2 X 125MW 50Hz COMBUSTION TURBINES, TWO GAS FIRED HRSG and TWO 75MW STEAM TURBINES

DETAILED OVERVIEW OF PLANT

1.0 INTRODUCTION

The plant equipment we are proposing is technically sized at operating at 386 MW (gross output) when operating at 50 Hz and on a choice of either Natural Gas, #2 Diesel oil and/or Heavy Fuel Oil.

The plant will consist of a twin plant with 2 X 125 MW General Electrical FRAME 9e combustion turbines, which are considered to be the best engines in the world and designed for the longest possible usage. In addition, the two turbines will have two fired HRSGs and two 75MW steam generators, usually known as twin 2-2-2 configuration. This would make the proposed plant a highly flexible design and one of the most energy and environmentally efficient plants possible.

The GE turbines have been selected and offered for several reasons:

- The best of European proven design with the longest possible life cycle.
- Suitable for operation in the harshest climate.
- Highest possible efficiency of any single or combined cycle power production method.

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- Suitable for use with NG, #2 diesel and/or HFO with the extreme limits as indicated in this document.
- State of the art controls and protective devices such as relays, monitors etc.
- Equipment, which has a process of continuous improvements to their products to ensure the plant has access to the best technologies now and in the future.
- Environmental reduction equipment to ensure compliance with World Bank standards.

**SITE ENVIRONMENTAL CONDITIONS (to be confirmed)**
Location: To be determined but assumed to be a hot climate.
Altitude: Up to 1000M
Max. Ambient Temperature: 45 deg C.
Min. Ambient Temp: 4.4 deg C.
Sun Temp. 80 deg C.
Humidity (Average of daily maximum): 77%
Mean rainfall in one day: 79mm
Maximum rainfall in one day: 138.3mm
Average wind velocity: 5.55 – 18.5 Km/hour
Relative humidity: 47%
Atmospheric pressure: 957 mbar
2.0 EQUIPMENT

1. COMBUSTION TURBINES

A. Design Conditions

<table>
<thead>
<tr>
<th>Site Conditions</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Design Ambient Dry Bulb Temp./Relative Humidity</td>
<td>50°C/ 90%</td>
</tr>
<tr>
<td>Maximum Ambient Dry Bulb Temp./</td>
<td>60°C</td>
</tr>
<tr>
<td>Minimum Ambient Dry Bulb Temp./Relative Humidity</td>
<td>-20°C / 60%</td>
</tr>
<tr>
<td>Barometric Pressure</td>
<td>1 BAR</td>
</tr>
<tr>
<td>Elevation</td>
<td>300M above sea level</td>
</tr>
<tr>
<td>Location</td>
<td>As required</td>
</tr>
<tr>
<td>Water Level</td>
<td>N/A – Evaporative Cooling Tower</td>
</tr>
<tr>
<td>Seismic Criteria</td>
<td>1997 UBC; Zone 1</td>
</tr>
<tr>
<td></td>
<td>Soil Profile Type Spc.</td>
</tr>
<tr>
<td></td>
<td>Importance Factor = 1.00</td>
</tr>
<tr>
<td></td>
<td>Occupancy Category III</td>
</tr>
<tr>
<td>Wind Design</td>
<td>1997 UBC; Exposure C</td>
</tr>
<tr>
<td></td>
<td>Importance Factor = 1.00</td>
</tr>
<tr>
<td></td>
<td>Basic Wind Speed = 70 mph</td>
</tr>
<tr>
<td></td>
<td>Summer Prevailing – SSW</td>
</tr>
<tr>
<td></td>
<td>Winter Prevailing - NW</td>
</tr>
<tr>
<td>Annual Rainfall</td>
<td>1.2M</td>
</tr>
<tr>
<td>Maximum Rainfall Rate</td>
<td>10cm/hr and 5 Minute Duration</td>
</tr>
<tr>
<td>Snow Load</td>
<td>10 psf; importance factor 1.1</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Circulating Cooling Water</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Design Condenser Inlet Temp. @ Design Ambient Temp.</td>
<td>20°C</td>
</tr>
<tr>
<td>Maximum Condenser Inlet Temp. @ Maximum Ambient Temp.</td>
<td>33°C</td>
</tr>
<tr>
<td>Minimum Condenser Inlet Temp. @ Minimum Ambient Temp.</td>
<td>4°C</td>
</tr>
<tr>
<td>Auxiliary equipment Inlet Temp.</td>
<td>5°C Above the Condenser Inlet Temperature</td>
</tr>
</tbody>
</table>
## Fuel

<table>
<thead>
<tr>
<th>Primary</th>
<th>Natural Gas, #2 Diesel, HFO</th>
</tr>
</thead>
<tbody>
<tr>
<td>Preheating</td>
<td>Included for Natural Gas</td>
</tr>
<tr>
<td></td>
<td>IP Economizer used for Heat</td>
</tr>
<tr>
<td></td>
<td>Source Heat to 185°C</td>
</tr>
<tr>
<td>Gas Fuel Booster Compressor</td>
<td>Not Included. Assumes Gas Fuel Available @36BAR at Terminal Point</td>
</tr>
</tbody>
</table>

## B. Combustion Turbine Equipment/System Definition

<table>
<thead>
<tr>
<th>Gas Turbine</th>
<th>Two (2) FRAME 9E Units</th>
</tr>
</thead>
<tbody>
<tr>
<td>Exhaust System</td>
<td>No Bypass Stack Included</td>
</tr>
<tr>
<td>Starting Means</td>
<td>Static Start Shared LCI</td>
</tr>
<tr>
<td>Air Filtration</td>
<td>Self-cleaning</td>
</tr>
<tr>
<td>Inlet Air Cooling</td>
<td>Not included</td>
</tr>
<tr>
<td></td>
<td>Provisions for future fogger installation</td>
</tr>
<tr>
<td>Compressor/Turbine Cleaning</td>
<td>Off-line &amp; On-line Compressor Water Wash</td>
</tr>
<tr>
<td>Emissions Control</td>
<td>Dry Low NOx (9 ppm)</td>
</tr>
<tr>
<td>Natural Gas Unfired</td>
<td></td>
</tr>
<tr>
<td><strong>Heat Recovery Steam Generator</strong></td>
<td>Two(2) Natural Circulation</td>
</tr>
<tr>
<td><strong>(HRSG)</strong></td>
<td>Reheat Units</td>
</tr>
<tr>
<td>Pressure Levels</td>
<td>Three (3)</td>
</tr>
<tr>
<td>Supplemental Firing</td>
<td>Fired</td>
</tr>
<tr>
<td>Emissions Control (SCR)</td>
<td>SCR to achieve 3.5 ppm Nox for Unfired and fired HRSG.</td>
</tr>
<tr>
<td>CO Catalyst Spool Place</td>
<td>Included, provision for future installation of CO Catalyst</td>
</tr>
<tr>
<td>Stack Closure Damper</td>
<td>Included</td>
</tr>
<tr>
<td>Economizer Recirculation</td>
<td>Included</td>
</tr>
<tr>
<td>Economizer Tubes</td>
<td>Included: heavy wall</td>
</tr>
<tr>
<td>24” x 24” HRSG Access Doors</td>
<td>Included</td>
</tr>
<tr>
<td>HRSG Stack Lifting Bean</td>
<td>Included: one (1) per HRSG</td>
</tr>
<tr>
<td>HRSG Double Drain Valves</td>
<td>Included</td>
</tr>
<tr>
<td>FAA Stack Lighting</td>
<td>Included on both HRSGs</td>
</tr>
<tr>
<td>Steam Vent Silencers</td>
<td>Included: 105 dBA Design Level</td>
</tr>
<tr>
<td>Steam Cycle</td>
<td>Three (3) Pressure Reheat</td>
</tr>
</tbody>
</table>

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<table>
<thead>
<tr>
<th>Component</th>
<th>Specification</th>
</tr>
</thead>
<tbody>
<tr>
<td>Deaeration</td>
<td>Deaerating Condenser</td>
</tr>
<tr>
<td>Total Plant Bypass Capability</td>
<td>Cascaded bypass @ 100% Unfired flow &amp; 100% Pressure per HRSG</td>
</tr>
<tr>
<td>HP/IP</td>
<td>100% Unfired flow &amp; 110% Pressure per HRSG</td>
</tr>
<tr>
<td>LP</td>
<td></td>
</tr>
<tr>
<td>Economizer Bypass</td>
<td>Not Included</td>
</tr>
<tr>
<td><strong>Steam Turbines</strong></td>
<td><strong>Two (2) 75 MW Units</strong></td>
</tr>
<tr>
<td>Configuration/Code</td>
<td>Two Casing; Factory Assembled, Combined HP/IP; Field Assembled, Double Flow LP; D11</td>
</tr>
<tr>
<td>Steam Inlet Conditions</td>
<td>1900 psis, 1050°F / 1050°F</td>
</tr>
<tr>
<td>Last Stage Bucket (LSB)</td>
<td>40 in.</td>
</tr>
<tr>
<td>Exhaust Flow</td>
<td>Down</td>
</tr>
<tr>
<td>Back Pressure</td>
<td>1.5 in. HgA@59°F unfired condition</td>
</tr>
<tr>
<td>Generator</td>
<td>Two (2) Gas Turbine Units and One (1) Steam Turbine Unit</td>
</tr>
<tr>
<td>Model</td>
<td></td>
</tr>
<tr>
<td>Gas Turbine Generators</td>
<td>Packaged</td>
</tr>
<tr>
<td>Steam Turbine Generator</td>
<td>Unpackaged</td>
</tr>
<tr>
<td>Cooling</td>
<td>Hydrogen</td>
</tr>
<tr>
<td>Terminal Voltage</td>
<td>18 kV</td>
</tr>
<tr>
<td>Frequency</td>
<td>50 Hz</td>
</tr>
<tr>
<td>Power Factor (pf)</td>
<td>0.85 Lagging</td>
</tr>
<tr>
<td>Generator Excitation</td>
<td>EX21 Static Auxiliary Bus Fed</td>
</tr>
<tr>
<td>Generator Seal Oil System</td>
<td>Scavenging Design</td>
</tr>
<tr>
<td><strong>Enclosures</strong></td>
<td></td>
</tr>
<tr>
<td>Gas Turbine Generator</td>
<td>Outdoor</td>
</tr>
<tr>
<td>Steam Turbine Generator</td>
<td>Indoor</td>
</tr>
<tr>
<td>HRSG</td>
<td>Outdoor</td>
</tr>
<tr>
<td><strong>Cooling System</strong></td>
<td></td>
</tr>
<tr>
<td>Gas Turbines/Steam Turbine/ Generators/Auxiliaries</td>
<td>Closed H₂O to H₂O</td>
</tr>
<tr>
<td>Steam Turbine Condenser</td>
<td>Lake Water Evaporative Cooling Tower</td>
</tr>
</tbody>
</table>
## Control Systems

<table>
<thead>
<tr>
<th>Plant</th>
<th>Mark VI and Distributed Control Systems (DCS)</th>
</tr>
</thead>
<tbody>
<tr>
<td>CT and Steam Turbine Generators</td>
<td>SPEEDTRONIC™ Mark VI (TMR)</td>
</tr>
<tr>
<td>HRSG Burner Management</td>
<td>Included</td>
</tr>
<tr>
<td>Continuous Emissions Monitoring</td>
<td>Not Included</td>
</tr>
<tr>
<td>Systems (CEMS)</td>
<td></td>
</tr>
<tr>
<td>Emergency Power Capability</td>
<td>Included (Emergency transformer for critical services)</td>
</tr>
<tr>
<td>Black Start Capability</td>
<td>Included</td>
</tr>
<tr>
<td>Generator Breaker</td>
<td>Low Side Included</td>
</tr>
<tr>
<td>Freeze Protection</td>
<td>Included</td>
</tr>
</tbody>
</table>

### C. Plant Operation

<table>
<thead>
<tr>
<th>Operating Mode</th>
<th>Base Loaded, 52 Start-ups per Year (weekend shutdowns)-40-60% Capacity Factor</th>
</tr>
</thead>
<tbody>
<tr>
<td>Plant Control Philosophy</td>
<td>Remote Manual Start-up/Shutdown; Automatic Operation Under Load</td>
</tr>
<tr>
<td>Remote Monitoring and Load Change Capability</td>
<td>Included through supplied RTU</td>
</tr>
<tr>
<td>Remote Dispatching Capability</td>
<td>Not Included</td>
</tr>
</tbody>
</table>

### D. Expected Noise Levels

| Gas Turbine-Generator Near Field  | 93 dBA |
| Steam Turbine-Generator Near Field | 95 dBA |
2. HEAT RECOVERY STEAM GENERATOR

The design is based on a Heat Recovery Steam Generators (HRSG) and will use the heat exchanger tube bundles in this design are arranged horizontally whilst the exhaust gas path is vertical.

The horizontal tubes are supported by tube plates and the pre-assembled bundles are top supported by the top beams of the main steel structure. The vertical HRSG has either a so-called “cold” casing concept or can be externally insulated. The choice is subject to the gas turbine exhaust temperature; in case of high temperatures the casing is internally insulated and lined with sheeting whereas external insulation is applied for gas turbines with lower exhaust gas temperatures. The exhaust stack is located above the tube bundles and supported by the main steel structure.

The “counter flow” evaporator design and proven experience with Natural Circulation provides the customer with the benefits of this type i.e.:

- Free expansion of headers and tubes
- Easy access to headers and bends for inspection
- Easy repair and maintenance

The heating surfaces are pre-assembled in the factory into complete modules including the tube support plates. No large cranes are necessary for site erection because the tube bundles are hoisted into place using a hydraulic jacking system placed on top of the main steel structure.

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The HRSG is based on Doosan Heavy Industries & Construction Co., Ltd or similar manufacturer.

3. STEAM TURBINE

The proposed design is based on using two approximately 100 MW Siemens SST Steam Turbines or similar by General Electric or other manufacturer. The SST is a single casing, double flow steam turbine with approximately 100 MW of power output. It can be used as an entire drive or as the low-pressure module of a multiple-casing turboset, directly driven or geared. This turbine, with its capacity to operate over a wide range of speed and power, is ideal for large steam volume flows. It represents a solution based on long experience of industrial steam turbines.

Design Concept

- Single casing, double flow condensing steam turbine
- Proven, modular and compact design
- Two steam inlets, customized steam path
- Throttle controlled with or without bleeds
Often used as low pressure part of the casing in multiple applications

The inlet flows into the turbine by means of two tangential inlets to equalize thermal and blade stress. Emergency stop valves and control valves are installed in the steam inlet pipes. The steam flows tangentially into the inner casing and then axially to both exhausts. The customized design of the steam path allows exact adjustment to surpass general physical limitations of the last stage blades. Double end drive is available, if required, e.g. for booster pump drive. Power output and typical optimized corresponding speed can vary between 10 MW at 15,000 rpm and 75 MW at 4,500 rpm. Both inner and outer casing are horizontally split for easy access. The guide blades are fastened in the inner casing or blade carriers to allow easy and rapid replacement.

Scope of Supply
The industrial steam turbine is available as a package which includes generator (or another driven machine), gearbox, and all other auxiliary systems, normally mounted on a base frame. We can deliver each of our machines with the configuration that fits best to your needs. The single casing, modular package design allows a wide variety of configurations to satisfy individual customer needs in the most economical way.

The SST turbines are designed for elevated installation on a turboset foundation or a separate base frame to a condenser or exhaust piping. One common condenser or two separate condensers can be used.

Technical Data
All data are approximate and project-related.
- Power output: approximately 100 MW
- Rotational speed: up to 15,000 rpm
- Inlet steam pressure: up to 30 bar / 435 psi
Inlet steam temperature: up to 400 °C / 750 °F
Bleeds: up to 2, at various pressure levels

Exhaust steam conditions
Condensing: up to 1 bar / 14.5 psi

Benefits
- Fast and early layout planning
- Short delivery time due to extensive pre-design
- Compact design minimizes space requirements of installation
- Easy access to mechanical components facilitates maintenance
- Remote control for simple operation
- High reliability, availability and efficiency

4. STEAM TURBINE GENERATOR

The proposed design is based on the application of two General Electric, Siemens SGen-A series (or similar) (air cooled), one for each of the three combustion turbines and one for the steam turbine.

Rated power for each of the three turbines: 75MW
Nominal Rated power for each of the steam turbines: 75MW
Rated frequency 50Hz
Rated voltage 15 kV 
Rated current As needed 
Rated power factor 0.85 
Rated speed 3000r/min 
Cooling mode air-cooled 
Excitation mode static excitation 
Apparent power: 165 MVA to 310 MVA 
Efficiency: up to 98.94 % 

SGen- A series / air-cooled generators will be provided using either Totally Enclosed Water to Air-Cooled (TEWAC) or Open Air-Cooled (OAC) systems (to be selected during detailed design).

Technical features

- Can be operated unattended
- Reduced complexity / higher reliability with fewer auxiliaries:
  - No gas storage or gas generation, etc.
  - No elaborate seals or seal oil system
- Ease in erection, commissioning and maintenance in the field
- Inertias which can enhance transient stability in remote/rural areas
- Open or closed cooling circuit option to accommodate varying site conditions and customer preferences
- High efficiency filters
- Pressurized shaft seals to enhance cooling air cleanliness
- Spring mounted stator to minimize vibration transmission to foundation
- Uniform temperatures over the entire stator and rotor lengths through:
  - Symmetrical ventilation of the stator and rotor
  - Indirectly cooled stator winding with excellent heat transfer
  - Radially ventilated stator core
  - Directly, radially cooled rotor winding
5. DESIGN BASIS FOR AUXILIARY EQUIPMENT

Instrumentation & Controls

- PLC-based control system for the turbines, HRSG and auxiliary systems will be included with the scope.

- Instrumentation & Controls Engineering

- Engineering documents and drawings shall consist of the following:

  - Process and Instrument Diagrams
  - Analog/Digital Functional Logic Diagrams
  - Instrument List
  - Input/Output List
  - SRS (System Requirements Specification)
  - Instrumentation Location Drawings
  - Instrumentation Detail Drawings
  - Motor List
  - ISA Data Sheets for Instruments

I & C Systems and Equipment

Control Mode
The start up and shut down, running monitor and control, events handling of the units are realized through a future central control room.

Each unit is provided with a backup panel on which are mounted a few of necessary backup monitoring instruments, I&C signals, TV sets, etc. On the control board are mounted a few of the emergency buttons and switches necessary for the safe shutdown of the turbine and the generators.

The equipment in the fuel oil room and the air compressor room is controlled through DCS.

The auxiliary systems such as the makeup water treatment system, the wastewater treatment system, the common pump room, etc., are controlled centrally respectively in their local control room. The makeup water treatment and the wastewater treatment systems plants are controlled through PLC.

Control Level

The monitor and control of normal operation, the alarm, shutdown and event handling can be performed in the central control room. The unit start-up can be performed automatically in the central control room with the assistance of a small amount of local operations and inspections. Each unit only needs one lead and two assistant operators in the central control room.

The monitor and control of the units are mainly performed through DCS, which has the functions of the Data Acquisition System (DAS), the Analog Control System (MCS), The Sequence Control System (SCS), the Furnace Safety Supervisory System (FSSS), the Bypass Control System (BPC), the heat-supply station control and the Electrical Control System (ECS). The operators use the keyboards, mice and CRI’s of the DCS operator station to monitor, adjust and control the units. Once the DCS fails in communication or all the operator stations fail, the operators can shutdown the unit by emergency means.
The design of MCS includes the perfect function of the coordination control between turbines and the design of SCS gives priority to subgroup function control.

It is planned to connect those measuring points which are comparatively centralized, such as the metal temperatures, the turbine metal temperatures, the generator winding temperatures, the generator core temperatures, etc., with the DCS via remote I/Q. It is also planned to include the controls of the monitor of the auxiliary supply systems, and the equipment in the circulating water pump house, the air compressor room, the fuel oil room and the heat-supply station in the common DCS system via remote I/Q. Bridges are used to connect the remote I/Q with the DCS of the unit, and the monitor and control of them can be performed on the DCS operator station of the units. However, normally the DCS operator station of common systems is responsible for the monitor ad control of the remote I/Q, and the DCS of the units are locked out for software. So the operator of the unit can monitor but cannot control of the remote I/Q on their station. When the DCS operator station of common systems fails or is under maintenance, the monitor and control would be transferred to the DCS operator station of the units.

The turbines are controlled through the Digital Electro Hydraulic control system (DEH), which is provided completely with the turbine proper and the hardware should be compatible with the DCS. The main function of the DEH includes turbine rotary speed control, load control, over-speed protection, stress monitoring, etc., The DEH communicates with the DCS for information exchange. However, the critical protection and interlocking signals between the DCS and DEH are realized through hardwiring. If it is allowable, the function of DEH can be incorporated in the DCS.

The Turbine supervisory Instruments System (TSI) are provided completely with the turbine proper to monitor continuously the important parameters of the turbine and produce alarms or trip signals when these monitored parameters exceeds their allowable limits.
Emergency Trip System (ETS), with independent redundant controllers, is provided completely with the turbine proper to protect the turbine safety.

The three units share one set of TDM. The Expert system software is used to acquire the real time data of TSI and analyze the possible failure. TDM has its communication port with SIS.

Traditional alarm system independent of the DCS is provided. A few windows are provided for emergency and important alarms. The DCS has its communication port with SIS. The main monitored points in the assistant workshops can communicate with the DCS and the SIS by the communication ports.

The air conditioner automatic control system, fire alarm and fighting system in the Plant are provided.

It is considered to purchase the DCS equipment from a well-developed, well-known and well-experienced supplier.

PLC shall purchase from a well-known supplier in the world and compatible with others in the Plant.

Smart type transmitters are provided.

Actuators to be provided should be integrated to the technology introduced. The binary instrument should be imported production.

**Plant Control**

The power plant is controlled and supervised from the Operator Interface System (OIS). The OIS workstation and the common and engine-wise central control panels are located in the control room where all the main supervision of the plant takes place. All actions necessary for the normal operation, such as start and stop of the engine generator sets, load increase and load reduction are activated and
supervised via the OIS workstation, using a mouse, keyboard and display. The
operator can also supervise key data from the plant such as various temperatures
and pressures as well as measurements of electrical variables such as generator
output, voltage and frequency.

OIS includes the following features:

- Graphical process status displays,
- Process trend displays as a free combination of six (6) measured values
  such as pressures, temperatures, speed, energy output, etc
- An alarm banner in the uppermost part of the displays informs about the
  latest occurred alarm.

The active alarm list informs the operator of possible problems in the process.
The OIS system contains four WOIS workstations with applicable software and
printers for printing reports and alarms. The workstations are backed up with
Uninterrupted Power Supply (UPS)

APPENDIX A
GENERAL ELECTRIC FRAME 9E
COMBUSTION TURBINES

FRAME 9E

GENERAL ELECTRIC FRAME 9001E (9E) COMBUSTION TURBINE

The MS9001E (9E) gas turbine is GE's 50 Hz workhorse. With more than 350 units, it
has accumulated over eight million hours of utility and industrial service, many in
arduous climates ranging from desert heat and tropical humidity to arctic cold.

Originally introduced in 1978 at 105 MW, the 9E has incorporated numerous component
improvements. The latest model boasts an output of 126 MW and is capable of
achieving more than 52 percent efficiency in combined cycle.

Whether for simple cycle or combined cycle application, base load or peaking duty, 9E
packages are comprehensively engineered with integrated systems that include
controls, auxiliaries, ducts and silencing. They are designed for reliable operation and
minimal maintenance at a competitively low installed cost. Like other GE E-class
technology units, the Dry Low NO\textsubscript{x} combustion system is available on 9E, which can achieve NO\textsubscript{x} emissions under 15 ppm when burning natural gas.

With its state-of-the-art fuel handling capabilities, the 9E accommodates a wide range of fuels including natural gas, light and heavy distillate oil, naphtha, crude oil and residual oil. Designed for dual-fuel operation, it can switch from one fuel to another while running under load. It can also burn a variety of syngases produced from oil or coal without modification. This flexibility, along with its extensive experience and reliability record, makes the 9E well suited for Integrated Gasification Combined Cycle (IGCC) projects.

In simple cycle, the MS9001E is a reliable, low first-cost machine for peaking service, while its high combined cycle efficiency gives excellent fuel savings in base load operations. Its compact design provides flexibility in plant layout as well as the easy addition of increments of power when a phased capacity expansion is required.

### Simple Cycle Performance 50Hz

- **Output**: 126.1 MW  
- **Heat Rate**: 10100 Btu/kWh (10653 kJ/kWh)  
- **Pressure Ratio**: 12.6:1  
- **Mass Flow**: 922 lb/sec (418 kg/sec)  
- **Turbine Speed**: 3000 rpm  
- **Exhaust Temperature**: 1009 °F (543 °C)  
- **Model Designation**: PG9171E

### Combined Cycle Performance 50Hz (S109FA) 50Hz (S209FA)

<table>
<thead>
<tr>
<th></th>
<th>50Hz (S109FA)</th>
<th>50Hz (S209FA)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Net Plant Output</strong></td>
<td>193.2 MW</td>
<td>391.4 MW</td>
</tr>
<tr>
<td><strong>Heat Rate</strong></td>
<td>6570 Btu/kWh</td>
<td>(6930 kJ/kWh)</td>
</tr>
<tr>
<td></td>
<td>6480 Btu/kWh</td>
<td>(6835 kJ/kWh)</td>
</tr>
<tr>
<td><strong>Net Plant Efficiency</strong></td>
<td>52.0%</td>
<td>52.7%</td>
</tr>
<tr>
<td><strong>GT Number &amp; Type</strong></td>
<td>1 x MS9001E</td>
<td>2 x MS9001E</td>
</tr>
</tbody>
</table>

**TWO NEW UNUSED GE FRAME 9e’S AVAILABLE TRI FUEL -**

- Year of manufactured: 2007
- Working hours working? NONE - these are NEW - unused.

<table>
<thead>
<tr>
<th>FUEL</th>
<th>Standard</th>
<th>Standard</th>
<th>Standard</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>TYPE</strong></td>
<td>Natural Gas</td>
<td>Distillate Oil #2</td>
<td>Heavy Oil</td>
</tr>
<tr>
<td><strong>OUTPUT</strong></td>
<td>126100 kW</td>
<td>123300 kW</td>
<td>115300 kW</td>
</tr>
<tr>
<td><strong>HEAT RATE (LHV)</strong></td>
<td>10650 kJ/kWh</td>
<td>10730 kJ/kWh</td>
<td>10960 kJ/kWh</td>
</tr>
</tbody>
</table>
HEAT CONS
(LHV)  |  1343×106 kJ/h | 1328×106 kJ/h | 1263.7×106 kJ/h
---|---|---|---
EXHAUST TEMP | 543 | 543 | 520
SHAFT SPEED | 3000r/min | 3000r/min | 3000r/min

Scope of Supply

1. Gas turbine generator package

2. Mechanical
   - Gas Turbine
   - Air Compressor
   - Combustors
   - Turning and Reduction Gear
   - Air Inlet facilities (Filters and Ducts)
   - Exhaust facilities (Ducts, Silencer) (less exhaust elbow)
   - Starting Motor system
   - Dual Fuel Combustors
   - Lube and Control Oil System
   - Closed Circuit Cooling Water system
   - Atomizing and Cleaning system
   - Instrument Air system
   - Enclosures, including HVAC, Fire-fighting, Electrical Switchboard for:
     - Gas turbine unit (external and internal)
     - Gas turbine auxiliaries
     - Electrical Switchgear
     - Control
     - Closed Circuit auxiliaries
     - Water Injection
   - GT Supervision, Control and Protection Systems
   - Fire Fighting (detection and protection) system
   - Gas Detection system
   - Thermal Insulation and Lagging
   - Compressor Washing and Cleaning facilities

3. Electrical
   - Electrical Generator, auxiliaries and related equipment (Circuit Breaker, Grounding Switch, Bus duct, Neutral Grounding cubicle, etc.)
   - Starting Motor system

4. Instrumentation & Controls
   - On board Instrumentation
   - Instrument Panels and Junction boxes
   - Control, Protection and Monitoring Panels
   - MMI (man-machine interface)

5. Miscellaneous
   - Special Tools
   - Anchor Bolts and Plates
   - Stair and Ladders
   - Steel Structures

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6. Special Tools and Maintenance equipment (for the above mentioned machinery)

7. Operating and Maintenance Manuals

**PERFORMANCES: SIMPLE CYCLE**

The following Gas Turbine performances:

**ISO Conditions**

With reference to the following conditions:
- Ambient Pressure: 1013 mbar
- Ambient Temperature: 15 °C
- Relative Humidity: 60%
- Gas Turbine Inlet/Exhaust Pressure drop: 89/127 mm H2O

The **Plant Performances at Generator terminals** when the plant is operated at GT new and clean conditions shall be:

**Base Load**

- Output Power: **126 MW**
- Heat Rate: **10096 BTU/KWh (10650 kJ/kWh)** (natural gas)

**Gas Turbine and Auxiliaries**

**Gas Turbine**

**General description**

The PG9171 (E) GT package was developed by a GE/ EUROPE authorized licensee with the frame 9E as basic equipment and within the license agreement with General Electric Co. (USA).

The PG9171 (E) is a single shaft, high efficiency gas turbine for power generation in 50 Hz grids, suitable for simple cycle and combined cycle application. The engine is designed for 3000-rpm nominal speed, to be directly coupled to a two-pole synchronous electric generator. This gas turbine unit includes all features and design solution coming from the operating experience of the MS9000 family, whose evolution has brought to the PG9161 (E) one of its highest reliability value. The PG9161 (E) unit consists of three compartments, one housing the auxiliaries, one the gas turbine itself, and the last one housing the exhaust plenum. Each compartment is equipped with access doors for easy site inspection and maintenance. The rotor is a single shaft assembly consisting of one compressor rotor joined to one turbine rotor by a flanged joint, and lays on three journal bearings (two elliptical and one tilting pad type). Two thrust bearings; one Kingsbury type (loaded) and one tilting pad type (unloaded) are also provided.

**Compressor**

The compressor rotor consists of 17 stages with 12.3/1 overall compression ratio. The compressor rotor consists of 15 wheels, shrunk onto a forged shaft (rotor stages 2nd to 16th), two stub shafts (1st and 17th rotor stages), 16 tie bolts and stator/rotor blades. The stationary blades
are assembled into two half rings (diaphragms) for each stage; the diaphragms are fitted into the compressor casing. The rotating blades are fitted on the discs by dove-tail roots and fixed by means of pins. The compressor external casing is totally made of gray cast iron. The compressor front portion contains the Inlet Guide Vanes (IGV) device that allows modulating the inlet flow during start up and optimize performance at part load operation. Air bleed ports provide cooling air for 1st and 2nd turbine stages (stationary and rotating buckets). The compressor end portion that discharges the air mass flow into the combustion chamber contains the compressor diffuser, devoted to eliminate flow swirl and then improve diffuser efficiency.

**Combustion Section**

The PG9161 (E) combustion system has been designed in order to ensure reliability, durability and flexibility, even in case of using different fuels. The combustion system is contained in a carbon steel casing, which is part of the compressor-combustor shell and provides housing for combustor wrapper, combustions chamber assemblies, fuel nozzles, spark plug ignitors, UV flame detectors, cross flame tubes, transition piece. The combustion takes place in 14 combustion chambers, circumferentially arranged around the machine axis. The hot gas flows from the combustion chambers toward the turbine section via 14 "S" shaped transition pieces. This special arrangement ensures a good mix between the film cooling air and the combustion gases, thereby optimizing the gas temperature pattern at the first turbine stage inlet. The combustion section consists of Hastelloy cylinders joined together with corrugated rings, which lead the cooling air film along the wall, thus improving cooling. The combustion chambers are installed and removed without lifting the combustor casing cover, in order to facilitate inspection and to reduce the inspection time. The transition pieces connecting the combustors to the turbine inlet are manufactured with NIMONIC 263 alloy, which yields good anti-corrosion properties together with high cracking resistance, and is furthermore easily weld able for maintenance at site, without needing heat treatment. Spark plug ignitors, located in the 10th and 11th combustion chambers, are used to ignite the fuel/air mixture; the remaining chambers are ignited through cross flame tubes that provide connection between every two adjacent combustors. Two ultraviolet (UV) flame scanners, located in the 4th and 5th combustion chamber are provided to detect ignition during start up.

The fuel is injected into the combustion chambers through fuel injectors, one per each combustion chamber, which are provided for single fuel operation.

**Turbine**

The 3-stage turbine rotor is constituted by 3 discs, forged in alloy steel and coupled each other by bolted connections.

All rotating blades are precision cast, and are attached to the wheels by straight, axial-entry, multiple-tang dovetails that fit into matching cut-outs in the rims of the wheel. The turbine stationary blades (nozzles) are precision cast according to the following table:

- first stationary row 18 segments x 2 vanes Cooled
- second stationary row 16 segments x 3 vanes Cooled
- third stationary row 16 segments x 4 vanes Uncooled

The cooling flow for the cooled profiles is bled from suitable compressor stages (see compressor section). The space between 2nd and 3rd rotor wheels is also cooled by compressor bleed air. Nozzle diaphragms are attached to the inside of both 2nd and 3rd stage nozzle segments. These diaphragms prevent air leakage past the inner sidewall of the nozzles and the turbine rotor. A turbine shroud is included, whose main function is to provide a cylindrical surface for minimizing bucket tip clearance leakage (a secondary function is to provide a high thermal resistance between the hot gases and the comparatively cool shell). This reduces the shell-cooling load and allows controlling the shell diameter and roundness and turbine clearances. The shroud segments are maintained in the circumferential position by radial pins from the shell. Joints between shroud segments are sealed by interconnected tongues and
grooves.

**Exhaust Frame and Exhaust Plenum**

The flanged end of gas turbine shell is bolted to exhaust frame. On the structural point of view, the frame consists both of an outer and an inner cylinder, interconnected by radial struts. The GT end journal bearing is supported from the inner cylinder. The exhaust frame, fabricated in ASTM A435 carbon steel, receives gas flow from the GT diffuser, and is connected to the exhaust plenum by flexplate expansion joint. The exhaust plenum consists of a box, open at one side and welded to its own base. It is fabricated in carbon steel, lined with 409 SS chromium steel sheet. Thermocouples for measurement of exhaust gas temperature and for transmitting the values to the GT control system are located in the final part of the exhaust plenum.

**Gas Turbine Control System (SUMIVAC)**

**Gas Turbine Auxiliaries**

The Gas Turbine includes the following auxiliaries:

- Oil Systems (Lubricating Oil system, Control Oil system)
- Inlet Air system (Filtration system, Inlet Air duct, etc.)
- Exhaust Gas facilities (silencer, vertical stack)
- Fuel system (dual fuel: natural gas, diesel oil)
- Compressor Washing system
- Enclosures including HVAC, Fire-fighting, etc.
- Lube Oil closed circuit Cooling Water system
- Instrument Air system
- Fire Fighting system (CO2 and dry chemical type)
- Gas Detection system
- Electrical equipment (Generator Neutral Grounding Cubicles, Generator Protection)
- Board, Low Voltage Distribution Board, Power Control Centre, Motor Control Centers, DC Power system, Uninterruptible power supply, Cables, Induction Motors, Grounding system, Vibration monitoring and protection system, Indoor Lighting system).

**Electrical Generator**

The electrical Generator is a synchronous machine, ventilated in open air-circuit, with air exchanger shell & tube cooler provided. Characteristics of generator as follows:

NOTE: Closed Cooling Cooler not included. Special Design for climate conditions

Rated Output: 163 MVA**
Rated Terminal Voltage (± 5%): 11.000 V
Rated Phase Current: 7400 A
Rated Power Factor: 0.85
Frequency: 50 Hz
Speed in RPM: 3000
Design Temperature: As per IEC 34
Insulation: Class F
Maximum Air Inlet Temperature: 40°C
Generator Excitation System: Static type
Response Ratio: >1.9 s-1
Power Consumption at rated load: _290 kW
** The Generator is oversized to allow upgrade to PG-1971-E at first overhaul.

**Electrical Systems**

**GAS TURBINE Generator**

The GT generator, endowed with related auxiliary systems and devices, shall be rated to operate continuously at full load.

The excitation system shall be static type with automatic and manual Automatic Voltage Regulator (AVR) system.

The main functional generator characteristics shall be as listed below:

- **Rated Capacity**: 139 MW (ambient air at 40°C)
- **Power factor**: 0.85
- **Voltage**: 11 kV
- **Frequency**: 50 Hz
- **Rotation speed**: 3000 RPM
- **Phases**: 3
- **Class of insulation**: F
- **Standard IEC**: at 835 m.

**Step-up Transformer**

- **Nominal power**: 6 MVA
- **Nominal ratio**: 15/6.9 kV
- **Winding connection**: Dyn11
- **Nominal impedance**: 8 %
- **Cooling**: ONAF/OFAF
- **Phases**: 3
- **Frequency**: 50 Hz
- **Standard IEC**

**Generator Protection System**

The generator protection system shall be made in two separated and redundant sections (Channel A and Channel B), and shall be supplied by two independent line feeders.

**General Features**

- The automatic synchronizing device shall be three-phases type, to avoid connection of the generating equipment to the HV grid unless all phases of HV supply are energized;
- Maximum voltage, minimum voltage and minimum frequency electric protections shall
be provided to disconnect the generator from the system when a system abnormality occurs that could result in an unacceptable deviation from nominal voltage or frequency at the point of supply;

- An unbalance current operation protection shall be provided to disconnect the generator from the HV system, in the event of loss of one or more phases of HV supply to the installation.
- In the event of failure of any supplies to the protective equipment, audible and visual alarm shall be provided. Alarm operation shall be followed by automatic timed disconnection of the plant.

In the following table the generator protection to be provided are listed:

<table>
<thead>
<tr>
<th>CHANNEL A</th>
<th>CHANNEL B</th>
</tr>
</thead>
<tbody>
<tr>
<td>Stator grounding protection 100% (earth fault)</td>
<td>Stator grounding protection 90% (earth fault)</td>
</tr>
<tr>
<td>Rotor grounding protection</td>
<td></td>
</tr>
<tr>
<td>Over voltage (maximum voltage/flux protection)</td>
<td>Over voltage (maximum voltage/flux protection)</td>
</tr>
<tr>
<td>Out of step</td>
<td>Out of step</td>
</tr>
<tr>
<td>Minimum voltage</td>
<td>Minimum voltage</td>
</tr>
<tr>
<td>Reverse power</td>
<td>Reverse power</td>
</tr>
<tr>
<td>Over frequency (1) Minimum impedance</td>
<td>Over frequency (1) Minimum impedance</td>
</tr>
<tr>
<td>Underbalance load</td>
<td>Underbalance load</td>
</tr>
<tr>
<td>Minimum frequency Generator overload</td>
<td>Minimum frequency Generator overload</td>
</tr>
<tr>
<td>Loss of Mains (unbalance current operation protection)</td>
<td>Loss of Mains (unbalance current operation protection)</td>
</tr>
<tr>
<td>Over voltage (maximum voltage/flux protection)</td>
<td>Over voltage (maximum voltage/flux protection)</td>
</tr>
<tr>
<td>Differential generator protection Loss of field</td>
<td>Differential generator transformer protection</td>
</tr>
<tr>
<td>Loss of field</td>
<td>Minimum frequency</td>
</tr>
<tr>
<td>Voltage underbalance</td>
<td></td>
</tr>
<tr>
<td>Died machine</td>
<td></td>
</tr>
<tr>
<td>Generator breaker opening failure</td>
<td></td>
</tr>
<tr>
<td>Ground fault on 6 kV side of generator transformer</td>
<td></td>
</tr>
<tr>
<td>Overload transformer</td>
<td></td>
</tr>
</tbody>
</table>

(1) Over frequency protection realized on the gas turbine protection system.

**Generator Neutral Grounding System**

The generator neutral shall be then earthed via a single-phase, 50 Hz, dry-type transformer. The secondary transformer winding shall be shunted by suitable grounding resistor. The transformer shall be sized to give an equivalent resistance to the capacitive reactance of the unit connected system, and rated for short time overload; the secondary resistor shall be a cast-grid type rated for short time (20 s) loading. All generator neutral grounding components shall be installed into a suitable enclosure for outdoor service.

The generator neutral grounding system shall consist of the following major components:

- Neutral grounding transformer
- Secondary resistor
• Neutral grounding disconnecting switch
• Neutral grounding bus
• Terminal blocks;
• Enclosure for outdoor service.

For additional Information:

PowerCom International
Tel: 866.327.8099