EXCITATION AND AUTOMATIC VOLTAGE REGULATOR SYSTEM

Note : example of specifications from a particular final user , that fix the general guidelines of the equipments manufactured by SEPAC CORP

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1. OBJECTIVE AND APPLICATION FIELD

This specification establishes the characteristics and procurement requirements that shall be met for the equipment for the upgrade of the generator excitation system for the generators of _____.

2. STANDARDS AND GUIDES THAT APPLY

IEC 255-22-4	Electrical Disturbance Tests for Measuring Relays and Protection Equipment Section 4: Fast Transient Disturbance Test.
IEC 22.3-1989	Electrical Disturbance Test for Measuring Relays and Protection Equipment Section Three: Radiated Electromagnetic Field Disturbance Test.
IEC 255-22-2	Electrical Disturbance Test for Measuring Relays and Protection Equipment Section Two: Electrostatic Discharge Test.
IEC 61000-4-2	Testing and Measurement Techniques Electrostatic Discharge Immunity Test.
IEC 1000-1-1	Electromagnetic Compatibility (EMC) Part 1: General: Section 1: Application and Interpretation of Fundamental Definition and Terms
IEC 1000-4-1	Electromagnetic Compatibility (EMC) Part 4: Testing and Measurement Techniques Section 1: Overview of Immunity Tests. Basic EMC Publication
IEC 1000-4-4	Testing and Measurement Techniques Section 4: Electrical Fast Transient/burst immunity test Basic EMC Publication.

3. DEFINITIONS

For this specification the following definitions are considered:

3.1. Discharge Circuit

This circuit is comprised of devices that allow the insertion of a discharge resistance in the field winding terminals of the generator during a de-excitation sequence, in a coordinated form with the opening of the field switch. This circuit must consider the use of a varistor as an element of protection against overvoltage.

3.2. Initial Excitation Circuit

The devices that allow the initialization of the excitation of the generator through the external supply sources.

3.3. Power Stage

The equipment that supplies field current for the synchronous machine (generator) excitation, comprised of an: excitation transformer, rectifying bridge, and power bars and/or buses, or AC and DC and sectioning elements.

3.4. On Line Generator

The operative condition of the generator when it is connected to a power electrical system, and is delivering active power and/or reactive to the electric network.

3.5. No load condition
Operative condition of the generator when it is at nominal speed and voltage in terminals, and is not connected to the electric power system.

3.6. Field Switch
Allows connecting and disconnecting the output of the excitation system to the field winding of the generator.

3.7. Alarms and Signaling
The devices that contain signal information and indication of the operative state of the excitation system.

3.8. Protection
The equipment which protects the excitation system devices when abnormal conditions, failures and/or incorrect operation are present.

3.9. Voltage Regulator
An automatic control system that maintains the voltage in the armature terminals at a value defined by a reference element.

3.10. Excitation System
The equipment that contains control and power elements which provide the required field current to maintain the voltage at the generator terminals under the voltage regulation or field current regulation operation. Additionally it contains the protection, monitoring, logging and sequence control functions.

3.11. Ceiling Voltages
The absolute maximum values of the DC positive or negative that the excitation system can supply at its terminals when the generator is rotating at nominal vacuum speed conditions.

3.12. Event Logging
Storage function with time-stamping of the state changes of the internal and external logic conditions of the excitation system associated with the protection operations, limit switches, excitation and stop sequences.

3.13. Failure Logging
Storage function with time-stamping of internal and external analog signal forms of excitation associated to currents, generator voltages and the excitation system as well as the control signals.

3.14. IRIG-B
Designation of the standard that defines the characteristics of time reference codification.

3.15. Power Outlet
AC terminal connection for supply of auxiliary test equipment and maintenance

3.16. Automatic Channel
Control loop associated with the terminal voltage regulation of the generator.

3.17. Field Current Regulator

An automatic control system that maintains the field winding current with a value defined by a reference element.

3.18. Manual Channel

Control loop associated with the regulation of field current.

4. SCOPE OF THE SUPPLY OF SERVICES AND EQUIPMENT

The scope of the providers supply includes the excitation system components as indicated in Figure No. 1,

The supplied equipment will include the required elements to couple the equipment to the excitation transformer and existing buses. The scheme indicated in Figure No. 1 has a descriptive not limitative function. The detailed requirements follow:

a) Two Excitation Control units operating under a mutual redundant scheme capable of realizing:
   - voltage regulation functions on the generator terminals,
   - field current regulation,
   - parameter measurement,
   - reactive compensation,
   - Automatic-Manual-Automatic tracker/follower/sequence?,
   - on-service system-redundant system tracker,
   - Power Stabilizer,
   - Limit switches,
   - excitation and de-excitation sequences,
   - transfer sequences,
   - alarms,
   - protections,
   - coupling and coordination with trigger logic of the turbine-generator-transformer set,
   - failure and event log,
   - time synchrony via IRIG-B port for the time-stamping of events and failures,
   - data communication and transfer,
   - complete redundancy,
   - configuration of trigger logic, and
   - complete configuration of parameters.

b) All the sensors required for the regulation and compensation functions required for the operation of the excitation control units.

c) **Power Stage**: The power stage required in this specification considers the substitution of the thrystor banks, the required modifications to current interconnection bars and disconnecting switches, the current excitation transformer will be used.

d) **Field Switch and contact for insertion of load resistance**: This switch shall be installed between the output of the thyristor bank and the field winding. It shall be electromechanical with

extinguishing chambers of magnetic arc blow, and a command bar for common operation of the main contacts and the insertion contact of the unload resistance.

e) **Initial Excitation Circuit**: The adequacies required to use the current initial excitation system supply (125 V dc supply)

f) **Unload Circuit Controlled by Auxiliary Contact of the Field Switch**: It must have an overvoltage varistor and Crow Bar protection array.

g) **Shunt Resistances**: Are required to have a current field measurement between the thyristor bank and the field switch, as well as the field current measurement between the field winding brush steps and the field unload elements.

h) **Cabinets**: The cabinets of the excitation system (voltage regulator cabinets, of rectifier bridges, field switches, excitation and de-excitation circuits) must form only one board (self-supported, rigid, designed for interior installation with panels that have front and back door access, inputs for the wiring and power cables via the upper and lower part, a steel base and a mounting channel.) The doors shall be hermetically sealed to dust. The cabinets of the rectified bridges and field switch shall also be explosion-proof. The dimensions of the cabinets shall allow its installation in the current location of the excitation systems.

i) **Configuration and Adjustment Software**: With failure event extraction for cases when the operating system in which the system operates is not available on the maintenance personal workstation of the central, the licenses of the required operating system shall be provided.

k) Communication interfaces required for the configuration terminal and each of the excitation control units.

l) Spare parts and special tools included in the Particular Characteristics

m) Mounting, installation and deployment of equipment with the materials included in the scope of the supply.

n) Training

o) Tests

p) Diagnostic equipment for programming, maintenance, and regulator tests and the application programs needed for the real-time logging of the process in the executed tests. The application programs and operating systems shall include the correspondent licenses.

q) Field voltage and current measurement, generator terminal voltage, active power, reactive generator power, frequency, Manual balance (Automatic with local indication on the excitation system cabinets.)

r) Voltage measurement, field current, balance, operation mode indication (Automatic or Manual.) Indication on the service excitation control unit and remote indication on the control console of the unit.

Self-Diagnosis
The excitation control units shall have a self-diagnostic function that allows the detection of internal failures in the control system. This function shall operate in a continuous form and generate a history of the detected events.

This function shall permit queries via the communication ports using diagnostic software, and should indicate its operating state through the state indication panel.

Disturbance and step test circuit
In the local indication panel, there shall be a device to produce analog signals for disturbance and step tests.

s) Auxiliary power supplies for dc/ac and ac/dc with redundancy, automatic transfer and failure and transfer alarm.

t) Information updated to the latest version at delivery date of the technical proposal of operating, maintenance and service instructions shall be supplied. Delivery of this information is required in a printed manner with a massive storage backup (PDF format on CD.) This information shall be updated to the date of start of operation to ensure that any modifications or corrections are included. The provider will supply the licenses of the required operating system.

u) Factory and on-site tests.

5. DESIGN CONDITIONS

5.1. Environmental Conditions
The boards and cabinets of the excitation system and the equipment contained shall be designed to operate at an environment temperature in the interior of –15 to 65℃ and relative humidity of 10 to 95% without condensation. All the equipment shall be designed to operate in a corrosive environment.

5.2. Operation Altitude
The excitation board must be designed to operate at a maximum altitude of 1000 (meters over sea level.)

5.3. Seismic Design
The system shall be designed to tolerate the effect of seismic movements, proper to the location of the installation.

5.4. Noise Level
The maximum allowed noise level is 75 bD at a distance of one meter from the cabinet at the maximum excitation power stages.

5.5. Transient Interference

The excitation system shall be designed to tolerate high-frequency electro-magnetical fields, electro-static discharges, transient radio-interference and transient overvoltages according to the tests established in Section 10.7 Technological Tests

6. CHARACTERISTICS

6.1. General

The excitation system shall be provided in cabinets that are constructed from fire delaying materials. The system must be capable of continuous operation in all the components and adequate from for the design conditions indicated in the previous chapter.

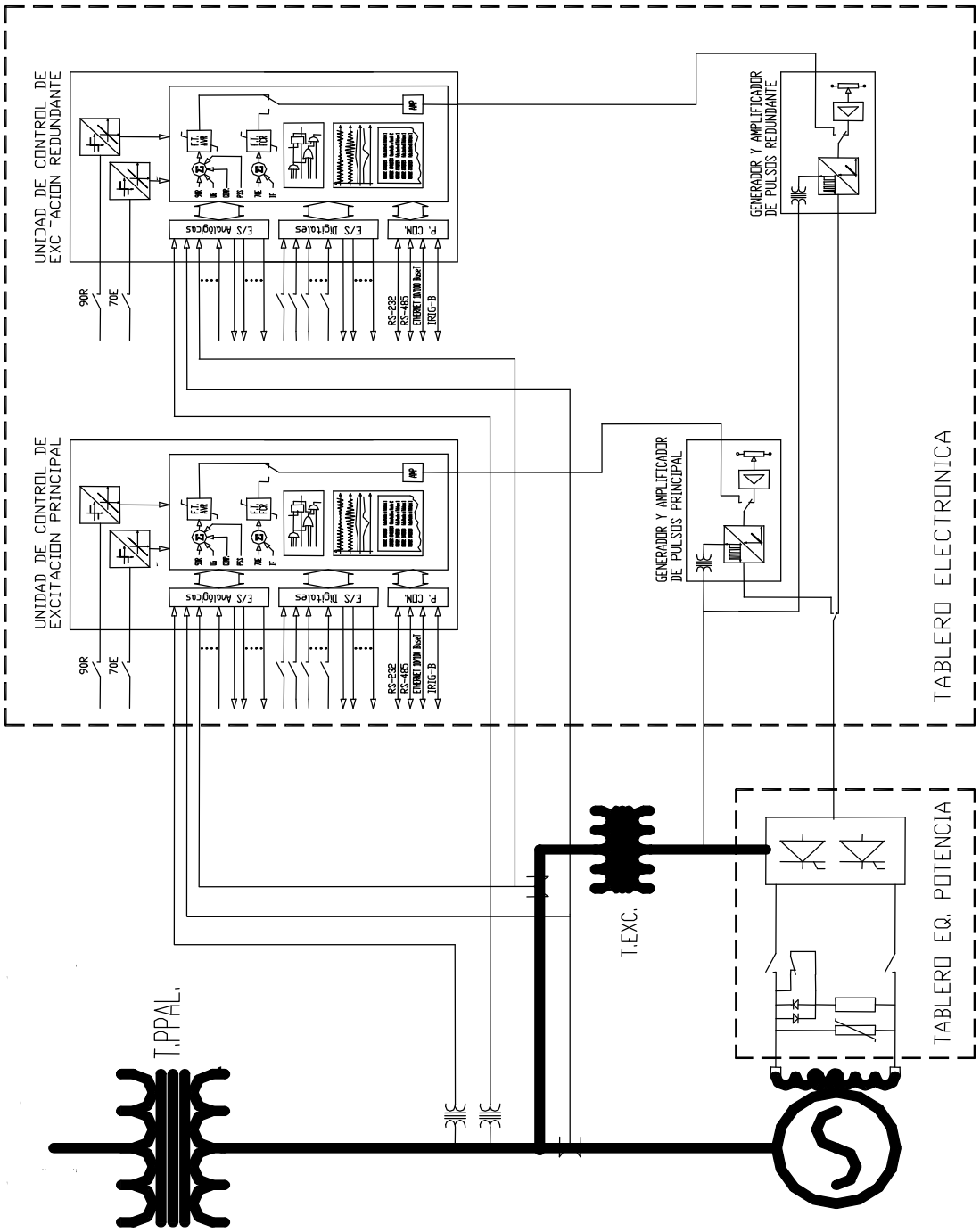

Figure. No.1 Schematic diagram of the Excitation System

It must be capable of providing the ceiling voltages that are specified in the particular characteristics.

All contacts of the protection devices, auxiliary and reserve that are included in the control circuits, protection, remote alarms and transductors will be wired to terminal terminal blocks grouped for external connection.

The components and electronic modules or the excitation system shall be of proved technology.

No technology different from those previously tested by the provider will be allowed. Demonstration of its reliability during operation at other installations for a period of time not less than 1 year shall be required; the information that endorses this point will be provided as part of the documentation contained in the technical proposal.

Neither components that contain devices with factory identification deleted, nor electronic modules embedded in resin will be accepted.

The supplied AC and DC equipment shall operate correctly and without deterioration for the normal life of the equipment between maximum and minimum limits indicated below:

For the thermo-electric central, the supplier shall consider a three wire three-phase system with a nominal voltage of 480 V ac between Phases @ 60Hz, for the supply of the auxiliary equipment. A system with a nominal voltage of 125 V dc for the cabinet wiring circuits, polarized power outlets, and 127 V ac for isolated ground power outlets with isolation transformers @ 300 VA minimum per power outlet.

Supplies - 480 V ac, 127 V ac, 125 V dc according to the use voltages

For 480 V ac minimal voltage of 424 and maximum voltage of 508

For 127 V ac minimal voltage of 96 and maximum voltage of 140

Para 125 V dc minimal voltage of 100 and maximum voltage of 140

Frequency variation of 5%

6.2. Regulation and Control Elements of the Excitation System

It shall contain two independent excitation control units operating under a redundant scheme. These shall be constructed based on digital microprocessor technology with numerical processing signal covering in the regulation channels from the signal retro-supply input to the output signal of the generator control trigger pulses to the thyristors as well as all the processing of signals in a logical state.

Each excitation control unit, will have voltage regulation signal channels with independent inputs to which THE USER will install retro-supply signals taken from different power transformers in the generator terminals.

The excitation control signals shall contain the following functions:

a) Two independent excitation control units operating in parallel in a redundant scheme, each shall contain:
   - One voltage regulation generator channel (automatic channel)

- Reactive compensation
- Limit switches minimal voltage
  Over excitement
  Volt/Hertz
- Stabilization of the power system
- Sequence Automatic - Manual – Automatic
- Automatic – Manual - Automatic tracker
- Main – Redundant tracker
- Logic control for operation of startup sequences - stop or system alarms of the excitation systems
- I/O interface for:

  Analog inputs

  - Field current retro-supply
  - Field voltage retro-supply
  - Generator voltage retro-supply
  - Analog signal for step test purposes (connected to a sum point of the error comparison device)
  - Signal for future input to the error detector (connected to a sum point of the error detector).
  - Additional signals required for other system modules

  Analog opto-coupled internal outputs 0-1 mA maximum charge 10 kOhms in connection terminal blocks for the following signals:

  - Active power
  - Reactive power
  - Generator Voltage
  - Generator current
  - Field voltage
  - Field current
  - Trigger pulse control voltage
  - PSS Input
  - PSS output
  - Frequency
  - Automatic channel reference signal
  - Manual channel reference signal

  State outputs with dry contact form “C” with a capacity for 125 V dc. 10 amp.

  - Generator main switch
  - Field switch
  - Initial excitation switch
  - Indication of PSS in service
  - Indication of Automatic-Manual channel in service
  - Limit switch operation Volt/Hz
  - Minimum excitation limit switch operation
  - Maximum excitation limit switch operation
  - Operation of excitation system failure trigger
  - Indication of the high-low limit automatic channel reference
  - Overvoltage of field winding

- Indication of hi-low limit manual channel reference
- Indication of on-service excitation control unit (2)

Digital state opto-coupled inputs @ 125 V dc.

- PSS remote enable-disable command
- The required by system design

- Communication ports for configuration and extraction of logs;

  1 EIA/TIA 232 configurable port EIA/TIA 485 for monitoring and configuration

  1 EIA/TIA 232 configurable port EIA/TIA 485 for monitoring

  2 Fiber optic interfaces for EIA/TIA RS-232 port

  * These ports can be replaced or auditioned by:

    1 10/100 BaseT Ethernet port with TCP/IP protocol

    2 Fiber optic Ethernet 10/100 base T Ethernet ports

- Time synchronization port

  1 IRIG-B for time synchronization of internal event logs

b) Redundant and independent power supplies for each excitation control unit. Each of the redundant power supplies of the excitation control units shall operate with 125 V dc, switchable automatically and without disruptions transient to 127 VAC self-supplied from the excitation transformer.

c) The voltage regulator must be capable of presenting the following characteristics:

- A response with an over-step lower than 25% of the step of .01 PU applied in vacuum without reaching ceiling voltages.
- Response time lower than 0.25 s
- Stabilization time lower than 1 s
- Lessening coefficient between 0.5 and 1
- Lesser coefficient between 0.5 and 1
- Open loop frequency response; a face margin equal or greater than 40° and a gain margin greater than 6 dB.
- Peak value of the amplitude of the response lower than 4 dB.

d) The voltage regulator must be delivered with the following information:

- The manufacturer must provide the cut frequency (ϖc) and the gain of the low frequencies of his system.
- For closed loop it is required that the manufacturer provides the bandwidth and frequency in which the peak value of his system occurs.
- The time needed to reach 95% of the difference between the specified ceiling voltage and the nominal field voltage with load, which should not exceed 25ms for a sustained decrease in voltage on a specified time (IEEE Std. 421.2.1-1990).
- Mathematical model and transference function for both the voltage regulator and the power stabilizer (PSS)

e) A laptop computer, to configure the parameters of the voltage regulator, field current regulator, logic and i/o of the excitation control units. This laptop computer must contain all required accessories including interconnection cables, proprietary communication interfaces for the excitation control units, software licenses and manuals. In addition, it must have the following characteristics:

- Portable processing unit, minimum processor speed 1.6 GHz, 256 MB memory, 30 GB hard disk, CDRW unit, 1.44 MB 3.5" floppy unit.
- Graphical multitasking operating system
- 10/100 baseT Ethernet card with TCP/IP protocol
- Graphical environment, multitasking software applications for configuration, diagnostics, event and failure log extraction.

6.2.1. Pulse Generators and Amplifiers

Each excitation control unit must have an independent trigger pulse generator and amplifier and the required circuits to operate over any of the two banks of rectifiers in any operation mode (independent or simultaneous.) The power supplies of the generators and pulse amplifiers must be independent.

6.2.2. Automatic Channel Reference (90R)

It must generate a reference signal in a continuous range of the generators nominal voltage between 80% and 110% from a vacuum operation to full load with steps no larger than 0.5% of the adjustment value and cover this interval lineally in approximately 1 minute. It must have indication on the local and remote alarm panels when it reaches its low and high operation limits. The operation of the 90R must be local to the excitation control units, and remote from the control unit console. The 90R must be of static type, no motorized devices will be allowed.

6.2.3. Manual Channel Reference (70E)

It must generate a reference signal in a continuous range of the generators nominal voltage between 30% and 110% from a vacuum operation to full load with steps no larger than 0.5% of the adjustment value and cover this interval lineally in approximately 1 minute. It must have indication on the local and remote alarm panels when it reaches its low and high operation limits. The operation of the 70E must be local to the excitation control units, and remote from the control unit console. The 70E must be of static type, no motorized devices will be allowed.

6.2.4. Reactive Compensator

It must be adjustable to compensate for any value between –12% and +12% in steps of 1% from the generators synchronous reactance (Xd).

6.2.5. Low Excitation Limit Switch or Internal Angle Limit Switch

In the region of sub-excitation, it must limit the operation of the generator. It shall allow adjustment to limit the operation of the unit according to the allowed interval by the generator's capability curve. The operation of this limit switch must generate an alarm signal that shall be installed in the excitation system boards, the control console and the event logger.

6.2.6. Maximum Field Current Limit Switch

In the region of over excitation it must prevent the overheating of the rotor winding according to the operation interval allowed by the capability curve of the generator. It shall operate with a characteristic of inverse time and when it approaches the damage region it shall reduce the excitation to place the generator in a secure operation zone.

6.2.7. Volts/Hertz Limit Switch

It must operate adjusting the generators voltage to avoid $(V/V_{nom})/(Freq/Freq_{Nom})$ entering the overheating damage zone of the generator, the main transformers, of services and excitation.

The regulator shall provide access for programming all the required adjustments. This limit switch protects the transformer and the generator from high Volts/Hertz conditions.

6.2.8. Power System Stabilizer (PSS)

It must detect system oscillation conditions expressed in the generator through power variations, frequency or speed, from which it shall generate a compensation signal and introduce it into the control loop to produce a lessed response which, in effect, improves the generator's stability. The input signal to the power stabilizer can prevent the rotor speed (w), or the frequency (Hz) or the electric power (MW) of the generator.

When operating, the power stabilizer should not have action during the operation of the load variator (65P), the frequency compensator (FC), the joint control and others that exist in the generation unit. The regulator shall provide access for programming of all required adjustments. For testing purposes, a diagnostic mode in which an analog output with indication of PSS operation is required. When the PSS is disabled, it must illuminate a light on the board of the voltage regulator.

The power stabilizer must be provided with an enable/disable function via a command available in the excitation system boards and the control console.

6.2.9. Field Current Regulation Channel (Manual Channel)

Each excitation control unit must have a regulation operation mode for field current, which will operate considering as reference the signal generated by the manual reference device 70E.

In this mode of operation, it must have adequate logic for when the unit operates in manual, and has a machine switch opening. The current reference is automatically adjusted to the value of current corresponding to the nominal vacuum voltage.

6.2.10. Automatic Tracking

The excitation control units shall have automatic tracking of the controlled parameters (field current, armor voltage) in both channels and between both excitation control units in a bi-directional form. This is necessary to allow automatic channel transfer or vice-versa of the main excitation control unit and the redundant excitation control unit, or vice-versa, with no disturbances in the generator voltage.

A transfer failure alarm shall indicate the type of failure. It shall have two balance measurers (with central zero) located in one of the cabinets of the voltage regulator and the other one in the units control console.

6.3. Transfer Logic Between The Excitation Control Units

The transfer logic shall operate giving priority to the voltage regulation functions before power transformer failure associated to the retro-feed or before total failure of the excitation control units. The field current regulation functions should only activate before a voltage regulation failure available through both excitation control units.

The transfer logic will operate both ways. If it has been transferred from unit 1 to unit 2 for a fuse failure of the voltage transformers and these have been re-established, the unit 2 shall transfer under a failure condition in its voltage regulation function to the unit 1.

The transfer of the excitation system to a field current regulation channel will only occur when the voltage regulation channels of both units have failed. When the system has re-established the functionality of an automatic channel in one unit, the system will indicate this condition, the transfer of the field current regulation channel to the voltage regulation channel will be realized in an automatic manner.

6.4. De-excitation Process

For the normal stop sequence of the excitation system, the operation of the thyristor bridges with negative voltage is required until the complete unload of the field winding, prior to the opening of the field switch.

For the emergency stop sequence, the field switch shall be capable of disconnecting the field winding in an immediate fashion coordinated with the operation of the unload devices.

6.5. Internal Control Sources

They must include all regulator filters, inverter, transformers, ac/dc sources, ac/dc converters and all that is required to condition the supplies provided by the auxiliary services network and battery banks of the central to required values internally, both of AC and DC.

6.6. Signaling and Alarms

It must have the required devices for visual alarm signaling and operative condition signaling in the boards of the power devices (rectifier bridges and field switch), in the board of the excitation control units and in the console of the generator control console.

6.7. Power Stage

6.7.1. Rectifier Bridges

It must be full wave three phase, with the number of rectifier bridges needed so that in case of the failure of one, the remaining one can operate without restriction to the maximum values required by the unit, besides complying to the following:

a) The rectifier bridges in service shall be activated by the pulse generators and amplifiers of the excitation control units.

b) The design of the ventilation equipment must be such that it avoids the entrance of foreign objects into the thyristor bridge, which can damage the bridge. The supply of the fan(s) must be taken from a dry type transformer, connected to the excitation transformer or for test purposes from the force supply provided from the auxiliary services network. The operation of the fan(s) shall be in Manual mode for testing purposes, and in Automatic when the unit is operating.

The cooling of the tryristors shall be from forced air through the fans. Each bridge shall have a minimum of two fans. Only one fan shall be required to maintain the temperature in admissible ranges for continuous use of the unit in normal operation with maximum load. The fan(s) shall have control, protection and failure signaling circuits.

For test or special conditions it will have an additional array of contacts to switch to an external power source.

c) There shall be unbalance current supervision in the rectifier bridge branches that shall send signaling to the local and remote alarm panel.

6.7.2. Excitation Transformers (does not apply)

6.7.3. Bars and/or Power Buses of DC and AC

From the current installation of AC bars and DC buses, the supplier will supply the required components for the interconnection of the cabinets and the excitation transformer to the thrystor cabinet and the thyristor bridge to the field winding of the generator. These components shall be capable of current conduction to accomplish the heat dissipation and temperature rise indicated in norm ANSI C37.23, under any operation condition of the unit. The surfaces for connections shall have a protection metallic coating.

For the case of thermo-electric centrals, the non segregated face bus for this interconnection shall be of outdoor type and include wall (if required), besides complying to the aforementioned.

The interconnection between the output cabinet of the excitation system and the field generator shall be done using copper bars with metallic surrounding.

Inside the cabinets of the excitation systems, an array for polarity change with “out of service” generator for inversion of the field circuit outwear balancing of sliding rings, shall be provided.

6.7.4. Field Switch

The field switch located on the output of the DC of the thyristor bank, and shall be capable of disconnecting the field generator circuit under the most adverse voltage conditions and current that the excitation and de-excitation systems produce under normal or failure conditions. The field switch shall have:

(a) Two contacts with arching cameras for disconnecting the field circuit and a contact with arching camera for insertion of the unload resistance. These three elements shall be operated from the same mechanical operation bar.

(b) Buttons located on the local board of the automatic voltage regulator as well as the control unit console to open and close the equipment. Buttons shall provide local and remote state signaling of the switch, as well as a local/remote excluding control selector.

(c) Mechanical opening device, without being included its operation in the blocking logic.

(d) Twelve auxiliary contacts with configurable image switch, between normally open and normally closed.

(e) Mounting in a cabinet with flexible bridles and links to connect the connection bars to the thyristor bank and the output of the brushes of the generators field winding.

6.7.5. Initial Excitation Circuit

The initial excitation circuit shall be capable of taking the voltage from the generator from zero up to the voltage required for the initial operation of thyristor bridges under the control of the voltage regulator or the field current regulator, from a 125 V dc supply. Its operation shall be in Automatic mode when an excitation order on both modes of operation (manual/automatic.)

6.7.6. Unload Circuit

This circuit shall have a unload resistance of non-lineal dependent characteristic in terminals that will be inserted by the corresponding contact of the field switch during the de-excitation sequence under normal stop or emergency stop.

6.7.7. Overvoltage Supressor

A protection system for overvoltage of the field winding to operate a Crow Bar type device, should be included.

6.7.8. State Indicators And Control Commands

The control command selector (transfer between operation channels, opening and closing of field switch, excitation raise/lower), as well as the state indicators required by the excitation system, shall be supplied and be installed in the control boards.

6.8. Protection

The excitation system shall have protection that supervises and ensures that the system is maintained inside its design operating conditions, and protects it in case of failures, with trigger and signaling in the local-remote alarm panel.

The operation of all protection, as well as related alarms, will be contained in the excitation system event logger.

6.8.1. Regulation Channel Protection

It must have protection that monitors the correct operation of the devices that comprise the voltage regulator.

When a transfer occurs from the automatic channel to a manual channel by the operation of some protection, a signaling indication that the transfer was automatic shall be provided. For the case of manual transfers by the operator, the aforementioned signaling shall not be provided. As minimum, the following protections will be included:

6.8.1.1. Retro-Supply Loss Protection

Protects in case of a failure in the retro-supply circuit for some unbalance in the phases or loss of phase. The corresponding transfer shall be realized to the redundant excitation control unit or, in a case where the redundant excitation control unit is failing, it transfers to the field current regulation channel.

6.8.1.2. Protection for Field Overcurrent.

This protection operates when the detected field current in DC exceeds the allowed limits by the rotor and cannot be controlled by the proper devices of the Automatic/Manual channels.

6.8.1.3. Protection for Power Supply Loss

This protection shall operate inside the "total failure" logic of the excitation control and initiate transfer to the redundant excitation control.

6.8.2. Protection of the Rectifier Bridge

The rectifier bridges shall have protection that monitors and protects when the generator is on-line. If a failure of the rectifier bridge occurs, the failing bridge must be blocked and maintain the rest operating.

6.8.2.1. Protection for Thyristor Overcurrent

This protection protects against excessive current conditions, and can affect the operation of the thyristors. It should be done through ultra-fast fuses installed in each thyristor, provided with contacts for alarm and signaling for the protection circuit for failure of thyristor. The operation of this protection shall block the failed bridge and maintain the rest of the rectifier bridges operating.

6.8.2.2. Protection for Thyristor Overheating

The voltage regulator shall have temperature sensors for each thyristor bridge. The operation of this protection shall block the failed bridge and activate transfer to the other rectifier bridge. If this is not available it should trigger an excitation system failure.

6.8.2.3. Protection For Over-Heating Of Overvoltage In Field Winding

This protection limits the overvoltage in the thyristors produced by any internal or external condition that generates overvoltage in the field winding that exceeds the capacity of the excitation system components.

6.8.2.4. Protection For Failure Of Trigger In Thyristor Gate

This protection supervises the continuity of the trigger pulses of the thyristors in an adequate form. The operation of this protection shall send a transfer to the redundant excitation control unit that has its own independent pulse generator.

6.8.2.5. Protection For Cooling System Failure

The operation of this protection shall send a block to the affected bridge and an alarm to the control panel and unit operation console. In case no existing bridge is in service to backup the load, a stop sequence must be generated.

6.8.2.6. Volts/Hertz Protection

It should operate with an adjustable delay time when the voltage exceeds the acceptable (V/V_{nom})/ ($Freq/Freq_{Nom}$) relation for the generator, the main, service and excitation transformers.

The regulator shall provide access for programming to all the required adjustments to protect the transformer and regulator from high Voltz/Hertz relations.

6.8.3. Protection for Field Winding

6.8.3.1. Protection For Failure Of Ground To Field Winding

The detection device for a ground failure in the field winding shall measure the capacitance of the field winding to ground, which will operate based on the response of this capacitance before the injection of a signal generated between the square wave oscillator and a distortion detector, that affects the variation of the capacitance associated with the winding isolation produced by isolation failure and damage in the brush contacts.

It should detect the damage process of the field winding isolation with an alarm when the isolation impedance is lower than 20 Kohms and trigger for an impedance to ground lower than 5 Kohms.

6.8.3.2. Protection For Damage of Brush Contacts

It shall detect damage in the brush contacts of the field circuit and the flexible twist of the grounding of the rotors arrow based in the principle indicated in the previous point.

6.8.4. Other Protections

As a minimum, it should contain the following functions:

6.8.4.1. Protection for Long Time in Forced Excitation

The purpose of this protection is to maintain the integrity of the excitation system and must operate when the initial excitation exceeds the time established for a normal sequence, this time should be defined by the manufacturer.

6.8.4.2. Protection for Overvoltage (Crow Bar)

Its purpose is to protect the rectifier bridges and the generator field from overvoltages for transient associated with de-excitation sequences, unloads, asynchronous operation and defective synchronization maneuvers.

6.8.5. Event and Failure Logger

The excitation system shall have a failure and event logger that can be integrated to each of the excitation control units, as long as they operate in a simultaneous way. Under the rest condition of the regulation and control functions, this logger can be contained in an external mode to these units.

6.9. Cabinets

They shall be wired to the ground network at just one point using a connector for copper wires of 2/0 to 4/0 AWG caliber.

They shall have exterior and interior tropicalized? finish with adequate coating, and selected according to specifications THE USER D8500-01, D8500-02 and D8500-03. In addition, all the bases, screw tracks, supports, washers and other metallic accessories should be galvanized by hot immersion method. All of the components and materials should be resistant to fire propagation.

The cabinets shall be supplied with a heater supply bus with thermo-magnetic switches in molded box of the following characteristics:

- general 3 pole switch, 127 V ac, 30 A and switches in each section of a pole, 127 V ac and 15 A.

The space heater should be:

a) For continuous operation with insertion–extraction device.
b) Of adequate capacity.
c) Protected with metallic meshes.

6.9.1. Wiring, Conductors and Terminal Tablets

The wiring inside the cabinets or boards for connection to external circuits, shall be taken to the terminal terminal blocks using water-proof conduit and accessories, unless the control devices are mounted in an outdoor resistant cover or that the contrary is specified. The placement of doors and modules should not cause modifications in the connections and wiring.

The terminal tablet shall be molded in thermo-fix, isolating, fire propagation resistant, halogen free material designed to avoid accidental contact with energized metallic parts, adequate for connecting only one solid or flexible conductor, labeled and including accessories as separating bars, bridges, test pins, etc.

The terminal terminal blocks and accessories shall be tropicalized to operate efficiently in humid and corrosive environments. The contacts of the control devices not used shall be wired to terminal terminal blocks for future connection to external circuits.

The connections inside the cabinets should be labeled on conductors and terminal blocks.

The conductors used for wiring to the boards, shall comply to the characteristics indicated in specifications THE USER E0000-24, E0000-25 y E0000-26, and shall be protected against cabinet borders and edges.

The connections to a common exterior cable should be located on terminals next to the same terminal block using bridges. The isolation and clear to ground should be designed in such a form that live parts support a voltage test of 1500 V @ 60Hz during one minute.

The signals and voltages of the instrument transformers current shall be concentrated in a connection block that allows the insertion of measurement equipment for testing purposes. Without interfering with the normal operation of the excitation system, it must supply the required accessories in the event that a connection block requires it.

6.9.2. Terminals And Terminations Of Force Cables

The terminal blocks should have terminals for machine screws of number 8 or 10 and with barriers between terminals. No pressure or staple shoes should be used.

The termination of the cables in the terminal blocks should be shoes of eye type with isolated socket.

Open shoes are not accepted. The eye shoes shall have enough mechanical resistance to not break with the vibration of the equipment in which they are installed.

6.9.3. Control And Instrumentation Cable Terminals

The connection mechanism of the terminals should be of staple type with screw, vibration tested, protected against the corrosion of salt environments, with wide contact areas that fasten, prevent the incorrect insertion and maintain a continuous contact with the conductor.

The conduit used for cable tending from the switches, controllers, etc, to terminal boxes and other components, should be of rigid steel, galvanized and of thick wall 19 mm diameter as a minimum. When flexible conduit is used, it must be sealed with an adequate cover. The conduit is not used as a ground conductor, a copper conductor is used for that purpose.

The conduit array must be done in such a way, that they drain condensed humidity to the terminal boxes.

Condensation shall not leak over the electric contacts or sensible parts. The conduits entering the cover and terminal boxes should be screwed.

The conduit unions and wiring armor, should secure its continuity to the ground power.

It should be foreseen that the equipment is connected to the ground system of the generator unit.

7. MANUFACTURING REQUIREMENTS

a) The equipment shall be manufactured according to the latest manufacturing norms and the best designs that exists currently, complying to the concepts indicated in sections 2,4,5 and 6.

b) During the manufacturing period, the provider will report monthly, in a direct fashion or via its representative before THE USER, the advances in manufacturing.

c) It should be demonstrated that the proposed equipment has been working for a minimum period of one year in a similar installation. If this can not be proved to CFE's satisfaction, the proposal will not be considered.

d) THE USER reserves the right to name a representative to prove the quality of the materials, manufacturing works and project advances.

e) During the equipment manufacturing, THE USER will reserve the right to testify that all the regulator and excitation system parts comply to the technology of the most modern design available and proved. The supplier will warrant that its obsolescence will cover at least 10 years from the date in which the order has been fulfilled, and that spare parts will be available during that period of time.

8. PACKAGING AND SHIPPING

The conditioning for packaging and shipping shall comply to specification THE USER L0000-11.

9. QUALITY ASSURANCE

The supplier will have a quality assurance system that complies to the requirements established in specification THE USER L0000-31. Supplier shall:

a) Warrant that the material and workmanship is free of defects and that it is of the type and quality specified, and will operate in the manner described in the proposal.

b) Notify the LAPEM of THE USER the test program, as well as provide the in-factory test protocols.

10. TESTS

10.1. Factory Tests

The wiring of each individual part of the equipment shall be installed, connected and verified by the supplier prior to shipping, unless other arrangements have been approved. THE USER reserves the right to be present at all the tests that they deem necessary, with all of their technical personal. The prior statement does not free the supplier of his responsibility.

In factory and during the equipment manufacturing, the manufacturer must execute the usual tests according to his experience and quality assurance, taking as additional tests THE USER proposes.

The supplier must attach in his proposal a list of the in-factory tests to be performed, and deliver a report of these tests. As well as deliver to THE USER a schedule of the tests, minimum 30 calendar days before the beginning of the tests, to allow for THE USER technical personal assistance; the

supplier must accept all feed back and perform additional tests if THE USER thinks they are required.

The rectifying equipment, regulators, logic and register control shall comply to all the aspects this specification mentions, in what refers to electronic susceptibility before internal and external electronic transients, for which it must comply to the electro-magnetical compatibility norms indicated, for substantiation. All internal noise tests, emitted radiation, radiation susceptibility, capacity to support transients (SWC), dielectric, temperature, humidity, burn-in, vibration and free-fall, should be executed.

The manufacturer shall exhibit certificates of accredited entities the accomplishment of the characteristics involved in the offered equipment.

10.2. Excitation System Tests

Testing procedure:

THE USER shall be provided with detailed and complete test procedure for the control systems, 100 days prior to delivery.

This Acceptance Test procedure shall be presented in a form ready for verification, and must be used during testing. Each test must include the following:

- system status before test,
- action that should be executed,
- results, system operation and final state.

In-factory simulation tests:

The simulation test should be executed with all system components in operation. THE USER reserves the right to be present at all the tests that it deems necessary, with its technical personal. This does not free the supplier from responsibility.

Rectifier bridge tests:

- low load voltage,
- of maximum current.

Measurement of the trigger pulses to the thyristor.

Checkout of all alarm circuits and protection trips.

Isolation test of the wiring (High-pot) with the thyristor (SCR's) in short circuit to avoid damaging them (only performed in-factory).

All the components subject to high voltage, shall be calculated for their operation at the highest rms line voltage and must pass all dielectric tests (high-pot) with application of 2.5 times the maximum rms, plus 1000 V during 1 minute.

10.3. Other Equipment Tests

The manufacturer shall provide THE USER with a complete and detailed acceptance test procedure for the testing of protection, cooling system of the rectifier bridges, field switch, etc, 100 days prior to the delivery.

10.4. Field Tests

The field tests are classified in 2 categories:

a) Service tests of the excitation system, that will be performed by the manufacturer in the presence of personal from CFE.

b) Behavior tests that should be performed by THE USER personnel. with the suppliers personal supervision, accepting beforehand that the tests performed will be according to their recommendations, which is why the supplier and its manufacturer shall warrant them in writing.

The damaged parts during the startup process will be substituted by the supplier without any additional charge to CFE.

The cost of any delay caused by a lack of forethought by the supplier during shipment will be covered by the supplier.

The behavior tests of the excitation system will be performed by LAPEMs personal of THE USER, any defect found in the equipment, previous and during the tests, will be corrected immediately by the supplier, on their own account. The tests shall continue and/or be repeated until it has been demonstrated all the equipment is operating according to this specification.

It is vital that at least 5 days before the start of the field tests, the supplier delivers to CFE's personal in charge of the tests, the following documentation:

- Copy of the Generators Capability Curve
- Copy of the Generators Saturation Curve
- Copy of the block diagrams and transfer functions with validation reports of :
  - Generators regulator voltage
  - Current regulator of the field generator
  - Power stabilizer
  - Reactive compensation system
  - Minimum excitation limit switch system
  - Maximum excitation limit switch
  - Volts / Hertz limit switch
  - Listing of the configuration values and the relation of adjustment values of gains and constants, limit switches, compensators and protection of the excitation system.

The penalty to which the supplier will be credited for the incomplete information and report of tests, will apply according to what has been established in the "Lineament for application of conventional penalties for delay in the accomplishment of acquisition contract, leasing and services celebrated with CFE".

The supplier will coordinate with CFE's personal to take special precautions, including the supply of barriers and danger signs for protection against damages to personnel or property during the performance of the tests.

The supplied instruments in local and remote cabinets shall be calibrated adequately by the supplier in acknowledged laboratories, which shall document the calibration to THE USER, by calibration certificates, which will be presented for acceptance.

Based on the results of the field tests, (deployment and behavior), THE USER will supply an acceptance document of the excitation system.

10.5. Tests for Regulation Functions and Excitation System

The excitation system shall be proved according to the procedure THE USER MPSR0-01.

a) The tests recommended by the supplier will be considered.

b) Primary field tests to:

- Transformers
- Switches
- Control equipment
- Excitation equipment
- Instrument transformers (TPs and TCs)

c) Phase sequences (in field)

d) Measurement of trigger pulses to the thyristors

e) Proofing of all alarm and trips by protection circuits

f) Excitation and de-excitation sequences

10.6. Mounting and Preliminary Verification of OperationalTests

The delivery of the excitation system will be performed as indicated:

a) The supplier will deliver on-site the assembled equipment and mounting accessories according to the supply delivery calendar.

b) The supplier will perform all mounting, power link connections, control links and auxiliary links in the dates indicated in the delivery schedule.

c) The provider will execute an on-site verification of the mounting conditions, preliminary tests and application of adjustments and configuration of the excitation system in the dates indicated in the delivery schedule.

d) CFE-LAPEM personal will subject the excitation system to the performance of the operational tests THE USER MPSR0-01 with the participation of the supplier who will perform all the operations and actions required by the excitation system. The excitation system will be inspected and evaluated on-site by CFE's personnel, to verify that the equipment meets the specifications required by THE USER and indicated in section 6.2 point (c) and the test procedure aforementioned.

e) Equipment and personal required for the aforementioned tests will be provided by CFE-LAPEM.

f) The activity calendar for the delivery and inspection of the equipment will be proposed by CFE.

g) Any change to the schedule for the delivery of the equipment will be agreed in writing between THE USER and the supplier.

10.7. Technological Tests

The technological tests are listed in the following table:

#	Name of the test	Norm or specification	Severity level
1	Cold	IEC 60068-2-1	-10 ºC 16 hours
2	Dry heat	IEC 60068-2-2	55 ºC 16 hours
3	Temperature and Humidity	IEC 60068-2-30	-5 ºC a +55 ºC con 95 % HR
4	Vibration	IEC 60068-2-6	0,5 g @ 10 Hz < F< 150 Hz, 10 cycles/axis
5	Lessed Oscillating Wave	IEC 61000-4-12	1 MHz < f < 1,5 MHz 2,5 kV < kV < 3,0 kV of crest of the first cycle
6	Rapid transient	IEC 61000-4-4	± 4 kV a ± 5 kV 5/50 ns
7	Immunity to radiated electro-magnetic fields	IEC 61000-4-3	10 V/m; 80 a 1000 MHz AM 80 %, 400 Hz
8	Voltaje Interruptions and falls	IEC 61000-4-11	Interruptions 95% / 5 s Falls 30% / 10 ms 60% / 100 ms
9	Electro-static discharges	IEC 61000-4-2	Level 4 ± 8 kV contact ± 15 kV air
10	Impulse voltage	IEC 60255-5	5 kV (peak value) 1,2/50 µs three positive impulses and three negative impulses
11	Statistical indexes of reliability MTBF, MTTR, MTBR	Manufacturers specifications	
12	Technical manual	NRF-002-CFE	

11. SPARE PARTS AND SPECIAL TOOLS

11.1. Spare Parts

The supplier will recommend the minimal spare parts required to warrant the excitation system operation during 10 years, describing these in the technical proposal. The recommended parts shall be quoted as optionals, in a detailed form in the technical and cost proposals. If THE USER requires specific spare parts, it will be indicated in the particular characteristics.

The recommended spare parts, will not be part of the supply of the provider and its acquisition is optional for CFE.

11.2. Special Tools

The provider supplies the configurator and accessories for tests and measurements of the excitation system, such as special connectors, specific tools, and specific test equipment for his equipment.

12. INFORMATION

Section 17 describes how the information is required by THE USER, giving the delivery times.

12.1. Manuals

The required manuals, diagrams, instructions, etc, shall be delivered in five sets, in print and in a massive storage medium (compact disk).

The manuals shall describe the procedure for the normal operation and the emergency operation of the equipment. They shall describe and illustrate the mounting, adjustment, operation and disassembly of each component. They shall also be clearly detailed, with identification and electrical parameters of the components in the electric and electronic diagrams, periodicity of the maintenance, spare part identification and typical problems with the recommended solutions, shall include data and adjustment curves in-factory and in field.

The modifications applied during the manufacturing process and delivery shall be integrated in a final revision of the final documentation at the end of the project.

The manuals shall be integrated as established in specification THE USER L0000-32.

No information conditioned by the following arguments shall be accepted:

- “The information contained in this documentation, shall be considered only for information purposes”
- “There can be differences between the descriptive documentation and the supplied equipment”

The information will be property of THE USER, and if needed, the manufacturer can establish the confidentiality agreements with CFE.

12.2. Blue Prints And Instructions

The provider shall supply originals of the block diagrams, schematics, wiring, electric and electronic that are required for its installation, testing, operation and maintenance. The supplier shall supply blue prints and instructions included in section 17.1, that cover the following information:

a) Dimensions, cuts, plants and regulators details.

b) Schematics and mechanical diagrams, electrical, logical and electronic of all the supplied equipment.

c) Complete brochures and instructions of all the equipment supplied and covering its functioning and maintenance.

d) Result of all simulation tests done on-factory.

e) Curves and general and partial behavior of the voltage regulator and the excitation system.

f) Test protocols and calibration of the equipment.

12.3. Parts And Wiring Listing

The provider will deliver a listing of cables connections for all cables that are in the cabinets, including the cable number, type, source and destination, as well as the listing of parts including a small description of each component and its physical location inside the cabinet.

13. INSTALLATION AND DELIVERY SERVICES

The supplier will perform the mounting, installation and delivery of all equipment and materials included in the scope of the supply. The supervision of mounting and deployment will be provided according to what is established in specification THE USER L0000-36.

14. TRAINING AND TRANSFER OF TECHNOLOGY

The training and transfer of technology shall include training courses for installation, testing, operation and maintenance.

Consider the following courses:

- Software for the Operation of the Test Configuration and Diagnostic of the Excitation System.
- Operation of the Configuration and Diagnostic of the event and failure loggers.
- Architecture and hardware components in the excitation system.
- Calculation of adjustments and configuration of regulation, compensation, logic and limitation, protection and logic functions, operation and maintenance of the excitation system.
- The duration of these training courses will be of at least 80 hours, on-site, for a maximum of 15 people, giving the theoretical aspect prior to installation, and a practical post-installation.