chillers to remove heat loads from various plant components.

Technical data

A) **Aux. C.W booster pump**

Motor

Model	HK165SR259FB
Frame	160L
Duty	cont
Type	HK-50
Bearings(drive/opposite)	6309ZZC3/6309ZZC3
Enclosure	IP54
Code	G
Insulation class	F
S.F	1.0
Nema design	B
Power(KW/HP)	15/20
Poles	4
Voltage	415 V
Current	28.8A
Frequency	50 Hz
Nema nominal efficiency	88.5%
Speed	1465 rpm
Max ambient	50◦C
Ref no	0F114083-002
Weight	143 Kg
Make	

Pump

Type	horizontal centrifugal pump
Model no	HES 150-200
Serial no	9904243-1
Capacity	260 M^3/hr
TDH	10 M
Speed	1450 rpm
Power	9.6 Kw
Design temperature	29◦C
HTP	11.8 bar
Fluid handled	sea water
Total weight	323 Kg
Bearing	6307
Make	HYOSUNG-EBARA CO ltd

I. AUXILIARY COOLING WATER SYSTEM

The function of the closed cooling water system is to remove the waste heat from the components of various Plant equipment and rejects it through the CCW coolers.

Design Basis

The system is designed to remove heat from the components in a safe, reliable, and economical manner with minimal vibration and noise. There are separated two (2) closed cooling water systems for simple cycle operation and combined cycle operation.

The closed cooling water system continuously supplies demineralized (passivated) quality water as a cooling medium for the Plant equipment in the closed loop cooling system.

Cooling water is supplied to the following equipment.

A) Simple cycle cooling GT
generator cooler GT lube
oil coolers Hydraulic
starting oil coolers
Air compressor coolers

B) Combined cycle cooling
Sampling cooler
ST generator air cooler
ST lube oil coolers
Water box priming pump coolers

Technical data

A) Simple cycle closed cooling water pump

Type	: Horizontal, centrifugal
Quantity	: Two (2) set
Serial no	: 9904243-5
Capacity	: 510 m^3/hr
Speed	: 1485 rpm
Design temperature	: 40◦c
Fluid handled	: demineralized water
Model no	: HES 200-330

J. CONDENSATE POLISHING UNIT (CPU)

The condensate polishing system treats OTSG feed water and provides feed water quality suitable for it‟s use.

The CPU package consists to 2 x 100% condensate polishing vessels 1x100%, back washing pump, and powdex coating system.

Condensate polishing system

1) Condensate polisher inlet quality

	Normal Quality	Startup or Inleakage
- Suspended Solids, ppb	1000	2500 – 5000
- TDS (Less NH_3), ppb	1000	2000
- Reactive SiO_2, as SiO_2, ppb	<100	100 – 500
- Total Fe, as Fe, ppb	<100	100 – 500
- Total Ca, as Ca, ppb	<50	50 – 100
- Na, as Na, ppb	25	50
- Cation Conductivity, □s/cm	3	3 – 5
- PH	8 – 9.4	8 – 10

2) Condensate polisher outlet quality

	Startup or Inleakage	Normal Quality
Suspended Solids, ppb	5	90% removal (2)
TDS (Less NH_3), ppb	25	90% removal up to pH 9.6
Reactive SiO_2, as SiO_2, ppb	10 (4)	90% removal up to pH 9.6 or 20ppb whichever is greater
Total Fe, as Fe, ppb	5	90 % removal
Total Ca, as Ca, ppb	2	90% removal up to pH 9.6
Na, as Na, ppb	5 (4)	90% removal up to pH 9.6 or 10 ppb whichever is greater
Cation Conductivity, □s/cm	0.1	0.2

K. WASTE WATER SYSTEM

The function of waste water system is to collect oily wastewater and chemical wastewater, into the waste water drain tank separately.

The collected wastewater will be delivered to the oil separator or wastewater treatment system on-shore, which is supplied by others before effluent to discharge.

STG or GTG lube oil will be drained to the lube oil drain tank for inspection or maintenance.

Design Basis

Waste water characteristics.

Description	Characteristic	Source	Collect tank capacity	Disposal
Oily wastewater	Oily water	Equipment drainage	120m3	Oil separator
T/R drain wastewater	Oil or oily water	Transformer equipment	-	Oil separator
Chemical wastewater	Chemical	Equipment chemical cleaning	50m3	W/T plant
Lube oil drain waste water	Lube Oil	Lube oil tank	12m3	Lube oil tank or disposal to on-shore

The oily waste water system included the following

pumps **Oily waste water pumps:**

- Oily wastewater pump	:	60m3/hr x 45mh x 2 sets
tag no	:	ED-M-PP02-B
serial no	:	6050
capacity	:	60 cu.m/hr
speed	:	1480 rpm
design temperature	:	32□c
fluid handled	:	sea water
type	:	horizontal centrifugal
model no	:	GMC 100D
TDH	:	32 m
Power	:	8 Kw
Hydro test pressure	:	3.8 bar g
Total weight	:	272 Kg
Bearings	:	6308/6308
Manufacturer	:	HYOSUNG EBARA CORPORATION
Year of manufacture	:	Sep 2000

L. PLANT ELECTRICAL SYSTEM

The plant generates power at 11KV and evacuates power to 220kV switchyard from each of generator step-up transformer on barge through over-headlines. There are three step up transformers

1. GST#1- 11KV/11KV/220KV-120MVA Three winding transformer
2. GST#2-11KV/11KV/220KV -120 MVA Three winding transformer
3. SST -11KV/220KV -70MVA Two winding transformer

GST is three winding transformer with input from two gas turbine generator at LV side (11KV) and output at HV side (220KV). SST is two winding transformer with Input from steam turbine generator at 11KV side and output of 220KV at HV side.

Also the 11KV is stepped down to 6.6KV through Unit Auxiliary transformers UAT#1 and UAT#2 for the plant auxiliary power. 6.6KV is used for running the Boiler feeder pumps and chillers during plant operation and also stepped down to 415V through Auxiliary transformers AT#1, AT#2, AT#3 and AT #4 for the plant auxiliary.

Design Criteria

The system parameters for utility are detailed below

System	Fault level	System Earthling
220kV, 50Hz, 3ph, 3wire	31.5kA/1sec	Solid earthling (BIL;950kV)
11.0kV, 50Hz, 3ph, 3wire	50kA/3sec	Neutral earthed through NGTR(<10A)
6.6kV, 50Hz,3ph, 3wire	20kA/1sec	Low Resistance through NGR (1200A)
415V, 50Hz, 3ph, 4wire	50kA/1sec	Solid earthling

The system/equipment are designed as per the following:

Motors/System	Voltage	System Earthing
Motors above200kW	6.6kV	Low Resistance
Motors 1kWup to 200KW	415V	Solid
Motors below1KW	240V	Solid
Controls for MCC UPS	110VAC	Solid
supply Illumination	110VAC	Earthed
System	240VAC	Solid
Space heater for panel /motor 55kw& above	240VAC	Solid
DC system	110VDC	Unearthed

M.V Switchgear

M.V switchgear is composed of vacuum circuit breaker (VCB) for 6.6KV motors and power feeding to 415V common

MCC and on-shore, control/metering instruments, integrated digital relays for protection, etc.

L.V switchgear is composed of four (4) common MCC, each of them having incoming air circuit breaker (ACB), MCCB for outgoing feeders, control/metering instruments, etc.

DC / UPS system

Battery backed D.C system consisted of redundant battery chargers and two battery banks are provided.
For critical loads redundant feeders with auto-changeover scheme is provided.
Some of the loads also require a secure A.C supply for its operation. For these loads, station DC fed inverter system, generally known as uninterrupted power supply (UPS) is provided for the followings;

- DCS
- Communication system
- Control, protection system etc.

Lighting system

Lighting system is designed to provide appropriate illumination for the plant in all times considering the nature of work to be carried out.
The power supply for lighting systems shall be derived from the following sources.

- Normal A.C system
- Emergency lighting system (DC)
- Battery backed exit lighting

Fluorescent lamps are used for offices, switchgear room, etc. High-pressure sodium vapor lamps & metal halide and LED lamps shall be used for high bay indoor area and outdoor area respectively as appropriate.

Grounding & lightning protection

The grounding & lightning system in general cover the followings;
- System neutral grounding
- Equipment grounding for personnel safety
- Lightning protection

All metallic, non-current carrying parts of all apparatus such as transformers, switchgear panels, control & protection panels, cable trays, crane rails, steel structures, etc. are bounded with grounding system.

Power supply to on-shore

For on-shore plant, the followings are provided from the barge;
6.6KV redundant feeders through interconnecting cable support
415V emergency power in redundant feeders through interconnecting cable support

Power Transformers GST 1 & GST 2

Rating	: 3 phase / 120 MVA
Voltage	: 220/11/11 KV
Capacity HV/LV1/LV2	: 120/60/60
Cooling	: ONAN/ONAF
BIL (KVP)	: 1050/75/75
Frequency	: 50 HZ
Connection & Symbol	: Star/Delta/Delta – Ynd11d11
Neutral Grounding	: HV solidly grounded
Type of Conservator	: Air Cell type (COPS)
Type of tank	: Conventional type with bolted cover
Type of tap changer	: Off Circuit tapping switch
Cooling Equipments	: Radiator with fans
Type of bushing	: HV – 245 KV OIP Condenser bushing LV 1 & LV 2 – 17.5 KV Porcelain bushing HV neutral – 36 KV porcelain bushing
No load loss	: 90 KW
No load current	: 1 %
Noise level	: 85 dB
Load losses	: 340 KW
Temperature rise	: Oil – 35 deg.c & Winding – 45 deg.c
Voltage variation	: + 5 to – 5 % of HV – Switch

Power Transformer SST

Rating	: 3 phase / 70 MVA
Voltage	: 220/11 KV
Capacity HV/LV	: 70
Cooling	: ONAN/ONAF
BIL (KVP)	: 1050/75
Frequency	: 50 HZ
Connection & Symbol	: Star/Delta – Ynd11
Neutral Grounding	: HV solidly grounded
Type of Conservator	: Air Cell type (COPS)
Type of tank	: Conventional type with bolted cover
Type of tap changer	: Off Circuit tapping switch
Cooling Equipments	: Radiator with fans
Type of bushing	: HV – 245 KV OIP Condenser bushing LV – 17.5 KV Porcelain bushing HV neutral – 36 KV porcelain bushing
No load loss	: 46 KW
No load current	: 1 %
Noise level	: 85 dB
Load losses	: 260 KW
Temperature rise	: Oil – 35 deg.c & Winding – 45 deg.c
Voltage variation	: + 5 to – 5 % of HV – Switch

Unit Auxiliary Transformers UAT 1 & UAT 2

Rating	: 3 phase / 18.5 MVA
Voltage	: 11/6.9 KV
Capacity HV/LV	: 18.5
Cooling	: ONAN/ONAF
BIL (KVP)	: 75/7 5
Frequency	: 50 HZ
Connection & Symbol	: Delta/Star – Dyn1
Neutral Grounding	: LV through neutral grounding resistor
Type of Conservator	: COPS
Type of tank	: Conventional type with bolted cover
Type of tap changer	: On load tap changer, Make – Easun-MR 2 X V III 350 D 10.19.1n W, 19 position with MA 2 motor driven mechanism
Cooling Equipments	: Radiator with fans
Type of bushing	: HV – 17.5 KV Porcelain bushing LV – 17.5 KV Porcelain bushing LV neutral – 17.5 KV porcelain bushing
No load loss	: 15 KW
No load current	: 1 %
Noise level	: 85 dB
Load losses	: 130 KW
Temperature rise	: Oil – 55 deg.c & Winding – 60 deg.c
Voltage variation	: + 10 to – 12.5 % of HV – OLTC

Auxiliary Transformers AT 1, AT 2, AT 3 & AT 4

Type	: 3 phase / Cast resin moulded transformer
Rating	: 2.5 MVA
Voltage HV/LV	: 6.6/0.413 KV
Frequency	: 50 HZ
Type of tap changer	: No voltage tap link (+/- 2.5 % X 2)
Tap Voltage	: F 6.93 / 6.765, R 6.6 / 6.434 / 6.27 KV
Winding Connection	: Dyn11
Cooling method	: AN
% Impedance	: 10.7 (IEC tolerance)
Temperature rise	: Primary winding – 70 deg.c Secondary winding – 90 deg.c
Winding Insulation class	: Primary Voltage – BIL 60 KV
Noise level	: 70 dB
No load losses	: 5.6 KW
Load Losses	: 19 KW

List of Onshore and Offshore AC Equipments

	Location	Total no	Each capacity	Total capacity in TR	Type	Make
1	Barge control room	1	8	8	package	CARRIER
2	Rack room	2	8,11	19	package	CARRIER,BLUE STAR
3	Roof top	1	20	20	package	CARRIER
4	Remote i/o panel	4	2	8	ducting split	BLUE STAR
5	Pump house -PLC	1	2	2	split	VOLTAS
6	Switch yard	3	2	6	split	VOLTAS
7	Work shop building(mech)	1	2	2	split	VOLTAS
8	DM plant	3	2	6	split	VOLTAS
9	Ware house	3	2	6	split	VOLTAS
10	Security building	6	2	12	split	VOLTAS
11	Energy meter room	1	2	2	split	VOLTAS
12	Nox panel	2	1.5	3	window	VOLTAS
	Total	**29**		**94**		

	Location	Total no	Each capacity	Total capacity in TR	Type	Make
1	Barge I & C room	1	2	2	split	VOLTAS
2	Gas skid	1	2	2	split	VOLTAS
3	MCC room	3	2	6	split	VOLTAS
4	6.6 kv room	3	2	6	split	VOLTAS
5	O & M building server room	1	2	2	split	VOLTAS
6	Naptha enclosures	4	2	8	split	VOLTAS
7	Battery bank room	1	2	2	split	VOLTAS
8	Ware house office room	1	2	2	split	VOLTAS
9	DM plant office room	1	2	2	split	VOLTAS
10	Work shop (elec & inst)	2	2	4	split	VOLTAS
	Total	**18**		**36**		

O& M Building

	Location	Total no	Each capacity	Total capacity in TR	Type	Make
1	Ground floor	5	5.5	5.5	CENTRALIZED	CARRIER
			17	17	CENTRALIZED	CARRIER
						CARRIER
			5.5	5.5	CENTRALIZED	CARRIER
			17	17	CENTRALIZED	CARRIER
						CARRIER
2	1 st floor	5	8.5	8.5	CENTRALIZED	CARRIER
			5.5	5.5	CENTRALIZED	CARRIER
			8.5	8.5	CENTRALIZED	CARRIER
			5.5	5.5	CENTRALIZED	CARRIER
			8.5	8.5	CENTRALIZED	CARRIER
3	2 ND floor	1	17	17	CENTRALIZED	CARRIER
	Total		**98.5**	**98.5**		

M. BLACK START DG SET

Black start DG set is a diesel engine driven generating unit. This is used for plant start up and auxiliary supply during grid failure leading to complete plant blank out. The unit is connected to 415 V CMCC 1 and supplies power to CMCC 1 and CMCC 2 through bus tie. There is a facility to extend power supply to onshore 415 V MCC for DM plant, Fuel Handling and plant lighting load.

Rating	1500 KW, 415 V, 1500 rpm, 50 HZ
Manufacturer	Mitsubishi
Diesel Engine	
Model	S16R – PTA
Type	Four cycle, water cooled, turbo charged
Output	Standby 2131 HP
No of cylinders	V – 16 cylinders
Speed	1500 rpm
Bore x Stroke	170 mm X 180 mm
Displacement	65.37 litre
Compression ratio	14.0: 1
Break mean effective pr	20.2 Kg/cm2
Rotating direction	Counter clockwise (flywheel side)

N. PLANT CONTROLS AND INSTRUMENTATION

Gas Turbine Control System

GE has provided many gas turbines to many customers with Simplex and Redundant gas turbine control systems which have been produced by Woodward.

Micro Net plus is the gas turbine control system which was supplied by GE. It is the latest in long line of electronic control system platform used to perform speed, load and process control for all types of prime movers. The standard Micro Net I/O modules are available to build up a custom control system for any type or any size of application.

The Micro Net plus control system is a flexible, state-of-the-art digital control
System designed specifically for prime mover control applications such as:

- Gas Turbine control
- Steam Turbine control
- Hydro Turbine control
- Diesel and Gas Engine control

System Features

Micro Net control system consists of Hardware and software parts:

Hardware parts:

- Chassis and slots
- Power supply units
- Motorola CPU5200 Processor
- HMI (Human machine Interface)
- I/O modules and FTM‟s (Field Termination Modules)
- Fibre-optic switch
- RIO – Remote I/O Panel
- LIO – Local I/O Panel

Software Parts:

- GAP – Graphical Application Program
- Watch windows
- Coder
- Application Manager
- Servlink OPC server
- Control Assistant

O. PLANT FIRE FIGHTING SYSTEM

The plant fire protection system consist of hydrant system, high velocity water spray system for transformers, fire detection and alarm system, CO2 fire fighting system for rack room and control room and portable extinguishers. The system is designed by M/S Agni Heavy Engineering Limited. Addressable Fire protection & detection system of Notifier is provided for entire Barge and semi addressable for remaining part of the Plant.

Emergency Fire Pump

Make	: Kirloskar Brothers limited
Model	: 6 UP4
Capacity	: 273 m3/hr
Total head	: 70 m WC
Shutoff head	: 72 m WC
Power required at duty point	: 76.57 KW
Efficiency	: 70%
Recommended minimum flow	: 100 m3/hr
NPSH required	: 3.5 m
Type of cooling	: Self cooling
Type of lubrication	: Grease
Type of pump	: Horizontal split casing centrifugal pump
No of stages	: Single
Type of coupling	: Spider coupling
Direction of rotation from driving end	: Clockwise
Diesel engine	
Manufacturer	: Cummins India Limited
Type	: Mechanical (Air less) direct injection, 4 Stroke cycle and cold starting type, Turbo Charged
Model	: NT-495-F1
Design standard	: BS:5514
No of cylinders	: 4
RPM	: 1500
BHP at rated rpm	: 127 BHP
Engine starting details	: 24 V electrical start
Fuel consumption	: 25 litre / hr
Fuel consumption at 150 % of rated	: 31 litre / hr
Type of cooling	: Water cooled with heat exchanger
Fuel tank capacity	: 200 litre
Battery	: 4 X 12 V – 180 ah capacity

P. START UP VACUUM SYSTEM

Start-up Vacuum Pump

Manufacturer	NASH KOREA
Type	Liquid Ring
Quantity	1
Hogging capacity at 10 inch HgA	595 Sm3/hr
Evacuation volume	450 m3
Hogging suction pressure	254 mm HgA
Suction temperature	33 deg.c
BHP	42 KW
No of stage	1
Speed	590 rpm
Hogging time required to reduce suction pr from atmosphere pr to 254 mm HgA	20 min
Discharge pr	Atmospheric
Material of construction –	
Casing	A48
Shaft	KSD 3752 SM45C (EQ. A576)
Rotor	A536
Pump direction of rotation	C.W from driver end
No of bearings	2
Type of bearing	Roller
Type of lubrication	Grease
Pump-Motor coupling	Flexible
Seal water requirement –	
Flow	7.95 m3/hr
Temperature	35 deg.c

Moisture separator

Dimension	O.D 390 mm X 1375 mm H
Material	KSD 3503 (EQ. A283)

Silencer

Size	O.D 460 mm X 1830 mm H
Type	Vertical
Material	KSD 3503 (EQ. A283)

Motor

Rating	45 KW
Poles	10 poles
Rotor Type	Squirrel Cage
Enclosure	Totally enclosed
Cooling method	Fan cooled
Frequency	50 HZ
Phase	3
Insulation class	F
Temperature rise at full load	90 deg.c
Voltage	415 V
No load current	75 A

Full load current	113 A
Starting current	670 A
Speed	590 rpm
Efficiency –	
At 1/2 load	85 %
At 3/4 load	87.5 %
At full load	88 %
Power Factor –	
At 1/2 load	54 %
At 3/4 load	60 %
At full load	63 %

Q. STEAM TURBINE DEAERATING CONDENSER

Heat duty at rated condition	473800000 KJ/hr
Heat duty at HP/LP bypass valve operation	669700000 KJ/hr
Maximum dissolved oxygen content	7 ppb
Condenser pressure	0.077 bara
Condensate temperature	40.8 deg.c
Manufacturer	HHI
Quantity	1
Applied design code	HEI
Operating life	30 years
Reference condition –	
Barometric pressure	1.004 bara
Relative Humidity	75 %
Ambient air temp	31 deg.c
Cooling water temp (sea water)	29 deg.c
Maximum makeup water	30 m3/hr
Type	Deaerating condenser
Hotwell capacity –	
From normal level to low level	3 minutes
From normal level to bottom	5 minutes
No of passes	2

Performance at rated condition

LP turbine exhaust –	
Flow	225619 m3/hr
Enthalpy	2266.7 KJ/Kg
Gland steam condenser drain –	
Flow	245 Kg/hr
Enthalpy	196.2 KJ/Kg
Steam Jet air ejector drain –	
Flow	300 Kg.hr
Enthalpy	193.5 KJ/Kg
Condensate leaving condenser –	
Flow	226164 Kg/hr
Enthalpy	170.8 KJ/Kg
Temperature	40.8 deg.c

Pressure	0.077 bara
Circulating water –	
Inlet temperature	29 deg.c
Temperature rise	8 deg.c
Inlet pr	2.2 bara
Flow	14565 m3/hr
Specific gravity	1.02
Head Loss	4.5 m

Performance at 100 % bypass

HP bypass –	
Flow	194040 Kg/hr
Enthalpy	2770.9 KJ/Kg
Temperature	162 deg.c
Pressure	5 bara
LP bypass –	
Flow	65812 Kg/hr
Enthalpy	2745.3 KJ/Kg
Temperature	143 deg.c
Pressure	3 bara
Condenser neck spray from CEP outlet –	
Flow	5983 Kg/hr
Enthalpy	191.2 KJ/Kg
Condensate leaving condenser –	
Flow	266236 Kg/hr
Enthalpy	191.3 KJ/Kg
Temperature	45.7 deg.c
Pressure	0.0993 bara
Cooling water inlet temp	29 deg.c
Cooling water outlet temp	40.3 deg.c

Tubing	
Diameter	25.4 mm
Thickness mm (BWG)	0.5 (25), 0.7 (22)
Effective surface area	5137 m2 (5292 m2)
No of tubes	7852 (8088)
- 25 BWG	7952
- 22 BWG	136
Effective length	8200 mm
Tube velocity	2.2 m/s
Cleanliness factor	0.9
Water box velocity (inlet)	1.964 m/s