EX2100e Excitation Control
35 A and 120 A Regulator Systems
Product Description

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1 Overview

GE has supplied more than 6,000 thyristor and regulator systems in over 70 countries during the last 40 years. The EX2100e Control Regulator system is GE's fourth generation digital excitation control system.

There are over 4,000 first and second generation GE digital excitation controls operating in 60 countries.

The EX2100e Excitation Control Regulator system is GE's most recent state-of-the-art control system for steam, gas, or hydro generators for both new and retrofit units. Control hardware and software design is closely coordinated between GE's system and controls engineering to ensure delivery of a true system solution. Integration is seamless between Excitation Control systems, Turbine Control systems, Static Starter Control systems, Integrated Control Systems (ICS), and the Human-machine Interface (HMI). For stand-alone retrofit applications, integration with customer distributed control systems (DCS) through serial or Modbus® Ethernet is supported. This document specifically addresses applications for the 35 A and 120 A (nominal) series of EX2100e Control Regulator systems.

EX2100e Control Cabinet (35 A Regulator System)

1.1 Acronyms and Abbreviations

ARCC	Active reactive current compensation
AVR	Automatic Voltage Regulator
COI	Control Operator Interface
CT	Current Transformer
DCS	Distributed Control System
ECTX	EX2100e CT Expansion Board
EDFF	EX2100e dc Fanned Feedback Board
EGD	Ethernet Global Data
EMC	Electromagnetic Compatibility
EMI	Electromagnetic Interference
ESYS	EX2100e System Interface Board for Customer I/O
EXAM	Exciter Attenuator Module
FCR	Field Current Regulator
FPGA	Field programmable gate array
FVR	Field Voltage Regulator
HMI	Human-machine Interface
HSLA	High-speed Serial Link Interface Board for Host Application Boards
HSSL	High-speed Serial Link
ICS	Integrated Control System
IGBT	Insulated Gate Bipolar Transistor
I/O	Input and output
PCM	Power Conversion Module
PF	Power Factor
PI	Plus Integral
PMG	Permanent Magnet Generator
PPT	Power potential transformer
PSS	Power System Stabilizer
PT	Potential transformer
PWM	Pulse-width Modulator
RCC	Reactive Current Compensation
RFI	Radio frequency interference
SCM	Shunt Contactor Module
SCR	Silicon-controlled rectifier
SCT	Saturable current transformer
SOE	Sequence of events
TCM	Transfer Control Module
TMR	Triple Modular Redundant
UBC	Universal Building Code
UCSB	Universal Controller Stand-alone Board
UDH	Unit Data Highway
UEL	Underexcitation Limit control
V ac	Volts ac (alternating current)
VAR	Volt-amperes reactive
V dc	Volts dc (direct current)
WBU	Warm Backup

2 Control Hardware

The EX2100e Regulator system is available in several configurations to provide control flexibility for Thyristor and Regulator systems. For small Regulator systems, two pulse-width modulated (PWM) power converter modules use Insulated Gate Bipolar Transistors (IGBT) to provide up to 35 A or 120 A nominal output. These systems can support the following applications:

- Saturable Current Transformers / Power Potential Transformers (SCT/PPT) regulator
- Brushless exciter regulator
- Direct current (dc) rotating exciter regulator

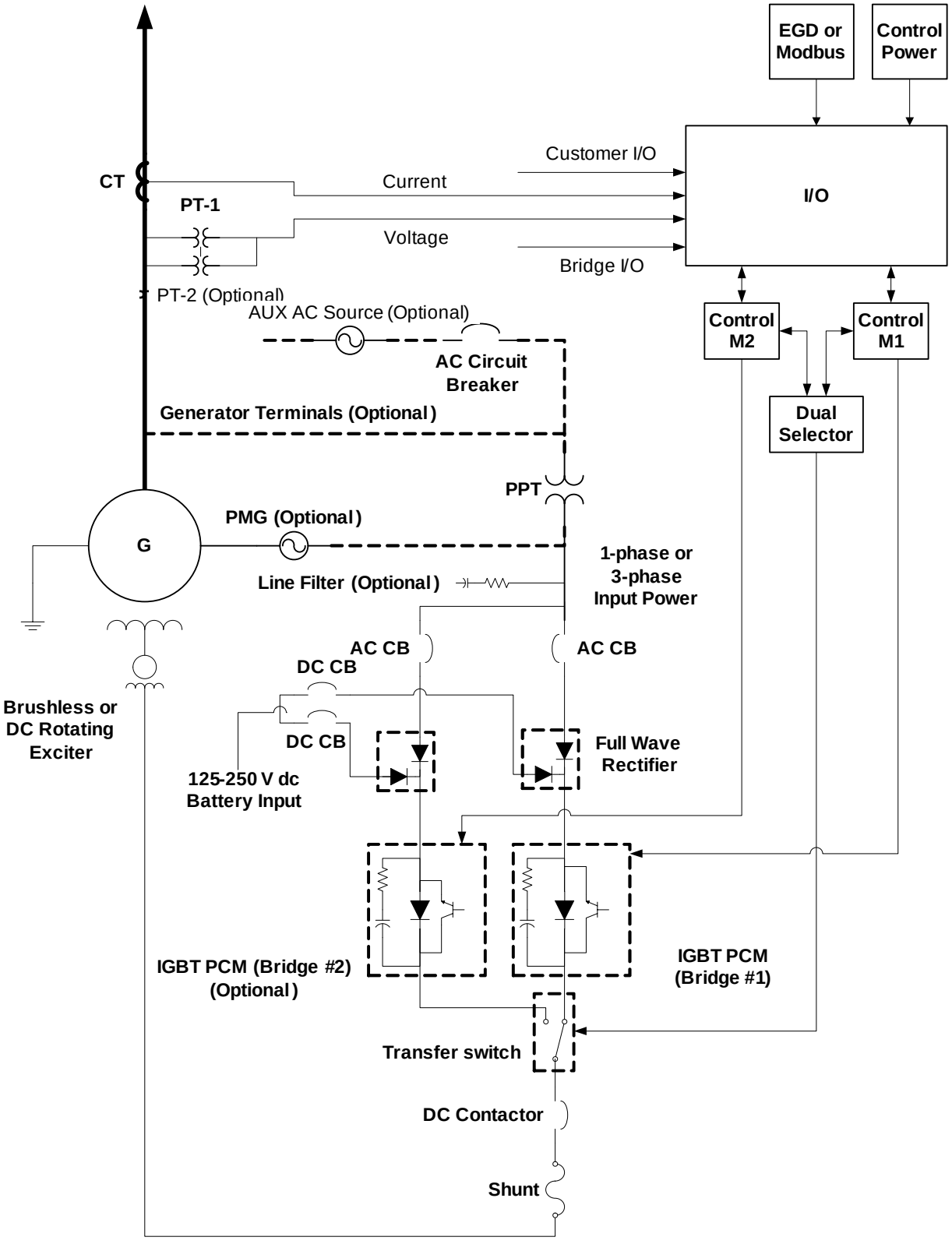
In the SCT/PPT regulator and dc rotating exciter regulator applications, the EX2100e Regulator system can de-sensitize the effect of the exciter time constant. It incorporates direct measurement of the generator field voltage and field current to enhance speed of response to system transients.

The architecture is a single control with a single Power Control Module (PCM) or dual control with dual PCM, including a customer interface sub-system, optional diagnostic local operator interface (touchscreen), optional control operator interface (COI) remote touchscreen interface, control power input module, and PCM. The PCM consists of a bridge interface sub-system, power bridge, optional ac and dc filter networks, and alternating current (ac) and/or dc isolation devices. For expanded input and output (I/O) capability, either VersaMax® or Mark* VIe control IONet I/O modules may be added.

The EX2100e Regulator system supports Ethernet local area network (LAN) communication to the following:

The EX2100e Regulator system incorporates a powerful diagnostic system and a control simulator to support rapid installation, tuning of control constants, and training.

- Turbine controls and ICS, HMI, Proficy*-based Historian, Programming Interface (PI-based) Historian, Onsite Monitoring System (OSM), and COI
- Extended I/O modules using the Ethernet Global Data (EGD) protocol
- Customer DCS through Ethernet or Modbus Ethernet remote terminal unit (RTU)
- ToolboxST* application
- GE Onsite Support* for monitoring and diagnostics



EX2100e Control 35 A and 120 A Regulator Systems Functional Diagram

2.1 Digital Controller (IGBT-based Systems)

The control and PCMs are panel-mounted.

The EX2100e Excitation control products offer a Regulator control system in a 800 mm (32 in) enclosure with supporting hardware based on the particular application. Other packaging options are available. The Regulator system can be purchased as part of a finished cabinet, or individual components can be shipped separately for onsite mounting to better serve retrofit applications.

An input PPT is not required for the PMG input, but it is required for an auxiliary bus or generator terminal feed.

Power conversion consists of an input section, a dc link, and the converter output section. The input section is a 3-phase diode bridge with input filters. The system accepts a primary ac input range of 90 to 280 V rms, nominal for the 35 A system, and up to 480 V rms for the 120 A system. The ac input is 480 Hz (maximum), which can be supplied as 1-phase or 3-phase from a permanent magnet generator (PMG), auxiliary bus, or generator terminals.

As a backup, the system accepts a secondary power input from a dc battery bank (125 to 250 V dc nominal). The dc secondary input is diode-isolated and combined with the 3-phase diode bridge output. These sources energize the dc link, which is an unregulated source voltage for the control output power through the IGBTs. The dynamic discharge (DD) circuit limits the dc link voltage level during events such as load rejection or unit trip.

The converter output section uses IGBTs to pulse-width modulate the dc link source voltage to its final value. The chopping frequency of the IGBTs is approximately 1,000 Hz. This output is fed to the exciter field as a regulated voltage or current. An output shunt monitors the field current. Continuous dc output is provided up to 100% rating with temporary forcing capabilities up to 210%. Regulated output flows through a dc contactor to the exciter field.

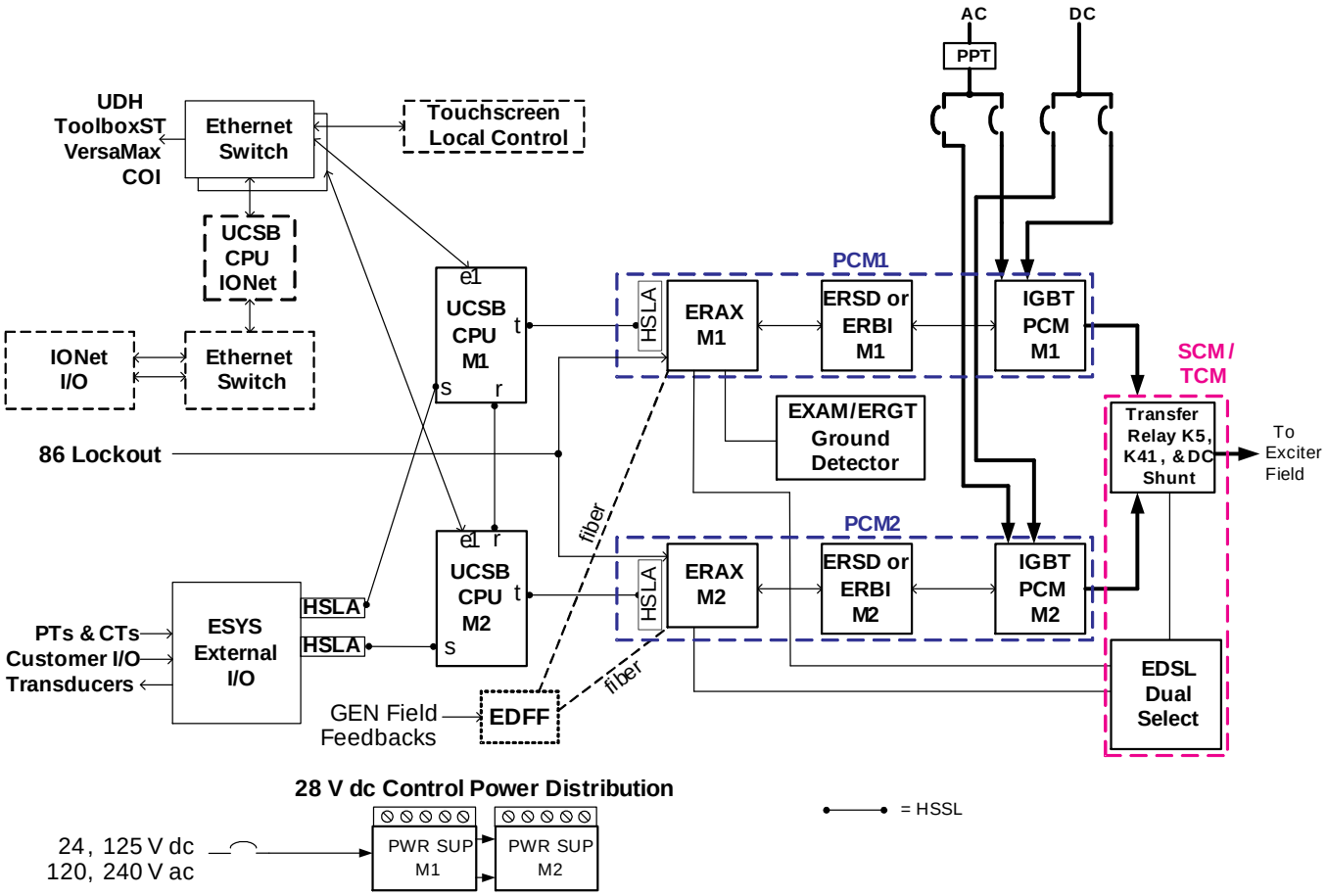
The EX2100e Regulator system contains interface boards that are interconnected through a high-speed serial link (HSSL) and cabled to their associated I/O terminal boards.

2.2 Dual Control (Power Bridge Warm Backup)

The EX2100e Regulator system is available in a warm backup (WBU) configuration, which includes dual exciter control I/O and protection. The control includes M1 (Master One) and M2 (Master Two), with two IGBT bridges that can accept separate or shared ac input power. The control configuration can also share a common dc output circuit to the exciter field through the transfer module. M1 and M2 are independent controls, each with automatic and manual regulator functions. Either M1 or M2 can control bridge firing, as determined by the operator. In the WBU configuration, M1 controls bridge #1, and M2 controls bridge #2.

To process application software, two independent Universal Controller Stand-alone Board Version B (UCSB) controllers, with separate PCMs and an output selector module (SCM or TCM), provide the dc output current for the exciter field (or SCT control winding).

The active power bridge receives the gating commands from the active control (M1 or M2), and supports the full-field voltage and current needs of the exciter field while the backup power bridge's gating circuit is inhibited. The operator has full control to select which of the dual power bridges is active or inactive. Bi-directional, bumpless transfer between active and inactive bridges is standard. The active master can also self-diagnose a failure or missed operation and activate the backup control and power bridge without operator intervention.

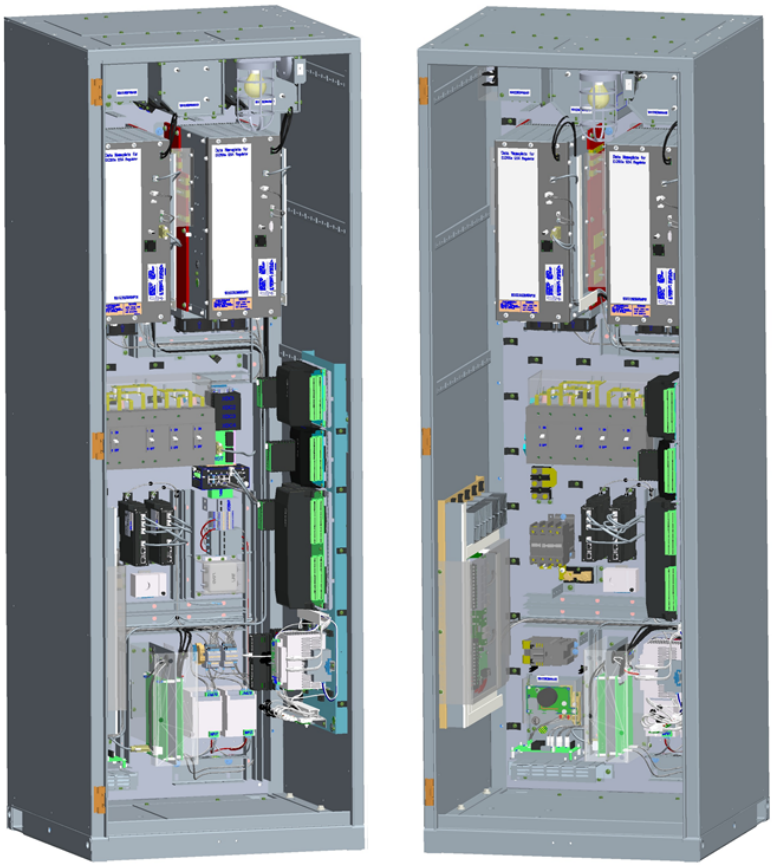


EX2100e Regulator Dual Control System Block Diagram

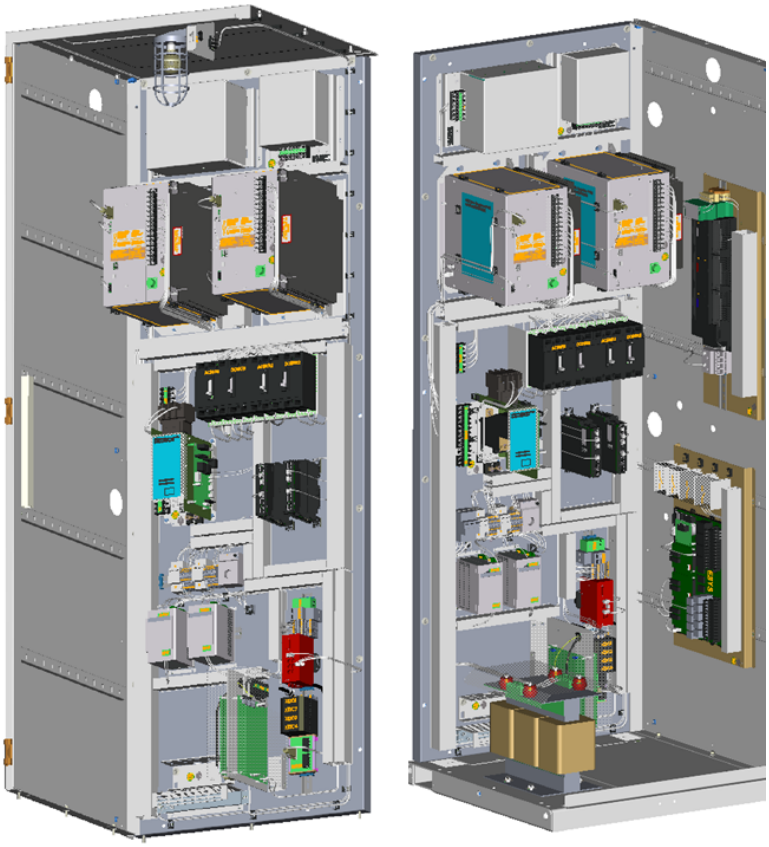
2.3 Control Cabinet

EX2100e Regulator system modules may be shipped as a parts kit for retrofit into existing control systems.

The EX2100e Regulator system is encased in a NEMA® 1/IP20 or IP21 freestanding, indoor metal cabinet for floor-mounting installation. An IP54 option for the cabinet is also available. The standard cabinet color is ANSI-70 (light gray) on exterior surfaces (other colors are available). Interior surfaces are galvanized steel. The equipment is designed to operate in an ambient temperature range of 0 to 40°C (32 to 104 °F). Depending upon the specific application, a current derating factor may apply at 50°C (122 °F).



EX2100e Control 120 A Regulator Cabinet



EX2100e Control 35 A Regulator Cabinet (Right Side Floor Hidden, Left Side Wall and Roof Hidden)

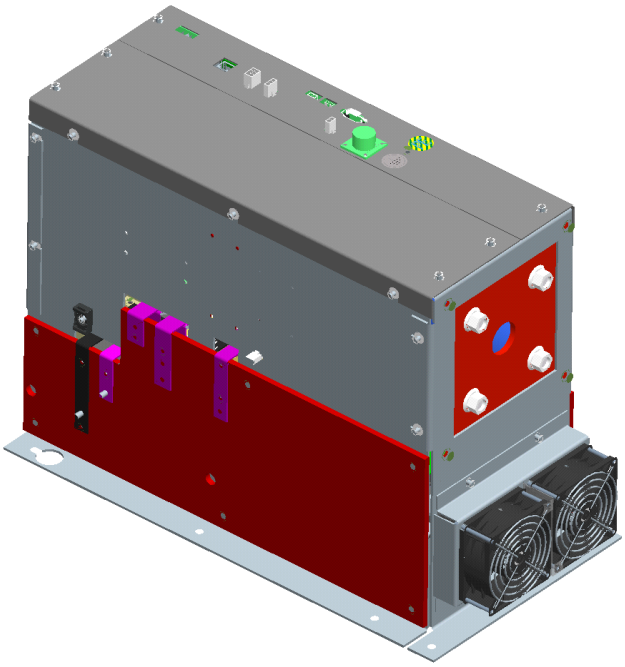
2.4 Power Conversion Module

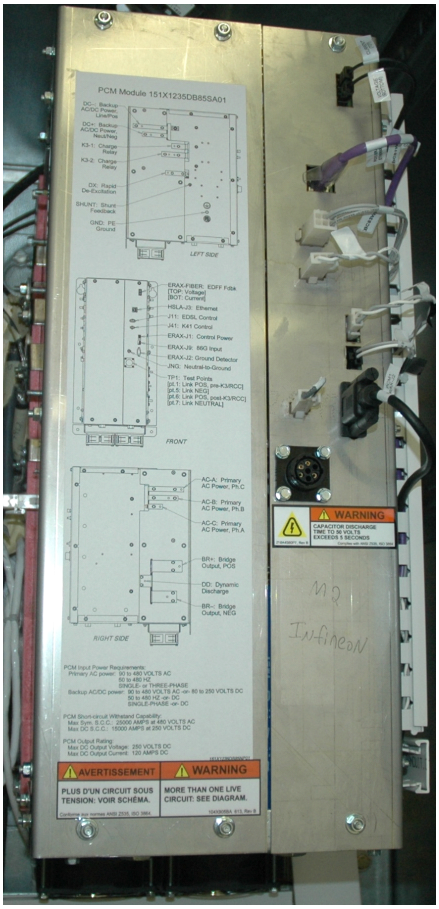
The Power Conversion Module (PCM) consists of an integrated IGBT inverter module that contains six IGBTs connected in a 3-phase inverter configuration. Two of the six IGBTs are used to create the PWM dc output for field excitation. A third IGBT is used to discharge the dc link capacitors into an external DD resistor to prevent overvoltage.

Input power is either rectified ac, dc from a station battery, or both.

In the dual redundant application, there is a primary control and PCM (M1) and a backup control and PCM (M2), which are identical. A transfer module evaluates the health of the primary and backup controls and selects which control is active to provide maximum reliability and availability.

35 A Regulator PCM





120 A Regulator PCM

3 Control Software

The EX2100e control software supports high performance and helps the customer and field engineers understand, install, commission, tune, and maintain the excitation control system. The exciter software is configured and loaded from the ToolboxST application and resides in the controllers. The software is represented on the ToolboxST Component Editor screen by control blocks that are linked together to display the signal flow.

The generator voltages and currents from the PTs and CTs are the source of the control signals needed by the automatic (generator terminal voltage) regulator, most limiters, and protection functions. They are wired to the ESYS, which acts as a signal conditioner to isolate and scale the signals. The conditioned signals are fed to the controller. The system simultaneously samples the ac waveform at high speed and uses advanced mathematical algorithms to digitally generate the needed variables.

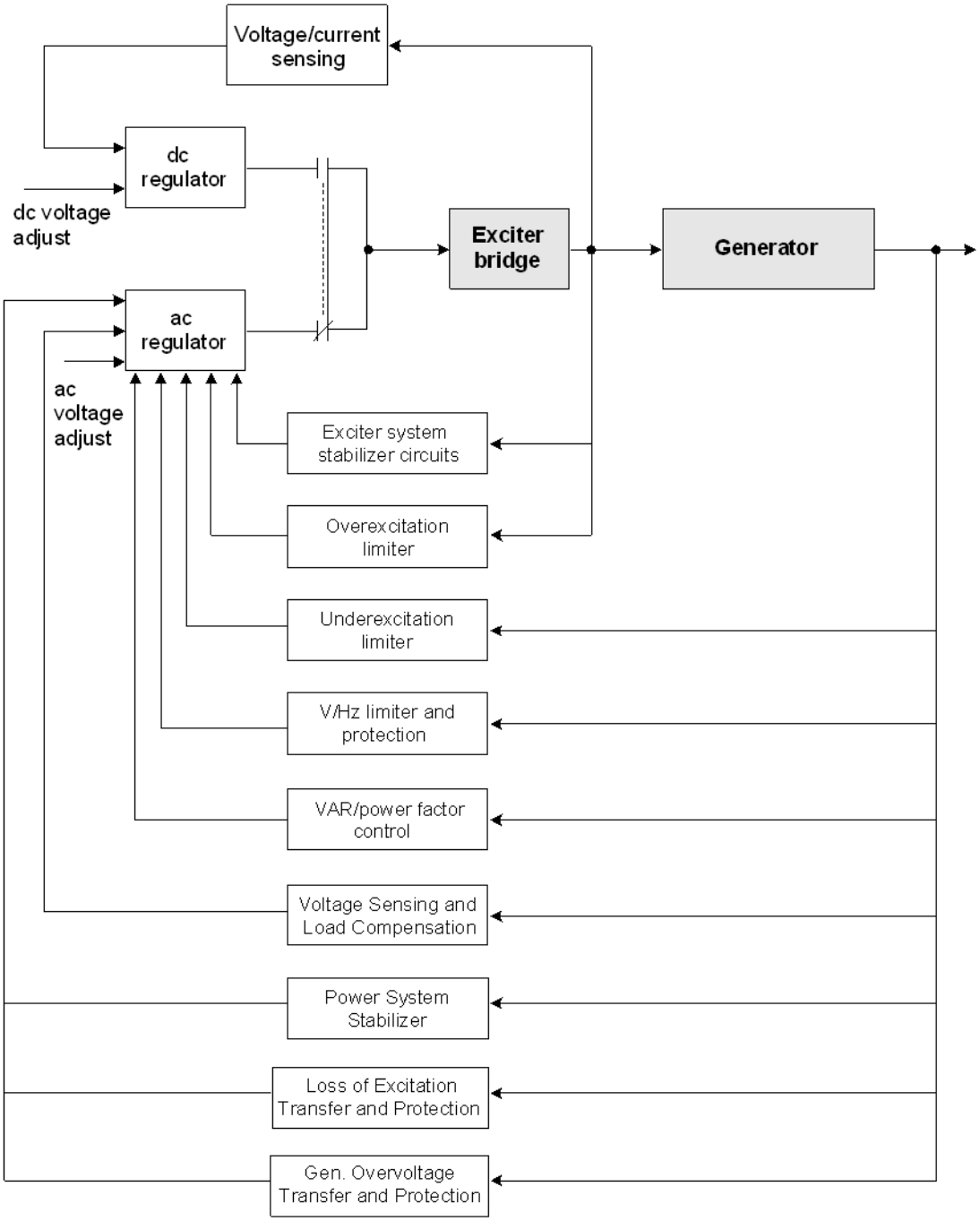
The output of the software transducer system includes the following:

- Generator voltage
- Generator active current (average in phase with watts)
- Generator reactive current (average in phase with reactive power, VARs)
- Generator frequency (current)
- Slip (signal representing the change in the rotor speed)

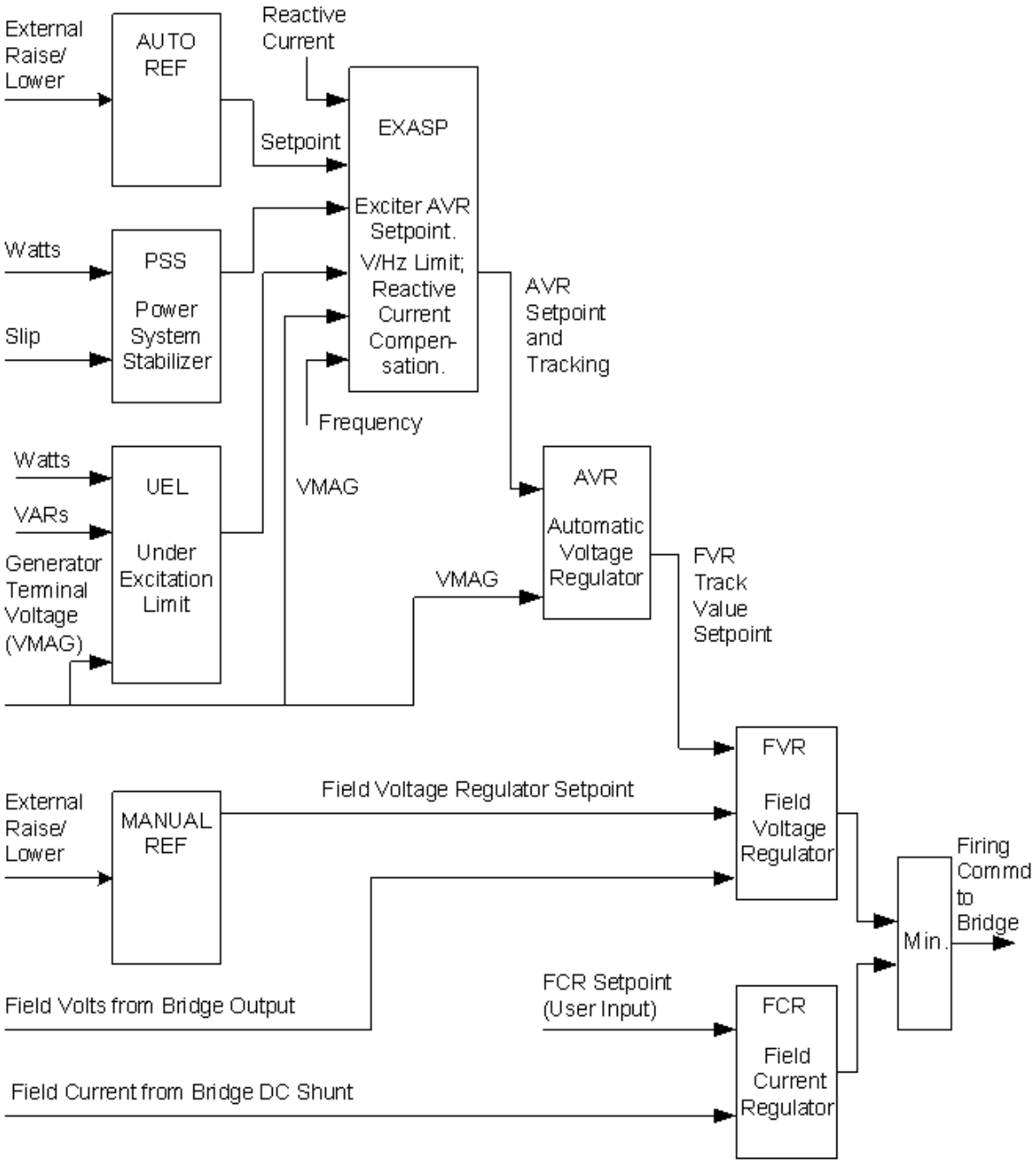
The transducer system uses the output to calculate the following:

- Generator power and VARs
- Magnitude of generator flux (V/Hz)
- Phase angle and power factor

The following figures provide a simplified overview of the exciter control system, displaying the main control functions. Both the generator field and stator currents and voltages are measured and input to the control system. In normal operation, the ac regulator is selected.



Software Overview Block Diagram (1 of 2)



Software Overview Block Diagram (2 of 2)

4 Specifications and Standards

Item	Description
Physical Characteristics	
Enclosure	NEMA 1/IP20 or IP21 freestanding, indoor metal cabinet, floor mounted Optional IP54 available
Cabinet dimensions (W x H x D)	Standard cabinet: 800 x 2290 x 830 mm (32 x 90 x 32.5 in) 35 A Simplex cabinet: 610 x 2286 x 508 mm (24 x 90 x 20 in)
Paint	Exterior: ANSI®-70 (light gray) (other colors available) Interior: Galvanized steel
Environmental Characteristics	
Ambient temperature	0 to 40°C (32 to 104 °F); current derating at 50°C (122 °F)
Ac input range	35 A: 90-280 V rms, nominal 120 A: Up to 480 V rms
Ac input frequency	480 Hz maximum
Nominal continuous output	35 A: 250 V dc at 35 A dc 120 A: 250 V dc at 120 A dc
Supported Standards	
Safety	UL508C Standard for Power Conversion Equipment CSA 22.2 No. 14 Industrial Control Equipment OSHA 29 CFR Part 1910 Subpart S, Electrical Safety Requirements
CE	Electromagnetic Compatibility (EMC) Directive 2004/108/EC: EN 55011: ISM equipment emissions (CISPR 11) EN 6100-6-4 & -6-2 Emissions and Immunity, Industrial Environment • EN 61000-4-2 Electrostatic Discharge Susceptibility • EN 61000-4-3 Radiated RF Immunity • EN 61000-4-6 Conducted RF Immunity • EN 61000-4-4 Electrical Fast Transient Susceptibility • EN 61000-4-5 Surge Immunity Low Voltage Directive 2006/95/EC: EN 50178 Electronic equipment for use in power installations 1997
IEEE™	421.1 Standard Definitions for Excitation Systems for Synchronous Machines (2007) 421.2 Guide for Identification, Testing, and Evaluation of the Dynamic Performance of Excitation Control Systems (1990) 421.3 High-Potential Test Requirements for Excitation Systems for Synchronous Machines (2004) 421.4 Guide for the preparation of Excitation Systems Specifications (2004) 421.5 Recommended Practice for Excitation Systems for Power Stability Studies (2005) C57.12.01 General Requirements
Seismic	IBC 2006/Universal Building Code (UBC) – Seismic Code section 2312 Zone 4

5 Testing

The following section is a brief description of the quality assurance tests performed on each exciter.

5.1 Routine Factory Tests

Each excitation control is subjected to routine factory tests including, but not restricted to, the following:

- Circuit continuity check
- Di-electric (hi-pot) tests in accordance with IEEE standard 421B
- Functional check of all components and devices for proper operation

5.2 Customer Witness Tests

All equipment goes through extensive testing with appropriate reviews and sign-offs. Refer to the section, Routine Factory Tests

Customers are always welcome to visit the GE factory to see how their equipment is engineered and manufactured.

After routine factory tests are complete, the customer can participate in a witness test. Two options are available:

- **Option A**: The customer examines the appearance and workmanship of the equipment, then reviews the engineering and test paperwork. This is a standard service for no additional charge.
- **Option B**: The customer witnesses a demonstration of the hardware and software. This is an added-cost item to the customer.

Glossary of Terms

Auto Regulator Reference (AUTO REF) generates the auto control (AC) setpoint variable for the automatic voltage regulator (AVR). Operator commands, (raise and lower inputs) come from direct inputs or over a data link from an HMI operator station, or from a plant DCS or remote dispatch system.

Automatic and Manual Reference Follower (Tracking) are software-implemented ramp functions that adjust the non-active regulator output to automatically track the active regulator. That is, when the auto regulator is controlling the generator, the manual regulator tracks, and when the manual regulator is controlling the generator, the auto regulator tracks. This provides for smooth transition when a transfer occurs from one regulator to the other.

Automatic Voltage Regulator (AVR) maintains the generator terminal voltage constant over changes in load and operating conditions.

DCS Interface (ModBus RTU) slave data link is supported to interface with customer DCS systems. This link uses TCP/IP support over Ethernet 10/100baseT hardware. Both commands and data can be supported.

Exciter AVR Setpoint (EXASP) combines a number of functions to produce the reference input to the AVR and the variables to support regulator tracking.

Generator Field Temperature Calculation measures the resistance by dividing the field voltage by the field current. From the known field resistance at 25°C (77 °F) and the linear resistance temperature change in copper, the algorithm calculates operating temperature. An adjustable high temperature alarm output contact is also included.

Generator Overvoltage Trip (59G) monitors the generator armature voltage and initiates a trip signal upon detecting an unacceptably high voltage.

Generator Simulator (GEN SIM) is a detailed generator model that is included as part of the excitation control system software. It can be configured to closely match the operation of the real generator. It can also be used for operator training, and can support the checkout of regulators, limiters, and protection functions while the unit is shut down.

Hydrogen Pressure/Temperature Limiter compensates the configuration parameters of key generator limiters and protection functions based on generator cooling. For hydrogen-cooled generators, the correct parameter is the internal hydrogen pressure, and for air-cooled generators, it is air temperature. The three limiters affected by pressure/temperature compensation are:

- Underexcitation limiter (UEL)
- Overexcitation limiter (OEL)
- Stator current limiter

Loss of Excitation Protection (40) detects a loss of excitation on synchronous machines using a two-zoned timed trip function that is based on resistance and reactance.

Manual Regulator (FVR) controls the generator field voltage or current, letting the generator output voltage. The manual regulator, like the AVR, uses a PPI regulator with integrator windup protection and its control output directly controls the firing command generator that controls the gating of the power bridge when enabled.

Manual Regulator (FCR) is a special application of the manual regulator and uses the generator field current as the feedback input. While it does regulate constant field current over varying field temperature, GE has not selected the FCR as its standard manual regulator because it inhibits the signal independence from the over excitation limiter.

Manual Regulator Reference (MANUAL REF) generates the manual setpoint variable for the manual voltage regulator (MVR). Operator commands, (raise and lower inputs) come in from direct inputs or over a data link from an HMI operator station or from a plant DCS or remote dispatch system.

Manual Restrictive Limiter limits the under-excited operation of the EX2100e while the manual regulator is selected (FVR or FCR). It also does not allow the manual regulator to track the automatic regulator when the unit is operating below the field voltage limit called for by the manual restrictive limiter.

Overexcitation Limiter (OEL) and Offline Overexcitation Protection (OLOT) protect the generator field from damage by events that require abnormally high field currents. These high currents, over an extended time, can overheat the field and cause damage. Generator fields are designed to ANSI standard C50.13, which specifies the overvoltage as a function of time that the field is designed to follow. This standard uses curves to describe the field overheating as a function of time and current.

Potential Transformer Fuse Failure Detection (PTFD) detects loss of PT feedback voltage to the voltage regulator. If the sensing voltage is lost or if it is single-phased, there is a transfer to the manual regulator and an alarm output is provided.

Power System Stabilizer (PSS) provides an additional input to the automatic regulator to improve power system dynamic performance. The PSS offered in the EX2100e control is a multi-input system using a combination of synchronous machine electrical power and internal frequency (which approximates rotor speed) to arrive at a signal proportional to rotor speed. This comes from the integral of accelerating power, but with shaft torsional signals greatly attenuated.

Reactive Current Compensation (RCC/Line Drop) has two modes: RCC and Line Drop. The RCC mode permits sharing reactive current between paralleled machines. Line Drop mode allows for better regulation of voltage at some point down stream from the generator terminals.

Stator Current Limit (SCL) determines the AVR/VAR control. When the generator stator current exceeds the rated value, the exciter changes from AVR control to a VAR control preset. Once the stator current is less than the rated value, the exciter returns to AVR control.

Transfer to Manual Regulator upon Loss of PT detects loss of PT feedback voltage to the ac voltage regulator. If the sensing voltage is lost, the regulator forces its output to ceiling for 0.5 sec and then transfers to manual. This is distinctly different from the PTFD function, which does not force the regulator to ceiling before transferring.

Underexcitation Limiter (UEL) is an auxiliary control to limit the AVR demand for underexcited reactive current. The UEL prevents reductions of the generator field excitation to a level where the small-signal (steady state) stability limit or the stator core end-region heating limit is exceeded. Performance is specified by identifying the region of the limiter action on the generator capability curve.

Unit Data Highway Interface (UDH) connects the exciter with the turbine control system, HMI or HMI viewer/data server, and GE controls. The UDH is based on EGD protocol. The UDH provides a digital window into the exciter where variables can be monitored and controlled. It also supports the ToolboxST application configuration and maintenance tool for the exciter.

VAR/PF Control is accomplished by slow ramping of the AVR reference setpoint. The VAR/PF is selected by operator command and the VAR/PF value is controlled using the raise/lower push-buttons. When the exciter interfaces with a Mark VIe turbine control system, this function is typically included.

Volts per Hertz Limiter (V/Hz Lim) limits the generator V/Hz ratio to the programmed setting in the EX2100e. This function uses two inputs from the software transducer, average generator voltage and generator frequency (its V/Hz ratio is configurable). Typically, the generator is considered to be operating acceptably within ±5% of rated terminal voltage at rated frequency.

Volts per Hertz Protection (V/Hz 24G) serves as a backup to the V/Hz limiter. The protection scheme consists of two levels of V/Hz alarm and trip protection. Typically, one level is set at 1.10 per unit over V/Hz with an inverse time period, and the other level is set at 1.18 per unit with a two second time period.

When out-of-limit operation causes the exciter to trip, the controller stops gating the power converter IGBTs. The field current flows back into the dc link and rapidly collapses as its energy transfers into the dc link capacitors. To prevent overvoltage of the dc link, the dynamic discharge (DD) resistor is automatically connected across the dc link to dissipate the energy from the field.