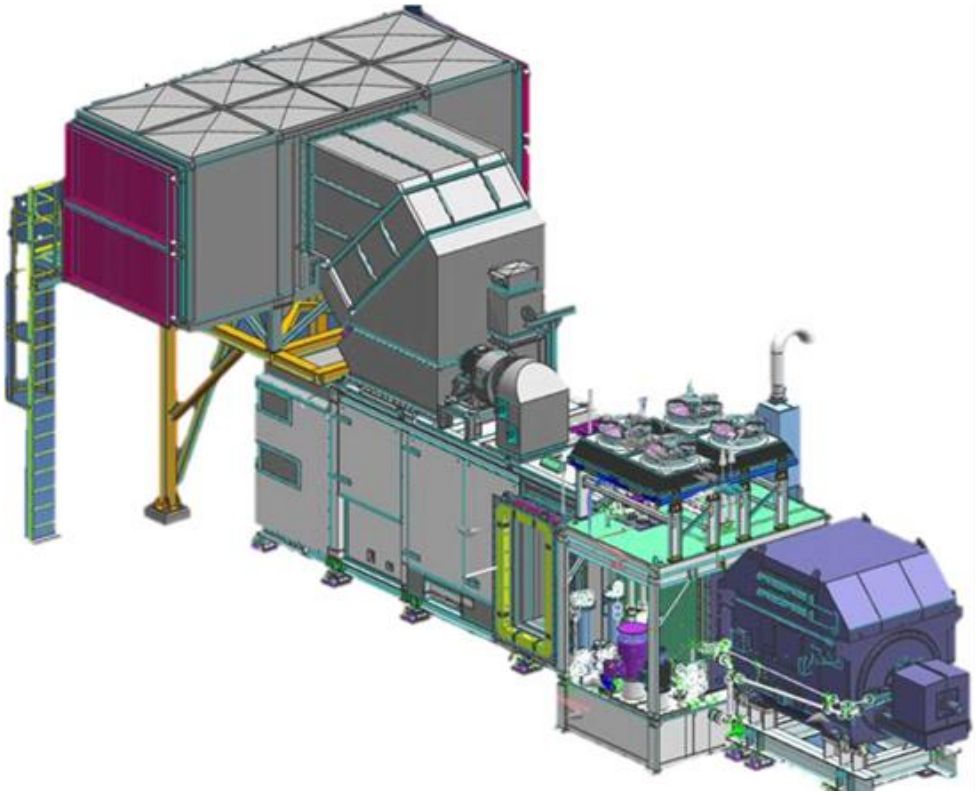
Spirit 12

GAS TURBINE POWER GENERATION SYSTEM

Technical Description



Contents

1. Overview

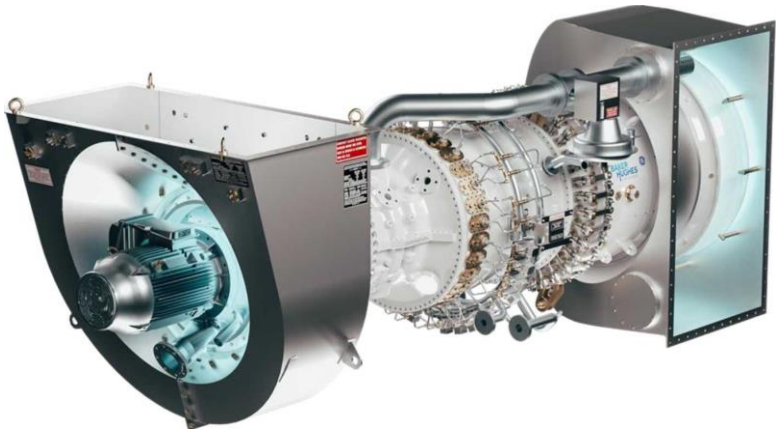
NovaLT12, the driver of Spirit™12, is a high-efficiency, simple cycle, two-shaft, heavy-duty gas turbine designed for
generator drive applications, whose maintenance philosophy is based on modular replacement. The Engine module consists of a Gas Generator and a Power Turbine.

Gas Generator (GG):

- inlet section
- 12-stage, high efficiency, axial flow compressor, with 3 inlet variable-geometry vane
- stages
- annular combustion chamber
- 2-stage high-pressure turbine (HPT) with air-cooled nozzles and buckets.

Power Turbine (PT):

- 2-stage low pressure turbine, with a variable-geometry inlet nozzle that can optimize
- part load operation of the engine
- exhaust section.



Air entering the inlet section of the gas generator is directed into the axial compressor by the inlet casing, and then compressed to a ratio of 19:1 (nominal rating at ISO conditions).

The compressed air leaving the axial compressor is directed into the annular combustor where it mixes with fuel in 30 burners. The fuel/air mixture is initially ignited by a spark plug and once combustion is self-sustaining, the spark plug is turned off.

Hot combustion gas is directed into the HPT, which drives the axial compressor rotor. This gas further expands through the power turbine, which drives the output load. Exhaust gases from the PT are turned 90° by the exhaust diffuser and then discharged through the exhaust plenum flange.

The gas generator rotor and the power turbine rotor are supported by two journal radial bearings each (2+2 in total) and provided with a thrust bearing for each shaft (1+1 in total). The thrust bearings are located close to the coupling side of the shafts to minimize the thermal displacement of the rotor flanges. The output power flange is located at the end of the PT shaft, opposite to the GG inlet, and in a shaft tunnel through the exhaust plenum.

The Gas Generator rated nominal speed is 11645 rpm. The Power Turbine rated nominal speed is 8900 rpm.

The package is compactly designed, with an emphasis on standardization and optimization of factory assembly.

Application Temp Range	+5°C / +40°C
Wind load (Km/h)	160 Km/h

2. Air Filtration System

Gas turbines manufactured by BHGE are requested to operate successfully in rural areas and heavy industrial zones, in Polar Regions and the tropics, in deserts and in coastal or offshore installations. In order to adapt machines to a variety of environments while realizing their full potential in performance and reliability, it is necessary to effectively treat the air entering the gas turbine. Environmental conditions play a major role in the selection and design of the Air Filtration System and its subsequent performance.

The main driving environmental factors are:

- Water/Moisture Concentration in Atmosphere
- Dust Level
- Particulate Type
- Particulate Size Concentration
- Temperature Range for selection of Anti-Icing system
- Amount of Snowfall
- Salt Concentration in Atmosphere

It is of main importance to select the right filtration technology for each installation site.

2.1 LT12 Air Filtration System Types

Four types of Air Filtration Systems are available as standard options to cope with several environmental conditions:

- GDX. Self-cleaning air filtration system, with horizontally hanging filter cartridges;
- TTD. Self-cleaning air filtration system, with vertically hanging filter cartridges;
- Combined Inertial/Self-cleaning air filtration system;
- Two or Three stage Static air filtration
-

3. Ventilation System

During all Gas Turbine working conditions (Startup, Normal Run and Shutdown) the ventilation system provides a continuous source of cooling air with the following main purposes:

- Remove heat from the enclosure
- Dilute possible hazardous gas leaks (In accordance to IEC 60079-10-1) to the point where the leak is no more hazardous, by respecting ISO 21789 requirements.
- Maintain the expected and appropriate temperature field, to allow the correct working and certification condition, of all the equipment placed inside the enclosure.
- Allow the appropriate the gas detection system working condition.

The package is provided with a negative pressure ventilation system to maintain the inside temperature below 80°C with the turbine in operation.

Air is circulated from the filter house through a suitable duct by one 100% flow AC motordriven centrifugal fan (Duplex AC fans are available as option, 1 main + 1 stand-by).

As per CAI standard design, no DC emergency fan is provided.

4. Inlet System

The primary function of the Inlet Duct System is to direct airflow from the inlet filter house to the inlet plenum and then to the axial compressor bellmouth with uniform flow and minimum pressure drop. The secondary function of the Inlet Duct System is to attenuate the noise emanating from the compressor bellmouth during gas turbine operation.

The Inlet Duct System consists of the following main components:

- Expansion Joint,
- Silencer Duct
- Transition piece to the GT inlet plenum
- Plenum Side Expansion Joint (in the GT Package scope of work)

5. Exhaust System

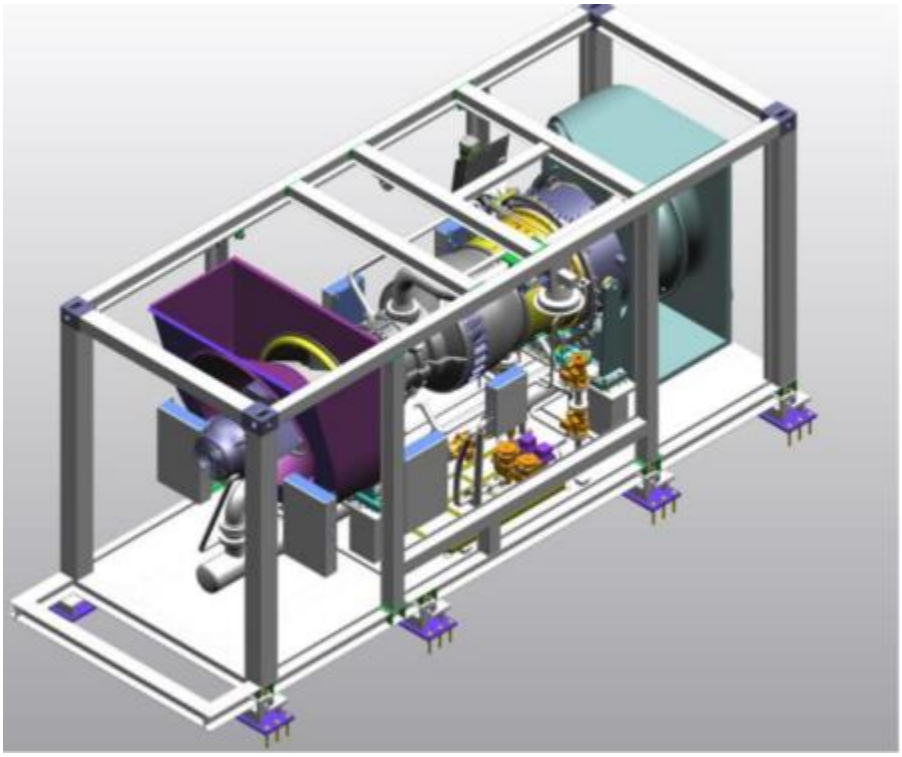
The primary function of the exhaust system is to direct the exhaust flow from the discharge of the gas turbine diffuser to the atmosphere or to a WHRU connecting flange with a minimum amount of flow disruption and pressure drop.

The secondary function of the Exhaust System is to attenuate noise coming from the GT exhaust plenum. The exhaust system includes an exhaust transition, expansion joints, silencer, and (as option) exhaust stack.

Spirit™12 features a lateral right exhaust. Vertical exhaust is available as option.

6. Baseplate

Baseplates are a structural member assembly made of rolled steel and plates which supports the machines and other associated equipment, with the required stiffness and allowed deformation. The baseplate is designed to withstand static loads (operation, lifting, wind etc.), emergency load (blast loads, machine failure etc.) and dynamic loads with acceptable stress and deformation values.



The baseplate contains the auxiliaries necessary for operation of the gas turbine including:

- lube oil distribution system and drain
- fuel gas system

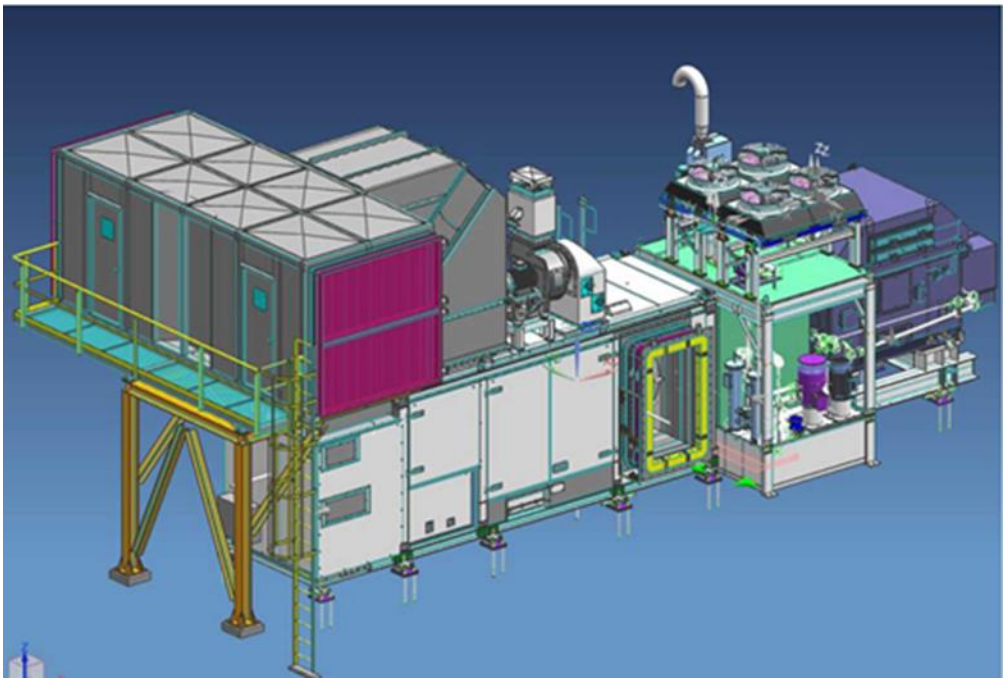
BASEPLATE DATA SHEET	
Overall dimensions	7,55 x 2,450 x 180 mm (LxWxH)
Main beam	HEA 180
Material	S355J2

7. Enclosure

The enclosure is a completely self-contained, weatherproof, insulated, and sound-attenuated system provided for Gas turbine and its auxiliaries. The enclosures are mounted on the equipment skids and supported by the baseplates. The enclosure sides include removable panels and/or doors to allow access to major components for inspection and maintenance and to permit removal of components by forklift. The engine area is furnished with hinged doors to facilitate engine removal from either left or right side of the package through lateral rails.

The enclosures include all the following items:

- Structural Frame for panels, instrumentation and electrical equipment supports in
- painted carbon steel.
- Panels for acoustic insulation in painted carbon steel.
- Fail-safe type dampers in stainless steel 316L material. The dampers are equipped with
- an opening device actuated by compressed air or carbon dioxide for CO2 firefighting
- system.
- Internal anti-panic device
- Door hinges and handles in stainless steel



8. Lube Oil System

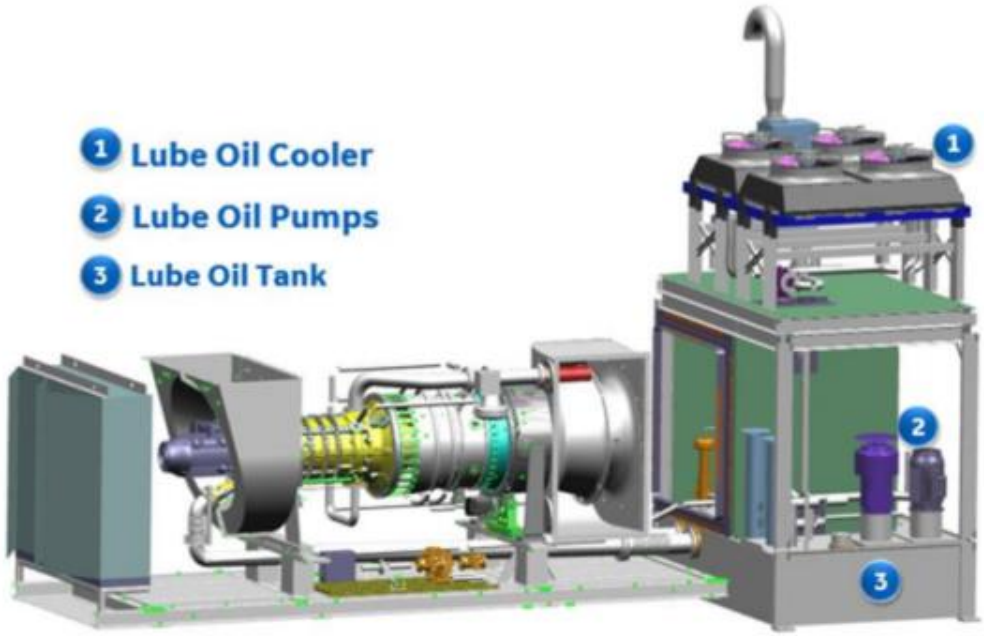
The Mineral Lube Oil System has the function of providing continuous, reliable and adequate filtered oil flow at proper temperature and pressure to the Gas Turbine, the Electric Generator and the Gearbox, for lubrication and heat removal. All operating conditions shall be covered: start up, normal operation, normal and emergency shut-down, cool down. The system is provided with devices that allow protection of the equipment against low lubricating oil pressure, high lubricating oil temperature and low lubricating oil level.

Spirit™12 package utilizes ISO VG32 Mineral Lube oil.

Main components of mineral lube oil system:

- Lube Oil Tank
- Lube Oil Piping

- Lube Oil Pumps:
  - AC Main pump: 30 kW (50Hz)
  - DC Emergency Pump: 6.5 KW (50Hz)
  - Mechanical Main pump – load gear driven (Option)
- Lube oil filter (Simplex, Duplex option)
- Lube Oil Heater inside oil tank
- Regulating Valves (TCV, VPR)
- Oil/Air Lube Oil Cooler
- Oil Mist Eliminator

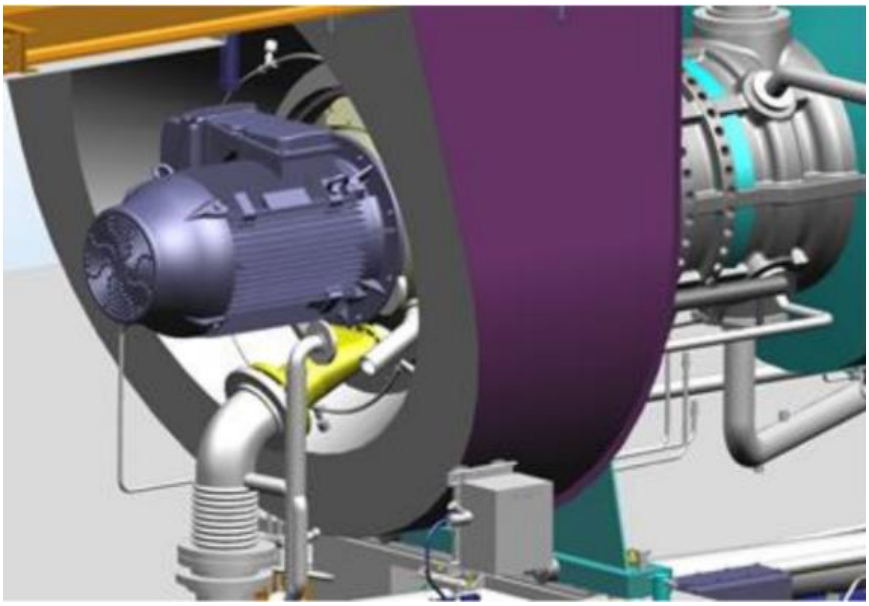


9. Starting System

The main function of the starting system is to accelerate the Gas Turbine up to self- sustaining speed at which stage the energy available in the combustion chamber is at least equal to sum of energy required by compression and mechanical losses in the Gas Turbine. The starting system is also required to drive the axial compressor to purge the gas turbine and exhaust duct of any volatile gases prior to initiating the ignition cycle. Other purpose includes turning during shut -down to facilitate cooling.

Spirit™12 is supplied with a fully automatic starting system consisting of a 90 KW electric motor powered by a VFD system (installed in CTRL room) connected to the Gas Generator shaft and supported directly to the gas turbine casing .

As soon as the gas turbine reaches the self-sustaining rotational speed, the starting systemautomatically disengages through an automatic clutch and the starting motor is turned off.



10. Fuel System

Natural Gas is the most commonly used fuel gas for the gas turbine because of good combustion properties and low emissions. Spirit™12 has DLE, Single annular combustion chamber.

Main components of the fuel gas system:

- No 2 Fuel Gas shut-off valves.
- No 2 Fuel Gas metering valves one for Pilot circuit and one for Premix circuit
- Fuel Gas piping (carbon steel)

Fuel gas pressure range is 35-38 barG, depending on fuel gas composition.

Fuel gas temperature range is as follows:

- Min: 28degC above dew point temperature at maximum supply Pressure.
- Max: 80°C

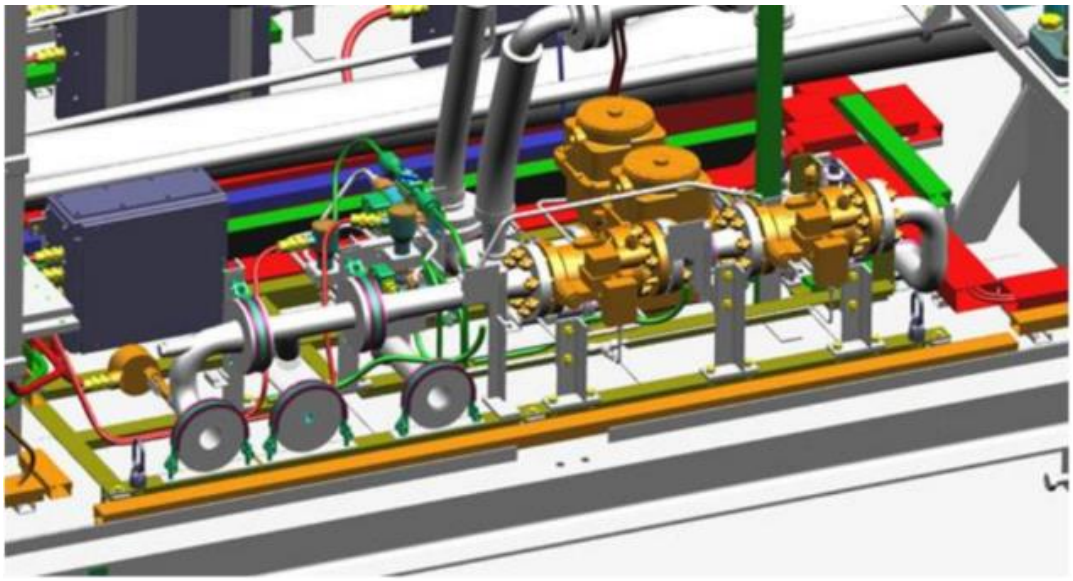
Fuel gas system is also equipped with warm-up line (where applicable) which is used, prior to startup the unit, to vent the Fuel gas when its temperature is below 28degC above fuel gas dew point. Warm-up valve is supplied loose and installed outside the package.

Last chance Y strainer is included in GE scope and it is installed inside the package. It's function is to filter any debris or other minor components which could damage the fuel nozzles and valves.

Fuel gas quality must be in accordance to GEI41040.

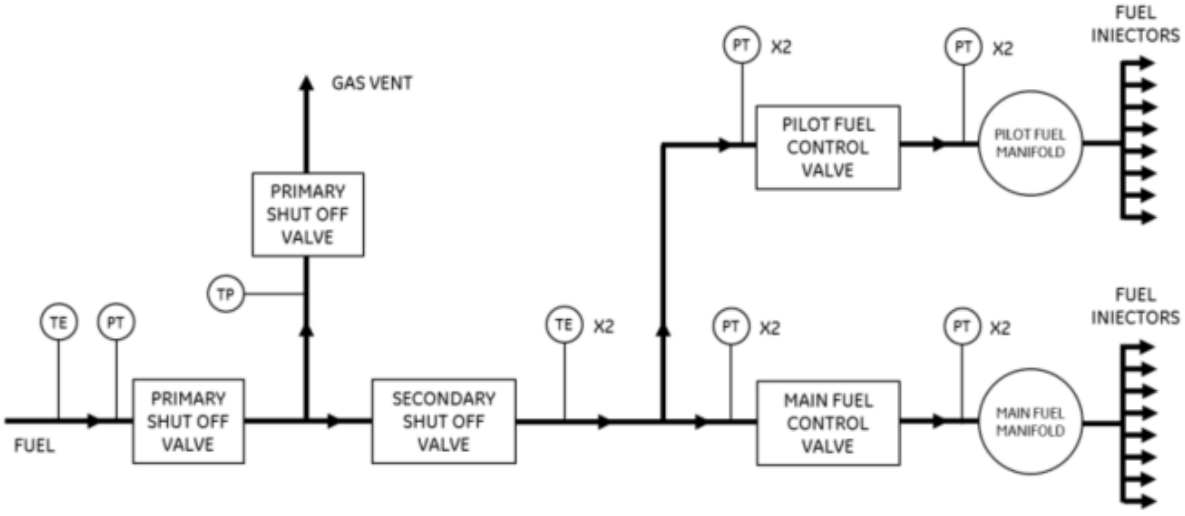
The Spirit™12 fuel gas skid is completely installed on the GT baseplate.

Shut off & vent valve, intended for maintenance and package isolation purpose, to be located outside of the enclosure, shall be provided loose by customer.



Fuel System Schematic:

The following picture represents the Spirit™12 Fuel System Schematic.



Typical fuel system schematic

LEGEND:
PT: Pressure Transmitter
TE: Temperature Element

11. Control System

Spirit™12 is equipped with a remote I/O panel (UCP1) installed on the main skid, located in a Local Electric Room (LEC) and a unit control panel (UCP2), off skid, suitable for the control and protection of the turbo-generator unit and auxiliaries.

The control system includes the following primary equipment:

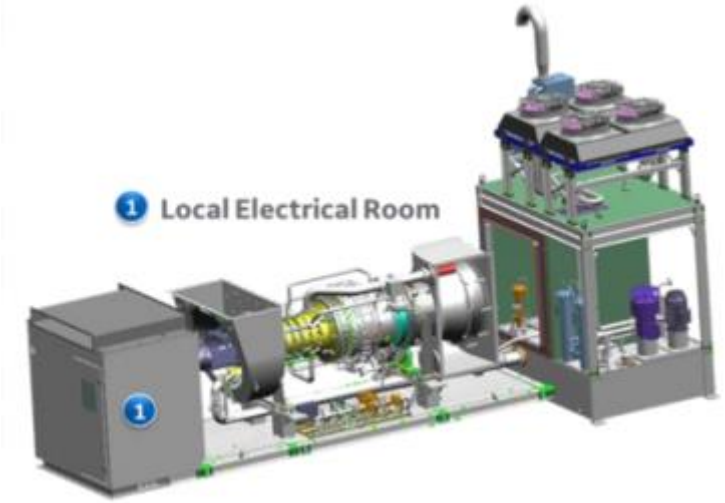
- Turbine control panel Speed-tronics Mark™ VIe/VIeS suitable to manage:
  - All gas turbine control, protection and safety logic, including auxiliaries
  - Integrated generator control
  - Fire and Gas system
- Generator control and protection panel

11.1 General Description

The unit control system controls and monitors the gas turbine, gearbox and electric generator equipment. The system architecture is based on Mark™ VIe/S hardware and software platform. The vibration and fire and gas system are integrated into the Mark™ VIe/S system.

11.1.1 Remote I/O panel (UCP1)

The remote I/O panel is installed on the GT Skid in a safe area inside a LEC (air conditioned local control cab) and contains Mark™ VIe and Mark™ VIeS cards to manage Gas Turbine skid I/O. The remote I/O panel is pre-wired on the GT skid before shipping which is the key to simplify the engineering, installation and commissioning.This panel is designed for operation and maintenance in safe areas. Cable entry is from the bottom through the MCT Roxtec (or equivalent).



11.1.2 Unit Control Panel (UCP2)

The unit control panel is installed in the customer's control room (air conditioning control room) in a safe area.

The panel contains mainly Mark™ VIe and Mark™ VIeS cards to manage:

- Interface with Generator Skid signals and other panels (e.g. MCC, DCP, GCPP, MVS, etc.)
- Loose Operator Interface (HMI) installed on Customer Desk
- Communication with customer DCS (using Communication gateway - option)
- OSM system to enable Remote Monitoring & Diagnostic.

12. Driven Equipment Systems

12.1 LT12 Electric generator

Synchronous generator with the following main technical features:

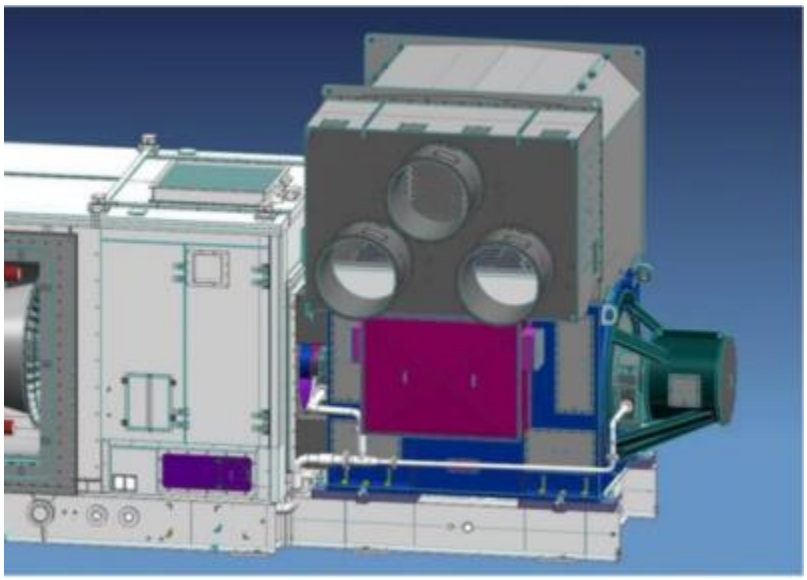
- IEC60034 / NEMA MG-1 as main applicable standards
- 4 poles
- Rated voltage 11 or 13.8 kV
- Rated frequency 50 or 60Hz
- Power factor 0.8
- Cooling type CACA IC616 / TEAAC or "open air" IC01 / WP2

for CACA #2 or #3 cooling fans; power output with one fan out of service is 67%, at max temperature rise for open air system clean is air expected. Dust and sand must be properly filtered, no ducts are provided

(*) Cooling CACW can be considered on job basis

- Insulation class / temperature rise: F/B or H/F
- Line side cubicle & neutral cubicle, fully equipped according SLD, provided with undrilled gland plates (limit of CAI supply)
- Excitation system (brushless with PMG or equivalent system)
- Generator to be installed in safe area
- Generator protection degree IP54
- Voltage regulation auto/manual, digital system - single channel

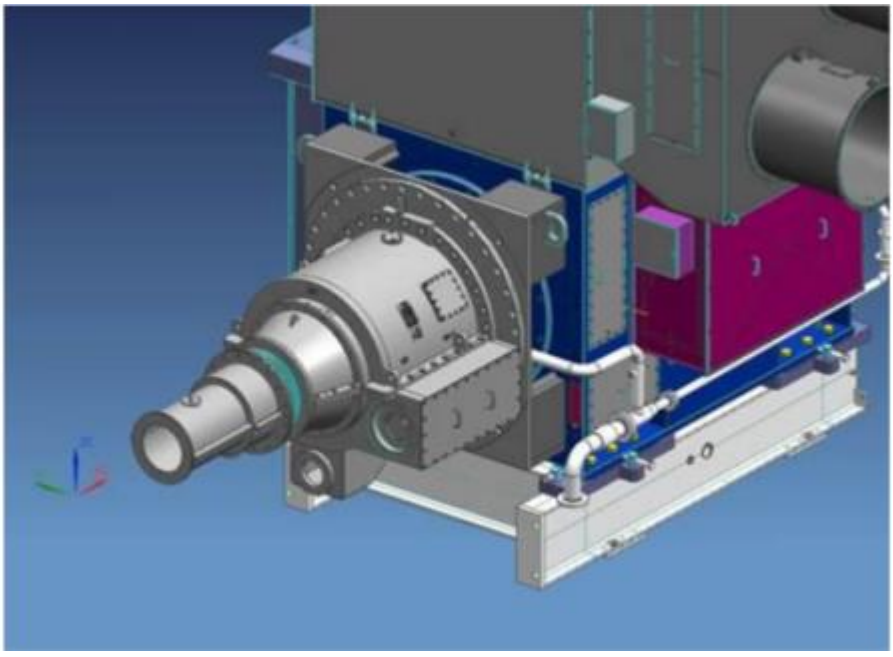
Several OPTIONAL features can be considered on job basis, e.g. on part redundancy and regarding equipment earthing (base is floating neutral point, std. option is NER 10A10sec)



12.2 Load Gearbox

Spirit™12 is equipped an epicyclic reduction-drive load gear which reduces the output speed of the gas turbine to the required operating speed of the generator, 1500/1800rpm. The gearbox is cantilever-mounted on the generator frame. It is coupled to the Low Pressure Turbine output flange through a balanced high-speed connecting coupling, covered by a coupling guard. The gearbox output low-speed shaft is directly connected with generator shaft. Gear lubrication is provided by the package lube oil system.

The gearbox also features also a PTO available for the mechanical lube oil pump option.



12.3 Generator control and grid interconnection

CAI will include a dedicated panel(s) equipment for generator control, including synchronization control, protection (IED) and excitation (AVR). Base solution is to have an integrated cabinet cantilevered on driven skid.

Generator equipment is designed to operate both in island mode, parallel with other generators and parallel to grid.

Automatic and manual (permissive) synchronization IEDs are included in CAI scope of supply. After all preconditions are met, with GT running at FSNL, GTG voltage and frequency, acting on AVR and governor respectively, are adjusted to match with grid parameters.

In this synchronization window a command to close the MV circuit breaker is issued, after synchronizing a minimum step load is required to GT to ensure a stable connection.

As optional items dedicated MV metal clad panel hosting the circuit breaker (synchronization point) can be provided, alongside with transducers and auxiliary items, including fiscal metering devices.

13. Water Washing System

Production is limited by gas turbine power capacity. Contaminants, ingested in the compressor and deposited in the flow path can lower power output and gas turbine efficiency. To limit the effects of the contaminants, the gas turbine axial compressor needs periodic cleaning by way of off-line compressor water washing. (On-line water washing is also an option.)

For a better efficiency of cleaning, periodical off-line washings are recommended.

An off-line washing trolley is provided. Washing manifolds are installed on the gas turbine.

Water tank, piping and structure are all in Stainless Steel 316L.

14. Fire Fighting System

The fire-fighting system has the function of machine protection equipment by discharging the extinguishing agent to create an inert atmosphere in the environment where the fire is detected, cooling the zone and extinguishing the fire. It also prevents re-ignition until the temperature of the metallic surfaces decreases below the ignition temperature of the combustible materials.

Spirit™12 features Potassium Aerosol firefighting system.

CO2 and Water-mist systems are options.

14.1 Aerosol system

Condensed aerosol fire suppression is a particle-based form of fire extinction similar to gaseous fire suppression or dry chemical fire extinction. The aerosol employs a fire extinguishing agent consisting of very fine solid particles and gaseous matter to extinguish fires. The condensed aerosol microparticles and effluent gases are generated by the exothermic reaction; until discharged from the device, the particles remain in vapor state. They are cooled and "condensed" within the device and discharged as solid particles.

Spirit™12 is equipped with two aerosol generators installed on enclosure roof to protect the gas turbine package. The aerosol devices are self-contained and function as both a storage container and as a nozzle that propels the gas, therefore no distribution network is required to transport or distribute the fire-extinguishing agent from a remote storage location.

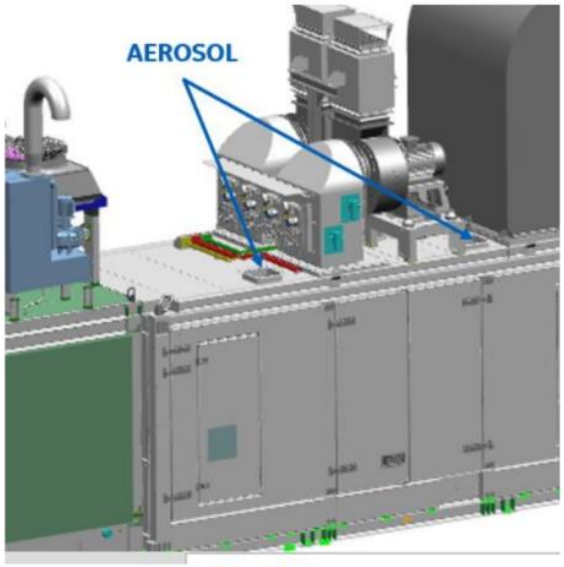
For each compartment, the aerosol release occurs with a single discharge.

Aerosol generators are designed to protect all the compartments simultaneously.
All the generators are released at the same time by electrical actuation of fire control panel.

The system can be actuated automatically by the Mark™ VIeS and manually with manual actuator close to the enclosure accesses.
Before aerosol discharge, there is a time delay of 30 seconds to insure safe evacuation of personnel (NFPA 2010 requirement).

Automatic aerosol discharge can be inhibited by an inhibit switch close to the enclosure access (NFPA 2010 requirement).

Duration of possible re-ignition of combustibles is 20 minutes (GT cool down time).
Ventilation openings are equipped with air tight dampers.



15. Noise

The Sound Pressure Levels refer to the noise emission of the equipment in free field condition with only one turbo-generator unit in operation.

Noise assessment is based on a unit constituted by NovaLT12 gas turbine, air intake filter group, exhaust group, electric generator and auxiliary skids.

Spirit™12 onshore package is designed in order to meet the following acoustic requirement:

Logarithmic average sound pressure level at 1.0 m from baseplate perimeter, at elevation1.50 m from walkways level around the whole train less than 85.0 dBA; the average value is evaluated according to ISO 9614-2 "Determination of sound power levels of noise sources using sound intensity -- Part 2: Measurement by scanning". The accuracy degree shall be defined after noise test.

The average 85 dBA @ 1 m sound pressure level is not guaranteed during pulse jet filters cleaning operations.

The average 85 dBA @ 1 m sound pressure level is guaranteed in free field condition over reflecting plan and with only one GT train in operation.

16. Service & Maintenance

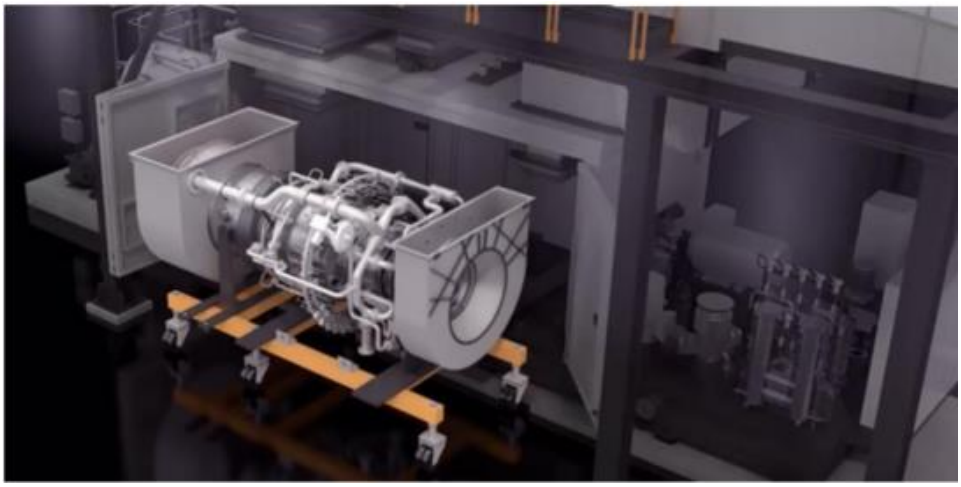
Spirit™12 maintenance intervals are shown in the following table:

ENGINE SWAP & OVERHAUL	
Hot Gas Path (hrs)	Major Inspection (hrs)
35000	70000

Engine inspection and overhaul is performed in a workshop. The engine module has been designed to be easily and quickly removed from the package. All the engine electrical connections are wired to two Junction Boxes installed on the engine support structure.

The preferred side for engine extraction is left. But right extraction is available on request.

The enclosure doors open completely allowing to slide the engine out on rails onto a trolley which can then be lifted to move the engine to the workshop.



WEIGHT & DIMENSIONS!*)		
Item	Weight (kg)	Dimensions (m)
Engine	11,452	5.6 (L) x 1.97 (H) x 2.15 (W)

Including support structure, inlet plenum and piping