

GENERAL SPECIFICATION

ELECTRICAL

GS EP ELE 013

Electrical requirements for generating units

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03	01/2011	General Revision
02	10/2008	Addition of PMS
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00	10/2004	First issue
Rev.	Date	Purpose of the revision

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General Specification		GS EP ELE 013
Electrical requirements for generating units		
Rev.: 04	Effective date: 10/2012	Page: 2 of 19

Contents

1. Scope	3
2. Reference documents.....	3
3. Design Basis.....	5
3.1 Standard general diagram.....	5
3.2 Generator.....	5
3.3 Unit Control Panel (UCP) and Power Management System (PMS)	5
3.4 Starting system for essential and emergency generating unit.....	13
4. Rating and performance	14
4.1 General.....	14
4.2 Unit Control Panel.....	14
4.3 Performance requirements for load acceptance and rejection.....	16
5. Inspection and tests.....	16
6. Design Life and Obsolescence	17
7. Documentation	18
7.1 List of documents.....	18
8. Other reference	19

General Specification		GS EP ELE 013
Electrical requirements for generating units		
Rev.: 04	Effective date: 10/2012	Page: 3 of 19

1. Scope

This specification defines the minimum requirements for the design, manufacture, inspection and testing of electrical equipment provided for generating units above 250 kVA.

This specification shall be read in conjunction with the General Specification **GS EP ELE 011** and the corresponding generating unit Project specification, drawings and data sheets, if any.

2. Reference documents

The reference documents listed below form an integral part of this General Specification.

External Documents

Unless otherwise stipulated, the applicable version of these documents, including relevant appendices and supplements, is the latest revision published at the effective date of this document.

Design and engineering shall conform as a minimum requirement to the current edition of the following in order of precedence:

- Applicable laws and regulations of the country in which the system will be operated. In cases where no "local" regulations exist, the French laws and regulations shall be used
- Company Particular Specifications and data sheet (if any)
- Company General Specifications
- Applicable International Electro technical Commission (IEC) Publications
- Applicable CENELEC Standards
- Applicable recognized standards and codes (UTE, BS, VDE, etc.) where IEC Publications have not yet been issued.

Reference	Title
IEC 62402	Obsolescence management - Application guide

Total General Specifications

Unless otherwise stipulated, the applicable version of these documents, including relevant appendices and supplements, is the latest revision published in the applicable yearly collection.

Reference	Title
GS EP ELE 011	Electrical requirements for packaged units
GS EP ELE 113	AC generators
GS EP ELE 137	Distribution boards
GS EP ELE 151	DC Uninterruptible Power Systems (UPS)

**General Specification****GS EP ELE 013**

Electrical requirements for generating units

Rev.: 04

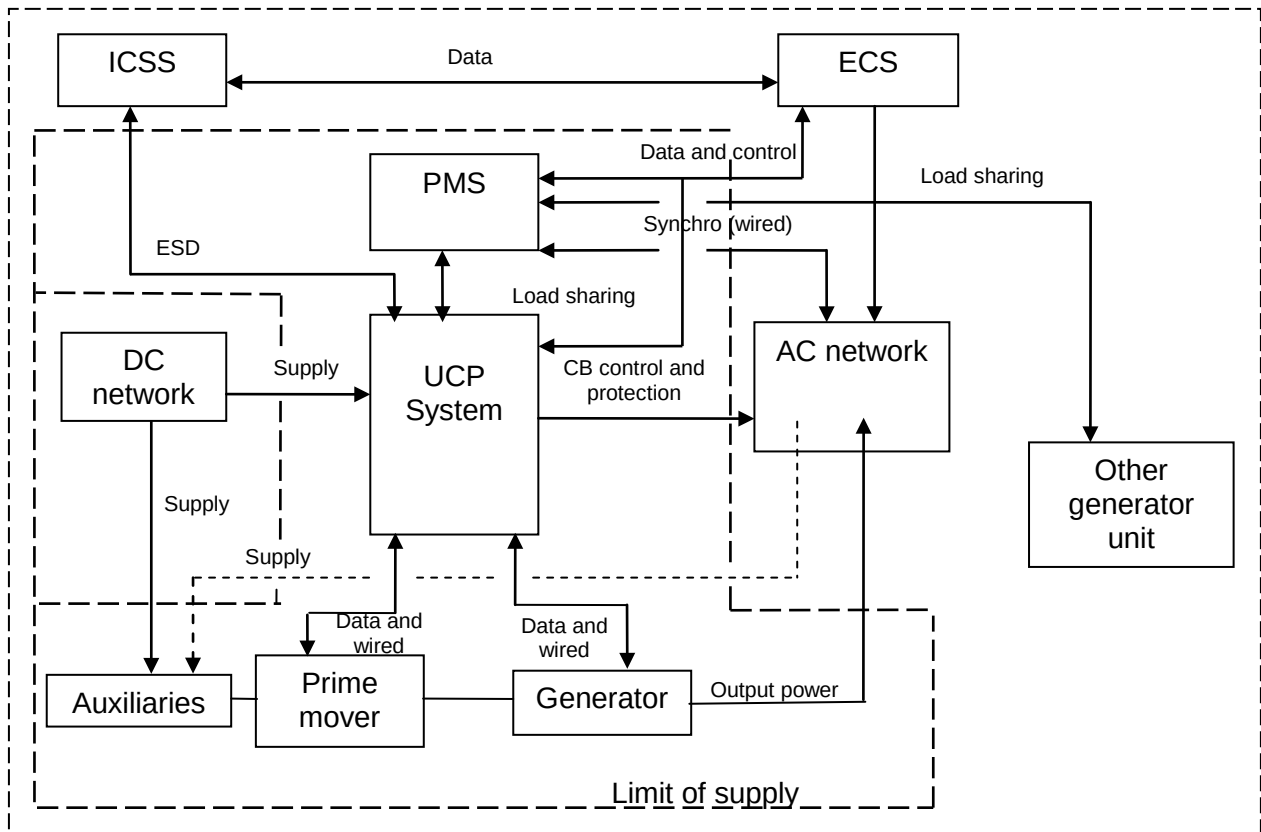
Effective date: 10/2012

Page: 4 of 19

Reference	Title
GS EP INS 110	Instrumentation for package units
GS EP INS 135	Cyber Security requirements for design and supply of ICSS and Package systems
GS EP MEC 011	Rotating Machine Package Specification - Diesel Engine Driven Emergency Generator
GS EP TEC 007	Obsolescence and Lifetime Cycle Management

3. Design Basis

3.1 Standard general diagram



ICSS: Integrated Control and Safety System

ECS: Electrical Control System

PMS: Power Management System (Active and Reactive load sharing system)

UCP System: Unit Control Panel

DC Network: Direct Current Network

AC Network: Alternative Current Network

ESD: Emergency Shut Down

Note: Wired means hardwired signal and Data means data exchanged through a serial link

3.2 Generator

The generator shall be in accordance with the general specification [GS EP ELE 113](#).

3.3 Unit Control Panel (UCP) and Power Management System (PMS)

The Unit Control Panel and the PMS shall be in accordance with the general specifications [GS EP ELE 137](#), [GS EP INS 110](#) and [GS EP INS 135](#).

General Specification		GS EP ELE 013
Electrical requirements for generating units		
Rev.: 04	Effective date: 10/2012	Page: 6 of 19

The generating unit shall be considered as a P3 type package as per **GS EP INS 110**.

The UCP shall allow easy communication with an Electrical Control System via a serial link.

3.3.1 Electrical protection

Unless otherwise specified, the generating unit protections and all hardware components shall be provided by the Package Supplier and installed into the Unit Control Panel.

The protections relay shall be of digital type with full testing facilities to allow secondary injection of the relays.

The protection system shall be supported by a software library of complete protection functions as defined in this specification.

The protections relay shall encompass a disturbance and fault recorder able to store at least 2.5 seconds of data triggered on status change and/or fault conditions with an adjustable time frame (typically [-500;+2000] ms).

A Maintenance Workstation shall allow users to activate all protections and logic. For all functions user's guide with aid of screen menus and windows, shall be available.

3.3.1.1 Turbine driven generator

Protection	ANSI code N°	Action
Earth overcurrent	51N	Open breaker and stop generator
Bearing overtemperature	26	Alarm (1 st) and stop generator (2 nd)
Bearing vibration	39	Alarm (1 st) and stop generator (2 nd)
Winding overtemperature	26	Alarm (1 st) and trip CB (2 nd)
Coolant overtemperature or failure	26	Alarm
Stator differential overcurrent	87 G	Stop machine
Instantaneous phase overcurrent	50	Trip circuit breaker
3 phases stator overcurrent	51 V	Trip circuit breaker
Stator reverse power	32	Trip circuit breaker
Stator under/over frequency	81	Load shedding or Trip circuit breaker
Stator under/over voltage	27-59	Trip circuit breaker
Overload	49	Trip circuit breaker
Neutral voltage displacement (1)	59N/64S	Stop machine
Rotor earth fault (2)	64R	Stop machine
Rotating rectifier diode failure	94 d	Stop machine
Field failure or loss of synchronism	40	Trip circuit breaker
Phase unbalance	46	Trip circuit breaker
Directional overcurrent protection	67 67N (3)	Stop the machine
Maximum and minimum excitation	76	Stop Machine

- (1) For generator connected to a network protected by earthing transformer (homopolar generator)
- (2) For generator above 5000 kVA
- (3) For generators running in parallel and connected to the earth via earthing resistors.

General Specification		GS EP ELE 013
Electrical requirements for generating units		
Rev.: 04	Effective date: 10/2012	Page: 8 of 19

3.3.1.2 Diesel or gas engine driven generator

Protection	ANSI code N°	Action
Earth overcurrent	51N	Open breaker and stop engine
Stator differential overcurrent (1)	87 G	Stop engine
Instantaneous phase overcurrent 3 phases stator overcurrent	50 51 V	stop engine
Stator reverse power	32	Trip circuit breaker
Stator under/over frequency	81	Load shedding or Trip circuit breaker
Stator under/over voltage	27-59	Trip circuit breaker
Overload	49	Trip circuit breaker
Winding overtemperature	26	Alarm (1 st) and trip CB (2 nd)
Neutral voltage displacement (2)	59N/64S	Stop machine
Bearing overtemperature	26	Alarm (1 st) and stop generator (2 nd)

(1) For generator above 1250 kVA

(2) For generator connected to a network protected by earthing transformer (homopolar generator).

3.3.2 Control functions

The following table gives the minimum required control functions and their initiation mode(s).

Those functions are noted as:

- “M” requiring manual initiation
- “A” initiated by automatic signal
- “C” operating on a continuous signal.

Electrical requirements for generating units

Rev.: 04

Effective date: 10/2012

Page: 9 of 19

Unit Control Panel	
Generating unit status	A
Start-up sequence	A, M
Synchronizing generator	A, M
Voltage regulation	C
Speed regulation	C
Frequency control system	C
Alarms	A
Shutdown sequence (Controlled Stop Sequence)	A, M
Emergency shutdown (Emergency Stop Sequence)	A, M
PMS	
Voltage regulation (during parallel operation)	C, M
Speed regulation (during parallel operation)	C, M
Synchronizing generator or group of generators	M
Active and reactive load sharing (during parallel operation)	C
ICSS	
Emergency shutdown	A, M
ECS	
Start-up sequence initiation	M
Load shedding	A

3.3.3 Voltage regulation

The voltage regulation shall be automatic and it shall be equipped with manual adjustment.

Unless otherwise specified, the Automatic Voltage Regulation (AVR) shall be of digital design type and shall perform a three phase regulation.

The parameters shall be readily adjustable. The voltage setting shall be manually adjustable.

Manual voltage control shall be achieved by the use of a separate, independent module controlling the field current with control switches or pushbuttons for increasing or decreasing the excitation.

All faults shall be indicated in the digital display to allow rapid finding.

The voltage regulation shall be powered from Permanent Magnet Generating system. Self excited generator is not authorized.

General Specification		GS EP ELE 013
Electrical requirements for generating units		
Rev.: 04	Effective date: 10/2012	Page: 10 of 19

Unless otherwise specified the voltage regulator shall be able to operate in either power factor, voltage or reactive power regulation mode as follow:

- Isovoltage control mode shall be used for one generating unit operating in islanded conditions
- Voltage/reactive power droop mode shall be used for parallel operation of two or more generating units on isolated networks
- Power factor mode shall be used for operation in parallel to a grid (or main power generation for an emergency/essential generator).

After AVR fault and shut down has been initiated, the generator shall be capable of restarting in manual voltage control.

The ceiling voltage and response to system faults shall be such that a rapid field forcing is obtained. The excitation system including the AVR shall be designed so as to allow for the generator to maintain the short-circuit requirements (current/time) as defined in relevant GS / data-sheets. The AVR shall have the following integrated functions:

- Rotor current limitation
- Stator current limitation
- Polar angle limitation.

Regulator drift shall be less than 1% for a 40°C ambient temperature.

3.3.4 Speed regulation

The speed regulator system / governor shall be a digital design and installed in the UCP.

Speed regulation shall be able to operate in isochronous, droop and base load mode:

- The isochronous mode shall be used for one generating unit on an isolated network
- The droop mode shall be used for parallel operation of two or more generating units on an isolated network
- The base load mode shall be used for test or when operating connected to a grid (or main power generation for an emergency/essential generator). The load setting shall be set by a fixed reference or an external contact, analog or digital input.

Speed regulation shall be provided with closed loops dedicated to output power and speed. A closed loop dedicated to actuator position is not authorised.

Manual control shall be achieved by the use of a separate, independent module controlling the frequency, with local control switches or pushbuttons for increasing or decreasing the speed.

3.3.5 Failed Speed Signal

Generating unit shall be able to operate in the event of loss of speed signal.

A contact to override the failed speed signal circuit shall be installed in order to test this function.

Prior to start-up of the prime mover, the speed signal override contact shall be of the time delay type to ensure that the failed speed sensor alarm circuit is enabled after start-up.

General Specification		GS EP ELE 013
Electrical requirements for generating units		
Rev.: 04	Effective date: 10/2012	Page: 11 of 19

3.3.6 Parallel operation

The generating units shall be able to operate in parallel up to their maximum output power.

The active and reactive loads shall be shared in accordance with their rating under all conditions and without hunting by means of an automatic load sharing device implemented within the PMS.

Even though droop mode is required, the steady state frequency and voltage shall be maintained by a centralised automatic frequency and voltage control system done by the Power Management System or PMS.

Manual control of the PMS speed and voltage settings shall be possible during parallel operation.

3.3.7 Synchronizer

Synchroniser shall be provided as part of the UCP or within a common synchro panel in order to allow for the synchronisation of the generating unit to the busbar.

When synchronisation of generating unit(s) over bus-tie or interconnecting feeders shall be considered, synchroniser shall be implemented within a common synchro panel or at the PMS level.

The synchronizer shall be provided by the package Supplier and specific arrangement will be defined in the project specification.

The synchronizer shall be able to operate automatically or manually.

The synchronizer shall utilise three phases for frequency, voltage and phase angle comparison.

The synchronizer shall provide a direct contact to close the generator circuit breaker.

Either automatic or manual signal command shall be monitored by independent synchronism check relay (ANSI 25) before breaker closure is permitted. Such synchrocheck relay will be provided and installed, by others, within the switchgear generator incomer cubicle. The synchronizer output shall remain disabled when the frequency and voltage difference are outside the permissive synchronizing window.

The synchronizer shall be part of a closed-loop feedback control system for the frequencies and voltages.

The synchronizer shall be able to alter generating unit frequency and voltage.

When the frequency, phase angle and voltage conditions are fulfilled, the duration of the synchronizing conditions is checked so as to ensure that they will still be met when the contacts of the circuit breaker close.

Individual generating unit shall be synchronised to their dedicated busbar and the circuit-breaker closed only when accelerating to avoid any reverse power to occur. In case of multiple unit synchronisation over bus-tie or interconnecting feeders, the least loaded groups shall be accelerating when coupling.

The synchronizer shall be provided with at least four operating modes. These modes are intended to facilitate system testing and installation checkout without electrically disconnecting the synchronizer from the control system.

General Specification		GS EP ELE 013
Electrical requirements for generating units		
Rev.: 04	Effective date: 10/2012	Page: 12 of 19

These four modes shall be able to be selected by an external switch and shall allow:

- Synchronization and automatic breaker closure
- Testing correct synchronizing operation, but without circuit breaker closure
- Checking for acceptable synchronization, but does not trim speed or adjust voltage. When synchronization is correct, the breaker is allowed to close
- Disabling of the synchronizer.

3.3.8 Power Management System (PMS)

The PMS shall be a stand-alone processor based control system including a Human-Machine Interface designed for the monitoring and control of active and reactive load sharing and operating voltage/frequency of generating units operating in parallel.

Depending on the criticality of the load sharing management (isolated platforms, interconnected networks, etc.), the PMS shall be based on the following configurations:

- Single controller, interface modules and HMI within a stand-alone cabinet OR
- Redundant Controllers, interface modules, local and/or remote HMIs.

The PMS shall remain an aid to Operators, therefore, its failure shall not stop operation of any part of the power generation. Complete assessment of operating configurations shall be performed during the Basic Engineering phase.

The PMS shall allow for:

- System voltage and frequency control (for single unit or group of generating units depending on the architecture and possible operating configurations)
- Active and reactive load sharing between paralleled generating units based on permanently refreshed load and generating unit capability
- Synchronisation of group of generating units over a bus-tie or interconnecting circuit breaker
- Manual setting of active power limitation on generating unit(s) (maintenance, etc.)
- Generator power capability setting (P/Q diagram)
- Manual setting of target setpoints (P, Q) for specific generating units
- Control of transformer on-load tap changers (when applicable)
- Setting of maximum/minimum active and reactive power import and export when connected to a grid and/or other power generation.
- Alarm management (discrepancy, low spinning reserve, generator target mismatch, power sharing mismatch, measurement fault, watchdog, etc.)
- P, Q, V, F trend displays.

General Specification		GS EP ELE 013
Electrical requirements for generating units		
Rev.: 04	Effective date: 10/2012	Page: 13 of 19

3.3.9 Load shedding

To perform the load shedding, the generating units shall transmit by direct link to ECS the following information:

- The instantaneous active and reactive power
- All shutdown and breaker trip signals
- The exhaust temperature (for turbine only)
- The actual turbine capability based on operating conditions (for turbine only)
- Maximum load step acceptance (based on actual turbine load).

3.3.10 Communication interfaces

The Communication interfaces shall be in accordance with the general specification **GS EP INS 110**.

All parameters, signals, measured values shall be exchanged via appropriate interfaces and serial communication channels to ECS (Electrical Control System) or ICSS (Integrated Control and Safety System).

All other input and output signals shall be wired to terminal blocks within the UCP for connection by others.

3.4 Starting system for essential and emergency generating unit

Generating unit shall be suitable for rapid starting and loading to full capacity within 30 seconds. In case of start failure an alarm shall be provided on remote control panel.

Essential and emergency generating units shall have two separate systems, fully independent of the plant support facilities:

- Primary electric or pneumatic starting system
- Secondary (back-up) hydraulic system.

For large generating units where the use of a hydraulic starting system as back-up cannot be implemented by engine Manufacturer, Supplier may propose a complete starting air system as defined in **GS EP MEC 011**.

Each system shall provide energy for six (6) consecutive starting attempts.

For electric starting system, each attempt shall consist of five (5) second cranking followed by ten (10) second rest.

The pneumatic and hydraulic starting systems shall be as per **GS EP MEC 011**.

When required electric starting system shall consist of:

- Nickel Cadmium batteries
- Battery box designed for Nickel Cadmium batteries
- Independent battery charger (even when the diesel engine is supplied with a driven generator as a Manufacturer standard)

General Specification		GS EP ELE 013
Electrical requirements for generating units		
Rev.: 04	Effective date: 10/2012	Page: 14 of 19

- Ammeter and floating/boost charging facility
- Manual start-up facility by-passing the driver controller (optional).

The battery charger shall be capable of full recharge in eight hours.

When the Battery Charger is used to supply control and command system, it shall be in accordance with **GS EP ELE 151**.

When battery charger and batteries are located in the electrical room and/or battery room the battery charger Supplier shall size the cables between the batteries and the battery charger.

3.4.1 Automatic starting Mode

The UCP shall directly monitor the emergency or essential network voltage and shall initiate an automatic starting sequence on voltage failure. The UCP shall have direct control of the switchgear circuit-breakers (normal incomers, bus-tie, essential or emergency generating units, etc.) to configure and re-energise the emergency or essential busbars.

For essential generating units requiring external water cooling loop, the UCP shall also control the relevant water lift and circulation pump and control valves to allow for black-start operation.

3.4.2 Manual start mode

Manual starting shall only be from the UCP.

Provisions shall also be made to periodically test the essential/emergency generator starting and automatic loading.

The generating unit shall be able to be synchronised and coupled with the normal generation.

4. Rating and performance

4.1 General

The generating units shall be designed for continuous service, at rated output under specified ambient conditions without harmful effects.

All electrical auxiliary consumers shall be deducted from the generator unit output rating.

Unless otherwise specified, the expected lifetime of the generating unit shall be at least 20 years.

Electrical equipment shall be suitable for at least three years uninterrupted operation under conditions specified.

4.2 Unit Control Panel

4.2.1 Voltage regulation

The excitation system shall be able to generate at the generator output:

- 150% of rated current for a period of at least 30 seconds
- 110% of rated current for a period of at least one hour, without dangerous overheating.

General Specification		GS EP ELE 013
Electrical requirements for generating units		
Rev.: 04	Effective date: 10/2012	Page: 15 of 19

The excitation system shall withstand the following duty cycle, repeated every five minutes:

- Continuous rated excitation current
- Excitation current at ceiling voltage for 10 seconds.

The excitation system shall be rated for 110% of the excitation current required during full load operation at rated voltage and rated power factor.

The excitation system shall allow 100% voltage to be maintained at 90% speed.

The output voltage of the generator shall be adjustable between 90% and 110% of the rated value during normal operation.

Steady state voltage variations at any load when operating isolated from electrical network shall be limited to $\pm 0.5\%$ of the rated voltage.

Voltage variation after instantaneous application of 100% load (at 0.8 lagging power factor) shall not exceed -15% and recovery to 97% of rated voltage shall occur within 1.5 seconds. This shall be demonstrated by detailed calculation note for all generating units.

4.2.2 Speed regulation

Speed shall be adjustable over the range 95% to 105% of the rated speed during normal operation.

Steady state speed variations, at any load when operating isolated from the electrical network shall be limited to $\pm 0.5\%$ of the rated speed.

Speed regulation shall be equipped with $\pm 5\%$ adjustable droop.

4.2.3 Parallel operation

The generating units shall operate within 3 or 4% of droop for speed and voltage.

Even though droop mode is required, the steady state speed variations shall be limited to $\pm 0.5\%$ of the rated speed.

Even though droop mode is required, the steady state voltage variations shall be limited to $\pm 0.5\%$ of the rated voltage.

4.2.4 Synchronizer

The phase match window shall be able to be chosen from 0.2 to 1 second and be adjustable to at least 10 degrees phase angle.

The voltage matching range shall be adjustable from 1% to 5%.

The synchronizer shall only be active within $\pm 10\%$ of the rated frequency.

4.3 Performance requirements for load acceptance and rejection

The generating units shall comply with the following performance requirements:

Load Acceptance	Minimum transient frequency % of Fn	Recovery time to more than 97% of Fn in seconds	Minimum transient voltage % of Un	Recovery time to more than 97% of Un in seconds
0..25% (PF = 0.8 lagging)	≥ 90%	≤ 3	≥ 90%	≤ 1.5
0..50% (PF = 0.8 lagging)	≥ 90%	≤ 5	≥ 90%	≤ 1.5
20..60% (PF = 0.8 lagging)	≥ 90%	≤ 3	≥ 90%	≤ 1.5
40..80% (PF = 0.8 lagging)	≥ 90%	≤ 3	≥ 90%	≤ 1.5
60..95% (PF = 0.8 lagging)	≥ 90%	≤ 3	≥ 90%	≤ 1.5
0..100% (PF = 0.8 lagging) Diesel Generator Only	≥ 90%	≤ 3	≥ 85%	≤ 1.5
60% Preload and largest Direct On Line motor start by simulation (see Note 1)	≥ 90%	≤ 5	≥ 85%	≤ 1.5
Load Rejection	Maximum transient frequency % of Fn	Recovery time to less than 105% of Fn in seconds	Maximum transient voltage % of Un	Recovery time to less than 103% of Un in seconds
100..5% (PF = 0.8 lagging)	≤ 110%	≤ 5	≤ 110%	≤ 1.5
100..0% (PF = 0.8 lagging)	≤ 110%	No trip	≤ 110%	No trip
Fn: rated frequency Un: rated voltage Note 1: Preload and motor characteristics shall be further defined during Basic Engineering				

Manufacturer shall confirm the speed variations and recovery time after sudden load impact and load rejection.

5. Inspection and tests

The package Supplier shall submit an Inspection & Test Plan (ITP) including subcontract items.

The package Supplier shall provide access in his factory and Sub-Supplier's ones as well to Company representatives at any time during the manufacture of the equipment.

Inspections and tests shall be carried out in accordance with applicable specifications and standards mentioned in this document.

The witnessing of inspection of any item shall be the prerogative of the Company but does not relieve the package Supplier of his responsibility to comply with the specification.

General Specification		GS EP ELE 013
Electrical requirements for generating units		
Rev.: 04	Effective date: 10/2012	Page: 17 of 19

The generator shall be tested at the Sub-Supplier's works and witnessed by the Company.

The package Supplier shall provide all auxiliary supplies (electricity, air, water, etc.) and load banks necessary to make the complete run test of the generating unit.

The generating unit shall be factory tested and when stated in the purchase order commissioned by the Supplier.

The Factory Acceptance Test (FAT) shall include, but not be limited to the following:

- Visual inspection and dimensional checks
- Compliance to standards and specifications
- Installation of equipment checking as well as cabling, wiring and accessibility
- Insulation resistance test for all electrical equipment (motors, lighting, Unit Control Panel, wiring, etc.)
- Earth continuity test
- Protection and relay setting checks (test done by current injection on the protection relay)
- Satisfactory functional operation of all control circuits and auxiliary systems.
- Partial load test
- Full load tests (optional)
- Load impact and load rejection (refer to section 4.3)
- PMS tests with full simulator to test/validate all project functionalities.

6. Design Life and Obsolescence

The obsolescence shall be managed as per [GS EP TEC 007](#).

Facilities are typically designed with an expected design life in the order of 25 years.

The generating unit design shall therefore take into account the requirement that the equipment will most probably require to be upgraded during the design life of the facilities in particular for all the electronic based components. These requirements shall be incorporated from Basic Engineering stage.

The design will include provisions to allow an upgrade of the generating unit to be performed with minimal disturbance.

All hardware and software that may be developed by the Supplier further to the generating unit delivery, shall ensure full ascending compatibility to allow for easy replacement of equipment that became obsolete with limited reconfiguration.

At the Bid stage, the Supplier shall detail his lifecycle management strategy focusing on product obsolescence, support options and further migration alternatives. The lifecycle/obsolescence management plan and associated cost shall be part of the Bid process evaluation.

The Supplier shall complete an inventory of all provided equipment (hardware and software) matching to different lifecycles phases, including all Sub-Vendors equipment (Operator stations, routers, relays, regulators, etc.).

General Specification		GS EP ELE 013
Electrical requirements for generating units		
Rev.: 04	Effective date: 10/2012	Page: 18 of 19

The Supplier shall guarantee that:

- Components (including software and hardware) shall remain in the “active products” range (i.e. supporting developments and releases) over a period of at least 5 years after the SAT
- An announcement to Customer is provided 5 years prior the end of the commercial phase
- Components (including software and hardware) shall be fully supported and available over a period of at least 15 years after the SAT
- Maintenance services including availability of engineering services shall be available to support the package and components during the plant life time.

7. Documentation

The Package Supplier shall provide all the drawings required for connection and co-ordination with other equipment in the plant as specified in the requisition, especially load requirements (400 VAC - 24 VDC - 230 VAC UPS, etc.) and remote control and feedback signals.

7.1 List of documents

The Package Supplier shall provide at least the following documents:

7.1.1 With the bid

- List of electrical consumers
- Power balances (24 VDC, 230 V - AC UPS; 230 V, 400 V, 6600 V)
- Completed data sheets (including generator and auxiliaries)
- AVR, governor and generator models including whole shaft line inertia (driver, gear box)
- Load acceptance (P, Q) performance function of spinning reserve/preload.
- Apparatus list
- String test procedure including load bank set-up
- Deviation list from Company and Project specifications
- List of proposed Manufacturers/Suppliers from the "Vendor List" for bulk items
- List of Subcontractors.

7.1.2 For approval

- Design drawings, calculation sheets
- Generator and auxiliaries data sheet
- AVR, governor and generator models including whole shaft line inertia (driver, gear box)
- Load acceptance (P, Q) performance function of spinning reserve/preload.
- General arrangement and interface drawings
- Unit Control Panel and PMS outline drawing and arrangement

General Specification		GS EP ELE 013
Electrical requirements for generating units		
Rev.: 04	Effective date: 10/2012	Page: 19 of 19

- Single-line and three line diagrams, schematics and logic diagrams
- Cable block diagrams (for turbine)
- Cable schedules, connection diagrams and wiring diagrams (for turbine)
- Cable sizing calculation note if any
- Interconnection diagrams
- Installation drawings including equipment location and cable routing
- Earthing lay out
- PMS Architecture
- PMS detailed functional analyses
- PMS mimic
- PMS FAT procedure
- Power requirement for each consumer (rated, absorbed, duty factor, etc.), equipment list
- Specification/data sheets related to supplied equipment (motors, switchboards, cables, etc.)
- HMI mimic displays
- Obsolescence management dossier.

7.1.3 Final documentation

A complete set of drawings shall be provided for each unit.

- As-built drawings
- FAT reports
- Operating and maintenance instruction manuals
- Electrical system operating and maintenance manuals
- Spare part list
- Sub-Supplier documentation.

8. Other reference

Following standard is applicable: [IEC 62402](#).