

Gas Turbine: 7FA+e with 171MW ISO output

General Electric PG7241FA

Unit 1

Gas Turbine-298390 (Location: USA)

Natural Gas fired

Nominal Output 171 MW ISO

LHV Heat Rate 9360 btu/kwh

Starting: Static Start

Inlet Air Filtration: Self Cleaning 2 Stage Pulse

Exhaust System Axial Exhaust

Emission Control Gas-Dry Low NOx

Outdoor Design

On-Base Accessory Compartment Lagging

Off-Base Acoustic Enclosure for Turbine Compartment

Acoustic Barrier Wall around Exhaust Diffuser

Generator-338X531 (Location: USA)

Model 7FH2

Hydrogen Cooling

KVA rating 213,000

Frequency 60 Hz

Power Factor (PF) 0.85 Lagging

Terminal /Voltage 18.0 KV

Generator Excitation EX2000P-Static Bus Fed

Off-Base Load Coupling Compartment Enclosure

Control System

Turbine-Generator SPEEDTRONIC Mark VI in PEECC

- All auxiliary equipment for Unit 1 is stored in USA

Gas Turbine: 7FA+e with 171MW ISO output

General Electric PG7241FA

Unit 2

Gas Turbine-298391 (Location: USA)

Natural Gas fired

Nominal Output 171 MW ISO

LHV Heat Rate 9360 btu/kwh

Starting: Static Start

Inlet Air Filtration: Self Cleaning 2 Stage Pulse

Exhaust System Axial Exhaust

Emission Control Gas-Dry Low Nox

Outdoor Design

On-Base Accessory Compartment Lagging

Off-Base Acoustic Enclosure for Turbine Compartment

Acoustic Barrier Wall around Exhaust Diffuser

Generator-338X532 (Location: USA)

Model 7FH2

Hydrogen Cooling

KVA rating 213,000

Frequency 60 Hz

Power Factor (PF) 0.85 Lagging

Terminal /Voltage 18.0 KV

Generator Excitation EX2000P-Static Bus Fed

Control System

Turbine-Generator SPEEDTRONIC Mark VI in PEECC

- All auxiliary equipment for Unit 2 is stored in USA

5.1 Gas Turbine Systems

5.1.1 Gas Turbine

Base-mounted PG7241 (FA) 60 Hz gas turbine including:

- Modulating IGV

5.1.2 Combustion System

- Dry Low NOx combustion system
- Combustion system features
 - . Thermal barrier coated liners
 - . Nimonic transition pieces
 - . Reuter Stokes SiC flame detectors
 - . With compressor inlet heating

5.1.3 Fuel Systems

5.1.3.1 Gas Fuel System

- Natural gas only
- Stainless steel gas piping
- Orifice type gas flow measurement system
- Single gas strainer
- Gas fuel temperature < 365F (185C)
- Gas fuel valves on accessory base
- Gas fuel cleaning equipment
 - . Fuel gas scrubber, cyclone type
 - . Duplex absolute separator filter

5.1.4 Lubricating and Hydraulic Systems

5.1.4.1 Pumps

- AC motor driven dual lube oil pumps
- AC motor driven dual hydraulic pumps
 - . Used for jacking oil also
- DC motor driven, emergency lube oil pump
- AC/DC motor driven auxiliary generator seal oil pump

5.1.4.2 Filters and Coolers

- Dual lube oil system filters
- Dual hydraulic oil filters
- Dual lube oil coolers
 - . With 90-10 copper-nickel straight-tubes
- ASME code stamp
 - . Lube oil coolers
 - . Lube oil filters

5.1.4.3 Lube Oil Piping

- 304L stainless steel lube oil feed pipe
- Carbon steel lube oil drain pipe
- Lube system valve stainless steel trim

5.1.4.4 Mist Elimination

- Lube vent demister

5.1.4.5 Oil Reservoir

- With heater for -20°F

5.1.4.6 Instrumentation

- Delta pressure switches for lubrication and hydraulic oil filters
- Lubrication oil header pressure transmitter
- Lubrication oil tank level transmitter
- Lubrication oil filter differential pressure transmitter
- Hydraulic oil supply pressure transmitter

5.1.5 Inlet System

- Inlet system arrangement
 - . Up and forward inlet system arrangement
 - . Inlet compartment supports straddle ductline
- Inlet filtration
 - . Two-stage static filter; prefilter and high efficiency filter
(Contract Change: converted to self-cleaning pulse system)
 - . Filter media (high humidity/corrosive environments)
 - . 50 micron moisture separator
 - . Weather protection on inlet filter compartment
 - . Inlet system differential pressure indicator
 - . Inlet system differential pressure alarm
 - . Inlet filter compartment support steel (Seismic zone 2A, $\leq 100\text{mph}$)
 - . Caged ladder access to inlet filter compartment
 - . Left hand access to inlet filter compartment
 - . Inlet filter compartment interior lighting
- Inlet heating
 - . Bleed heat manifold located in duct
 - . DLN premix turndown inlet bleed heat control
 - . Compressor pressure ratio operating limit bleed heat control
 - . Inlet bleed heat control valve(s)
- Inlet ducting
 - . Inlet silencing
 - . Inlet duct section arrangement per proposed mechanical outline
 - . Inlet expansion joint

- . Inlet 90 degree elbow
- . Inlet transition piece
- . Inlet ducting support steel (Seismic zone 2A, <=100mph)
- . Compressor inlet humidity sensor
- . Compressor inlet temperature thermocouple
- Inlet system atmospheric protection
 - . Zinc rich paint inside and outside of inlet filter compartment
 - . Epoxy overcoat inside and outside inlet filter compartment
 - . Galvanized inlet filter compartment support steel
 - . Zinc rich paint inside and outside of inlet ducting with epoxy top coat inside ducting
 - . Epoxy top coat outside of inlet ducting
 - . Stainless steel inlet silencing perforated sheet
 - . Galvanized inlet ducting support steel

5.1.6 Exhaust System

5.1.6.1 Arrangement

- Exhaust diffuser with an axial exit
- Exhaust expansion joint

5.1.7 Couplings

- Rigid load coupling
- Load coupling guard

5.1.8 Gas Turbine Packaging

- Lagging and enclosures
 - . On-base accessory compartment lagging
 - . Off-base acoustic enclosure for turbine only
 - . Off-base load coupling compartment enclosure
 - . Acoustic barrier wall around exhaust diffuser
- Compartment ventilation, pressurization and heating
 - . Dual turbine compartment vent fans
 - . Dual accessory compartment vent fans
 - . Dual load compartment vent fans
 - . Heated turbine and accessory compartments for humidity control
- Plant arrangement
 - . Turbine designed for installation outdoors
 - . Right hand accessory module
 - . Exterior unit walkways by customer, mounting pads by GE
 - . Interior unit walkways
- Turbine and accessory base painting
 - . Standard primer only
- UBC Seismic Zone 4 (except for inlet and exhaust)
- UBC Seismic Zone 2A for inlet
- Hazardous area classification

- . NEC Class1, Group D, Division 2
- . Turbine compartment
- . Natural gas fuel compartment
- Special features
 - . Dual (metric-English) indicators and gauges
 - . Blank set of nameplates for customer engraving

5.1.9 Fire Protection System

- Fire detection system
 - . Turbine and accessory compartments
- Smoke detection system
 - . Control cab/PEECC
- Compartment warning signs
- CO2 supply system
 - . One low pressure CO2 tank per unit
 - . Tank suitable for 0-120°F (-18 to 49°C)
- Fire protection piping
 - . Turbine and accessory enclosures
- Hazardous atmosphere detectors in turbine and gas fuel compartments
 - . CHx detectors - natural gas compartment
 - . CHx detectors - turbine gas compartment
- Hazardous atmosphere detector readout
 - . CHx

5.1.10 Cleaning Systems

- On base piping for on and offline compressor water wash system
- Water wash skid not included

5.1.11 Cooling Water System

- Cooling system temperature regulating valve

5.1.12 Starting Systems

- Static start
 - . Generator start with inverter/regulator
 - . Static start isolation transformer - Oil filled
 - . Isolation transformer fed from auxiliary bus
 - . 12-pulse, water cooled LCI
 - . Single dc link reactor
 - . Water-to-water heat exchanger, shipped loose

- Rotor turning systems
 - . Turning gear and motor for rotor cooldown
 - . Rotor indexing (borescope inspection)

5.1.13 Miscellaneous Systems

5.1.13.1 Special Systems

- Exhaust frame blowers on turbine compartment roof

5.2 Generator

5.2.1 General Information

- Hydrogen cooled generator with conventionally cooled armature
- Outdoor installation
- 60 Hz generator frequency
- Generator voltage 18.0 kV
- 0.85 power factor (lagging)
- Capability to 1.00 power factor (leading)
- Class .F. armature and rotor insulation
- Class .B. temperature rise, armature and rotor winding
- Generator bearings
 - . End shield bearing support
 - . Elliptical journal bearings
 - . Roll out bearing capability without removing rotor
 - . Insulated collector end bearing
 - . Online bearing insulation check
 - . Offline bearing insulation check with isolated rotor
- Monitoring Devices
 - . Two velocity vibration probes at turbine end, one at collector end
 - . Provisions for key phasor-generator
 - . Provisions for permanent flux probe
 - . Proximity vibration probes
 - . Two probes per bearing at 45° angle
- Generator Field
 - . Direct cooled field
 - . Two-pole field
 - . Finger type amortisseurs

5.2.2 Generator Gas Coolers

- Coolers shipped installed
- Generator gas cooler configuration
 - . Five (5) horizontally mounted simplex coolers
 - . Coolers located in generator base
 - . Cooler piping connections on left side as viewed from collector end
 - . ASME code stamp
 - . Single wall cooler tubes
 - . Victaulic cooler couplings

- . Plate fins
- . Cooling water manifold and isolation valves
- Generator gas cooling system characteristics
 - . Generator capacity with one section out of service 80% with Class “F” rise
 - . TEMA class C coolers
 - . Maximum cooler pressure capability - 125 psi
 - . Coolant 100% fresh water
 - . Fouling factor 0.001
- Generator gas cooler construction materials
 - . 90-10 copper-nickel tubes
 - . Carbon steel tube sheets
 - . Carbon steel waterbox and coupling flanges with epoxy coating
 - . Aluminum cooler tube fins

5.2.3 Generator Lube Oil Systems and Equipment

- Bearing lube oil system
 - . Generator lube oil system integral with turbine
 - . Sight flow indicator
- Bearing lift oil system
 - . Stainless steel lift oil piping and tubing
 - . Lift oil supplied from turbine oil system
- Lube oil system piping materials
 - . Stainless steel lube oil feed pipe
 - . Carbon steel lube oil drain pipe
 - . Welded oil piping

5.2.4 Generator Grounding Equipment

- Neutral grounding equipment
 - . Neutral ground transformer and secondary resistor
 - . Mounted in terminal enclosure
 - . Motor operated neutral disconnect switch

5.2.5 Generator Temperature Devices

- Stator winding temperature devices
 - . 100 ohm platinum RTDs (resistance temperature detector)
 - . Single element RTDs
 - . Grounded RTDs
 - . Nine (9) stator slot RTDs

- Gas path temperature devices
 - . 100 ohm platinum gas path RTDs
 - . Single element temperature sensors

- . Four (4) cold gas
- . Two (2) hot gas
- . GTG-2 (common cold gas)
- Bearing temperature devices
 - . Chromel alumel (type K) thermocouples
 - . Dual element temperature sensors
 - . Two (2) bearing metal temperature sensors per bearing
- Collector temperature devices
 - . 100 ohm platinum RTDs
 - . Single element temperature sensors
 - . Collector air inlet temperature sensor
 - . Collector air outlet temperature sensor
- Lube oil system temperature devices
 - . Chromel alumel (type K) thermocouples
 - . Dual element temperature sensors
 - . One (1) bearing drain temperature sensor per drain

5.2.6 Packaging, Enclosures, and Compartments

- Paint and preservation
 - . Standard alkyd beige primer
- High voltage bushings
 - . High voltage bushings shipped installed
 - . Six (6) ambient air cooled, high voltage bushings
- Generator terminal enclosure (GTE)
- Line-side terminal enclosure
 - . Terminal enclosure shipped separate
 - . Isolated phase bus duct connection
 - . Phase sequence R-C-L when looking at enclosure terminals
 - . Outgoing power connection on right side when viewed from collector end
 - . Lightning arresters
- Neutral terminal enclosure
 - . Neutral terminals integral with line-side terminal enclosure
 - . Neutral tie
- Collector compartment/enclosure
 - . Collector compartment/enclosure shipped separate
 - . Outdoor
 - . Collector/brush holding rigging
- Compartment lighting and outlets
 - . AC lighting
 - . Collector compartment
- Foundation hardware
 - . Generator shims
 - . Generator alignment key(s) - collector end

- . Generator alignment key(s) - turbine end
- . Generator alignment key(s) - axial

5.2.7 Hydrogen Systems and Accessories

- Hydrogen gas manifolds
 - . Auto purge gas purge control manifold
 - . Hydrogen/CO2 control valve assembly
 - . H2 Bottle manifold not provided
 - . CO2 bottle manifold not provided
- Seal oil system
 - . Control unit mounted in collector compartment
 - . Stainless steel seal oil feed pipe
 - . Carbon steel seal oil drain pipe

5.2.8 Electrical Equipment

- Motors
 - . TEFC motors
 - . Coated with antifungal material for protection in tropical areas
 - . High ambient motor insulation
 - . Motor heaters connected to ac power
 - . Extra severe duty motors
 - . Cast iron motor housings
- Heaters
 - . Generator stator heaters
 - . Generator collector heaters

5.2.9 Generator Excitation Systems, Static Components

- Bus fed static excitation with hot backup bridge

5.2.9.1 Excitation Module Features

- Control/monitor/display through TCP
 - . Voltage matching in turbine control system
 - . Power factor controller in turbine control system
 - . VAR controller in turbine control system
 - . Selection of automatic or manual regulator
 - . Raise-lower of the active regulator setpoint
 - . Enter setpoint command
 - . Display field amps
 - . Display field volts
 - . Display transfer volts
- Built-in diagnostic display panel
 - . Automatic voltage regulator (AVR)
 - . Manual voltage regulator (FVR)

- . Automatic and manual bi-directional tracking
- . Reactive current compensation (RCC)
- . Volts per hertz limiter (V/Hz LIM)
- . Volts per hertz protection (24EX) (Backup to 24G)
- . Over excitation limiter (OEL)
- . Offline/online over excitation protection (76EX)
- . Loss of excitation protection (40EX)
- . Bridge ac phase unbalance protection (47EX)
- . Under excitation limiter (UEL)
- . Generator overvoltage protection (59EX)
- . Generator field ground detector trip (64FT)
- . VT failure detector (VTFD) (60EX)
- . Field over-temperature alarm
- . Field ground detector alarm (64FA)
- . Exciter phase voltage imbalance (47EX)
- . Bridge over-temperature (26EX)
- Dual source internal bulk power supply
- Millivolt shunt for field
- Surge protection
 - . VT disconnect and CT shorting switches
 - . Two phase current sensing
 - . Three phase voltage sensing
 - . Single pole dc field contactor/bridge
- Thyristor bridge circuit filtering
- Shaft voltage suppressor circuit (mounted in panel)
 - . Field de-excitation circuit (with field discharge inductor)
 - . Bridge disconnect; ac no load

5.2.9.2 Performance

- 2.0 response ratio and 160% VFFL (100°C) ceiling @ $V_t = 1.0pu$

5.2.9.3 Excitation Enclosure Location

- Installed in LCI/EX compartment

5.2.9.4 LCI Features

- LCI located in LCI/EX compartment
- LCI disconnect switch (89SS)
 - . Located in generator terminal enclosure
- LCI fuse
 - . Located in compartment with LCI

5.2.9.5 PPT Features

- Freestanding oil-filled PPT for outdoor installation

- PPT fed from auxiliary bus

5.2.10 LCI and Exciter Compartment

- LCI/EX compartment

5.2.11 Generator Current Transformers and Potential Transformers

- Current transformers (CTs)
 - . C400 current transformers (CTs)
 - . Line side CTs
 - . CT 19A, C (excitation)
 - . CT 21, 22, 23 (generator differential relay)
 - . Neutral CTs
 - . CT1, CT2, CT3
 - . CT4, CT5, CT6
 - . CT7, CT8, CT9
- Potential transformers (PTs)
 - . Fixed
 - . VT2, generator line side

5.3 Gas Turbine-Generator Controls and Electric Auxiliaries

5.3.1 Control Cab/Packaged Electric and Electronic Control Compartment (PEECC)

- Weatherproof, climate controlled, base mounted enclosure
- Supplemental wall-mounted air conditioner

5.3.2 Gas Turbine Control System Panel Features

- Triple modular redundant (TMR)
- Skid mounted control panel
- Auto/manual synchronizing module with synchronizing check function
- Generator stator overtemperature alarm (49)
- Droop control
- Load limiter
- Purge cycle
- Customer alarm/trip contact for CRT display
- Additional customer input contacts (digital), as available
- Additional customer output contacts (digital), as available
- Provision for analog inputs from customer, as available
- Provision for analog outputs to customer, as available
- Vibration alarm readout and trip
- Electrical overspeed protection

- Constant settable droop
- Power factor calculation and display
- Power factor control
- VAR control
- Manual set point preselected load
- IRIG-B interface (time signal by others)

5.3.3 Local Operator Station

- Commercial grade personal computer
- Color monitor
 - . Table top
 - . 17 in. screen
- Mouse cursor control
- Table top AT 101 keyboard
- Printer
 - . 24 pin dot matrix
- Display in English language
- 50 ft of arcnet cable between gas turbine control system panel and local operator interface <I>/HMI for indoor use
- RS232C two way serial link (MODBUS) via local HMI

5.3.4 Remote Control and Monitoring Systems

- RS232C two way serial link (MODBUS) via remote HMI
- Multi-unit remote HMI
 - . One per site
- Commercial grade personal computer
- Color monitor
 - . Table top
 - . 20 in. screen
- Mouse cursor control
- Table top AT 101 keyboard
- Printer
 - . Printer, color ink jet
- Power 120Vac 60 Hz

5.3.5 Rotor, Bearing and Performance Monitoring Systems

- Performance monitoring systems
 - . Performance monitoring sensors wired to gas turbine control system
 - . Performance calculations in <I>/HMI
- Vibration sensors
 - . Velocity vibration sensors
 - . Proximity vibration sensors
- Bently Nevada 3500 monitor
 - . With local display panel

- . Relay outputs wired to gas turbine control panel
- . Mounted with generator control panel
- Bearing thermocouples
 - . Bearing drain thermocouples
 - . Bearing metal thermocouples
- Borescope access holes

5.3.6 Generator Control Panel

5.3.6.1 Generator Control Panel Hardware

- Mounted in PEECC
- Skid mounted with turbine panel
- DGP with test plug capability
- DGP without ModBus communication interface
- DGP with communication interface
- DGP with IRIG-B interface
- DGP with oscillography capture
- DGP with redundant internal power supply
- Generator breaker trip switch (52G/CS)
- Humidity sensor readout
- Hazardous atmosphere detector readout
- Bentley Nevada vibration monitor(s)

5.3.6.2 Digital Generator Protection System (DGP)

- Generator overexcitation (24)
- Generator undervoltage (27G)
- Reverse power/anti-motoring (32-1)
- Reverse power/anti-motoring (32-2)
- Loss of excitation (40-1,2)
- Current unbalance/negative phase sequence (46)
- System phase fault (51V)
- Generator overvoltage (59)
- Stator ground detection (64G1)/(59GN)
- Generator over/under frequency (81O-1, 81U-1)
- Generator differential (87G)
- Voltage transformer fuse failure (VTFF)

5.3.6.3 Generator Protection Discrete Relays

- Synchronizing undervoltage relay (27BS-1,2)
- Reverse/inadvertent energization protection relay (50RE/86RE)
- Generator differential lockout relay (86G-1)
- Second generator lockout relay (86G-2)

5.3.6.4 Features Integrated Into Gas Turbine Control System

- Gas turbine control system with speed matching, synchronization and check
- Manual synchronization displayed on gas turbine control system <l> / HMI
- Auto/manual synchronizing module displayed on gas turbine control system <l> / HMI
- Load control in gas turbine control system
- Temperature indication for generator RTDs
- Generator voltage matching (90VM)

5.3.6.5 Generator Control Panel Metering

- Generator digital multimeter
 - . VM - Generator volts
 - . AM - Generator Amps: Phase 1, 2, 3 and Neutral
 - . MW - Generator MegaWatts
 - . MVAR - Generator MegaVARs
 - . FM - Generator frequency
 - . MVA - Generator MVA
 - . PF - Generator power factor

5.3.6.6 Generator Control Panel Transducers

- Generator watt/VAR transducer 4-20 mA output for input to TCP (96GG-1)
- Generator TCP/droop control transducer 4-20 mA output (96GW-1)
- Generator watt/VAR transducer 4-20mA output for customer (96GG-2)

5.3.7 Generator Protection

- Generator electrical protection equipment
 - . Ground brush rigging

5.3.8 Batteries and Accessories

- Lead acid battery (these were not supplied previously and GE will provide a credit towards the supply when ordered).
- Single phase battery charger
- Second battery charger
- Battery and charger mounted in the PEECC

5.3.9 Motor Control Center

- MCC mounted in control cab/PEECC
- Tin-plated copper bus-work
- 65 kA bracing
- 480V 60 Hz auxiliary power

5.3.10 Motor Features

- TEFC motors less than or equal to 200 hp
- Coated with antifungal material for protection in tropical areas
- High ambient motor insulation
- Energy saver motors
- Extra severe duty motors
- Cast iron motor housings
- All redundant motors to be lead/lag
- Motor heaters
- . Rated 110/120 volts, 50/60 Hz
- WP motors >200 hp

5.4 Services

- Technical advisory services: approximately \$400,000US credit available towards GE services.
- Documentation
 - 1 set of English language service manuals, including Operation, Maintenance and Parts volumes (CD Only)
- Turbine maintenance tools (1 set per site)
 - . Guide pins (for removal or replacement of bearing caps, compressor casing and exhaust frame)
 - . Fuel nozzle wrenches
 - . Fuel nozzle test fixture
 - . Spark plug electrode tool
 - . Clearance tools
 - . Fuel nozzle staking tool
 - . Combustion liner tool
 - . Bearing and coupling disassembly fixture
- Generator maintenance tools (1 set per site)
 - . Rotor lifting slings
 - . Rotor removal equipment including shoes, pans, pulling devices
 - . Rotor jacking bolts
- Installation equipment
 - . Trunions for generator
 - . Jacking bolts for generator
 - . Foundation/installation washer and shim packs

Amendment 1

Additional Scope Added:

- Self-Cleaning Pulse inlet filter system and 500 lb Hoist
- Backup Generator Protection with function 78
- Power System Stabilizer
- 2nd Breaker Synchronization – serial version (line breaker 52-L)
- Three (3) CTs for the Neutral Side and Three (3) for the line side for the Back Up Generator Protection System
- Function 27TN for both the DGP and the Beckwith M-3425 to provide 100% Stator Ground Fault Protection (in combination with 64G1)
- Add Islanding Mode Operation capabilities, subject to operational restrictions known to Buyer

Amendment 2

Additional Scope Added:

- Clarified that above Islanding Mode Operation was only being added to the Petrobras GTGs #1 & #2
- Replace the GE Standard MODBUS interface with ETHERNET

Typical Equipment Photos



