GEH-6781 L

EX2100e Excitation Control

User Guide

Oct 2018

GE Internal

Revised: Oct 2018
Issued: Oct 2010

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Document Updates

Revision	Update Location	Description
L	*Acronyms and Abbreviations*	Added UCSx, UCEC, CSLx, CSLB
	Overview	Updated the Attention to state that any reference to UCSB infers UCSB, UCSC, or UCEC
	Throughout the document	Replaced UCSB with UCSx
	Control Boards	Added IS420UCEC to the list of available controller boards/ modules Added new section *UCSC Controller*, including a description of the UCEC module
K	*Control Power Supplies*	Clarification of EX2100e DFE power supply
	125-28 V DC Power Supply Module	
	Overview	Added an Attention to state that any reference to UCSB infers UCSB or UCSC
	Related Documents	Added GEH-6721_Vol_II
	Acronyms and Abbreviations	Added UCSC
J	*Control Software*	Added new firmware functions
H	*UCSB controller*	Added information that the UCSB is available in two platforms: UCSBH1A and UCSBH4A
G	*Control Operator Interface*	Updated this section to notify the user that the COI has been made legacy, and to describe the graphEX-OI operator interface
	Touchscreen Operator Interface	Added this section to include the touchscreen as an available operator interface

Acronyms and Abbreviations

HX2500, HX1200, HX800, HX300	SCR sizes in EX2100e H-variant control systems
ac	Alternating current
ACOM	Analog common
AVR	Automatic or ac voltage regulator
C	Protection controller in a redundant system
CCOM	Control common
CHM	Collector Health Monitor
COI	Control Operator Interface
CSLA	Compact PCI High Speed Serial Link Expansion Board Version A
CSLB	Compact PCI High Speed Serial Link Expansion Board Version B
CLSx	Compact High-speed Serial Link Expansion Board Version x, where x designates either A or B version
CT	Current transformer
DACA	AC to DC converter in control power supply
DFE	Digital Front-end
dc	Direct current
DCOM	Digital common
CSLA	Compact Serial Link Expander Board
EAUD	EAUX High-speed Contactor Option Board
EAUX	EX2100e Auxiliary Function Interface Board
EBAC	EX2100e Bridge AC Feedback Board
EBRG	EX2100e Bridge Interface Board
ECTX	EX2100e CT Expansion Option Board
EDEX	Exciter De-excitation Board
EGD	Ethernet Global Data
EDFF	EX2100e DC Feedback Board
EDIS	EX2100e Power Distribution
ESWA	GE Industrial Ethernet Switch with 8 ports
ESYS	EX2100e System Interface Board
EXAM	Exciter Ground Detector Attenuator Board
HSLA	High-speed Serial Link Interface Board
HSSL	High-speed Serial Link
GPA	Gate Pulse Amplifier
HMI	Human-machine Interface
I/O	Input and output
LAN	Local area network
LED	Light-emitting diode
level H	High-level signal
level H(S)	High-level signal, special handling
level L	Low-level signal
level M	Medium-level signal level
LOTO	Lockout / tagout
P	Power signal
level P(S)	Power signal, special handling
M1	Primary controller
M2	Backup controller
OEL	Overexcitation Limit control
P125	Positive side of 125 V dc power supply
PCM	Power Conversion Module
PCT	Power Current Transformer
PLC	Programmable logic controller
PMG	Permanent magnet generator
PPE	Personal protective equipment
PPT	Power Potential Transformer
PRV	Peak reverse voltage
PSS	Power System Stabilizer
PT	Potential transformer
R125	Return side of 125 V dc power supply
RFCT	Sensors for CHM
SCR	Silicon-controlled rectifier (thyristor)

SHCOM	Shield common
SVS	Shaft Voltage Suppression
TMR	Triple Modular Redundant
UCEC	Module assembly of UCSC controller and CSLB
UCSB	Universal Controller Stand-alone Version B
UCSC	Universal Controller Stand-alone Version C
UCSx	Universal Stand-alone Controller Version x, where x designates either B or C version
UDH	Unit Data Highway
UEL	Underexcitation Limit control
VAR	Volt-amperes reactive
WBU	Warm backup

Related Documents

Document Title	Document (Part) Number
EX2100e Excitation Control 100 mm, 77 mm, 53 mm, and 42 mm Thyristor Systems Product Description	GEA-S1302
EX2100 and EX2100e Excitation Control Power System Stabilizer User Guide	GEH-6676
ToolboxST User Guide for Mark Controls Platforms	GEH-6700
EX2100e Excitation Control 77 mm, 53 mm, and 42 mm Thyristor Systems Installation and Startup Guide	GEH-6780
EX2100e Excitation Control User Guide	GEH-6781
EX2100e H-variant Excitation Control User Guide	GEH-6791
EX2100e Excitation Control 77 mm, 53 mm, and 42 mm Thyristor Systems Maintenance Guide	GEH-6782
EX2100e Excitation Control for Regulator Systems Installation and Startup Guide	GEH-6783
EX2100e Excitation Control for Regulator Systems Maintenance Guide	GEH-6784
EX2100e Excitation Control 100 mm Thyristor Systems Maintenance Guide	GEH-6785
EX2100e Excitation Control 100 mm Thyristor Systems Maintenance and Troubleshooting Guide	GEH-6786
EX2100e Excitation Control for H-variant Thyristor Systems Installation and Startup Guide	GEH-6793
EX2100e Excitation Control for H-variant Thyristor Systems Maintenance Guide	GEH-6792
EX2100e Excitation Control Operational Guide	GEH-6794
EX2100e Excitation Control Digital Front-end Thyristor Systems and Separated Controls Application Guide	GEH-6787
EX2100e Excitation Control Diagnostic Alarms for Regulator Systems Troubleshooting Guide	GEH-6788
EX2100e Excitation Control Diagnostic Alarms for Thyristor Systems Troubleshooting Guide	GEH-6789
Receiving, Handling and Storage of GE Drive and Excitation Control Equipment	GEI-100256
De-excitation Control Board IS200EDEX_B Instruction Guide	GEI-100466
EX2100 and EX2100e Excitation Control Exciter Attenuation Module (EXAM) Instruction Guide	GEI-100509
Excitation Control Exciter Regulator Static Converter (ERSC and ERSD) Instruction Guide	GEI-100525
Excitation Control Exciter Regulator Third-party Ground Detector Terminal Board (ERGT) Instruction Guide	GEI-100531
EX2100e Excitation Control DC Fanned Feedback (EDFF) Board Instruction Guide	GEI-100770
EX2100e Excitation Control Regulator Auxiliary I/O (ERAX) Board Instruction Guide	GEI-100771
EX2100e Excitation Control System I/O Interface (ESYS) Module Instruction Guide	GEI-100772
EX2100e Excitation Control Dual Regulator Selector (EDSL and ERSN) Board Instruction Guide	GEI-100773
EX2100e Excitation Control Bridge AC Feedback (EBAC) Board Instruction Guide	GEI-100774
EX2100e Excitation Control CT Expansion (ECTX) Board Instruction Guide	GEI-100775
EX2100e Excitation Control Bridge Interface (EBRG) Board Instruction Guide	GEI-100776
EX2100e Excitation Control Power Distribution (EDIS) Instruction Guide	GEI-100777
EX2100e Excitation Control High-speed Contactor Driver (EAUD) Board Instruction Guide	GEI-100778
EX2100e Excitation Control Auxiliary Interface (EAUX) Board Instruction Guide	GEI-100779
High-speed Serial Link Interface (HSLA) Board Instruction Guide	GEI-100782
EX2100e Excitation Control 100 mm, 77 mm, 53 mm, and 42 mm Thyristor Systems Application Guide	GEI-100783
EX2100e Excitation Control for 35 A Regulator Systems Application Guide	GEI-100784
EX2100e Excitation and LS2100e Static Starter Control Systems Touchscreen Local Operator Interface Instruction Guide	GEI-100787
EX2100e Excitation Compact High-speed Serial Link Expansion (CSLA) Board Instruction Guide	GEI-100788
EX2100e Excitation Control Regulator Bridge Interface (ERBI) Instruction Guide	GEI-100796
Industrial Ethernet Switch (ESWx) Instruction Guide	GEI-100810
Collector Health Monitor (CHM) Operator User Guide	GEK102858
Mark VIe and Mark VIeS Control Systems Volume I: System Guide	GEH-6721_Vol_I
Mark VIe and Mark VIeS Control Systems Volume II: General-purpose Applications	GEH-6721_Vol_II

Safety Symbol Legend

Warning	**Indicates a procedure, condition, or statement that, if not strictly observed, could result in personal injury or death.**
Caution	**Indicates a procedure or condition that, if not strictly observed, could result in damage to or destruction of equipment.**
Attention	**Indicates a procedure, condition or statement that should be strictly followed to improve these applications.**

Control System Warnings

Warning

To prevent personal injury or damage to equipment, follow all equipment safety procedures, Lockout Tagout (LOTO), and site safety procedures as indicated by Employee Health and Safety (EHS) guidelines.

Warning

This equipment contains a potential hazard of electric shock, burn, or death. Only personnel who are adequately trained and thoroughly familiar with the equipment and the instructions should install, operate, or maintain this equipment.

Warning

Isolation of test equipment from the equipment under test presents potential electrical hazards. If the test equipment cannot be grounded to the equipment under test, the test equipment's case must be shielded to prevent contact by personnel. To minimize hazard of electrical shock or burn, approved grounding practices and procedures must be strictly followed.

Warning

To prevent personal injury or equipment damage caused by equipment malfunction, only adequately trained personnel should modify any programmable machine.

Warning

Always ensure that applicable standards and regulations are followed and only properly certified equipment is used as a critical component of a safety system. Never assume that the Human-machine Interface (HMI) or the operator will close a safety critical control loop.

Contents

Notes

1 Overview

The EX2100e Excitation Control produces the field excitation current to control generator ac terminal voltage and/or the volt-amperes reactive (VARs). It is a Thyristor system designed for generators on both new and upgraded steam, gas, and hydro turbines. The EX2100e excitation control supports both static excitation systems and rotating exciters, such as brushless and Alterrex*. This document describes the function of the EX2100e excitation control and the individual control and protection circuits. Power supplies and the distribution of power are also covered.

The exciter is a flexible modular system that can be assembled to provide a range of available output currents and several levels of system redundancy. The available options include:

- Power supply from a potential, compound, or auxiliary source
- Single or multiple bridges
- Warm backup (WBU) bridges
- Simplex or redundant control configuration

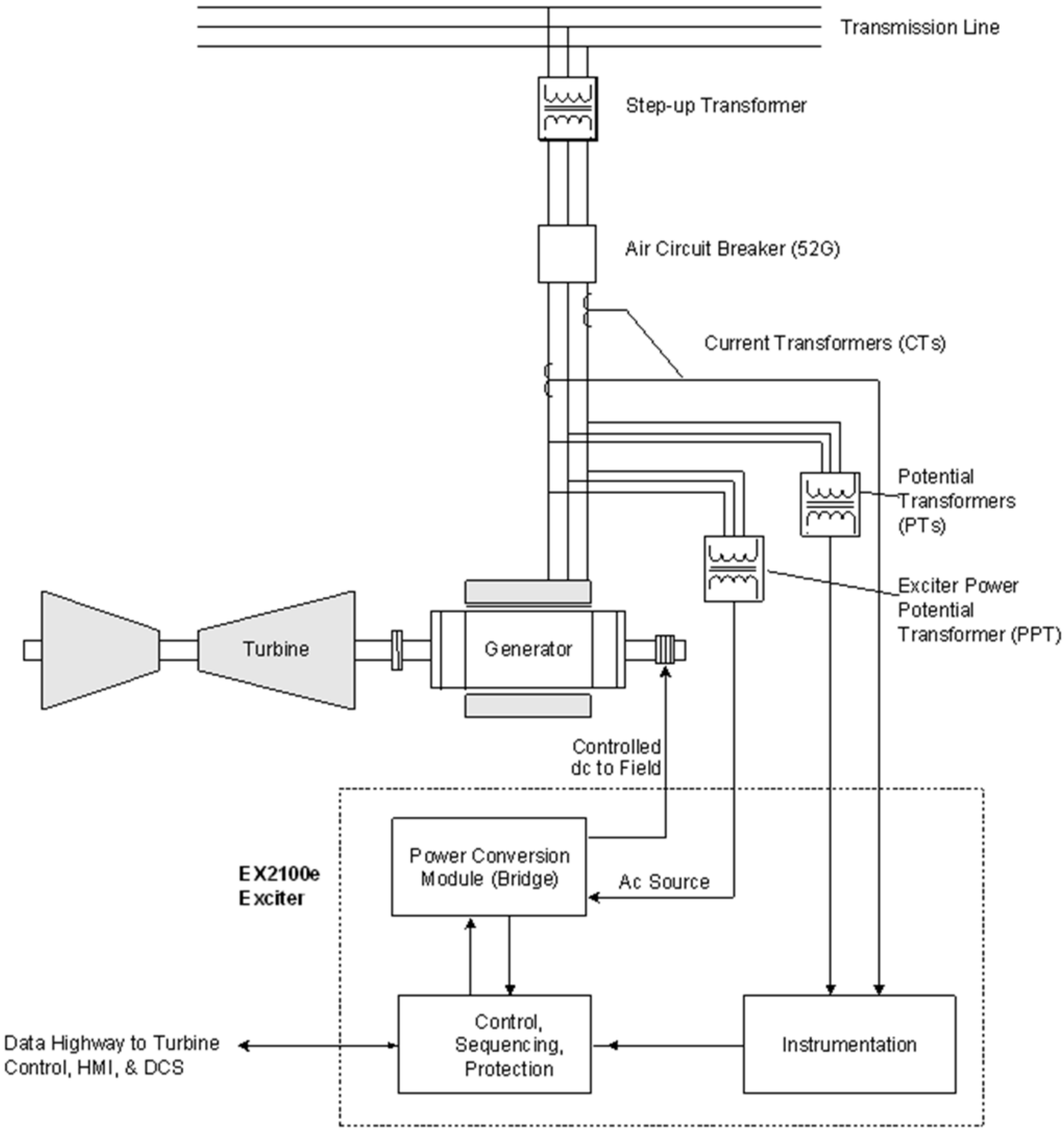
Power for the exciter is drawn from a Power Potential Transformer (PPT) connected to the generator terminals, or from an excitation transformer connected to an auxiliary bus. Generator line current and stator output voltage are the primary feedbacks to the exciter, and dc voltage and current is the controlled output to the generator field.

Note The term *exciter* refers to the EX2100e digital static exciter.

The architecture supports Ethernet local area network (LAN) Unit Data Highway (UDH) communication with other GE equipment, including the ToolboxST* application for configuration, the Mark* VI or Mark VIe turbine control, the LS2100e Static Starter control, Human-machine Interface (HMI), and engineering workstation.

Attention

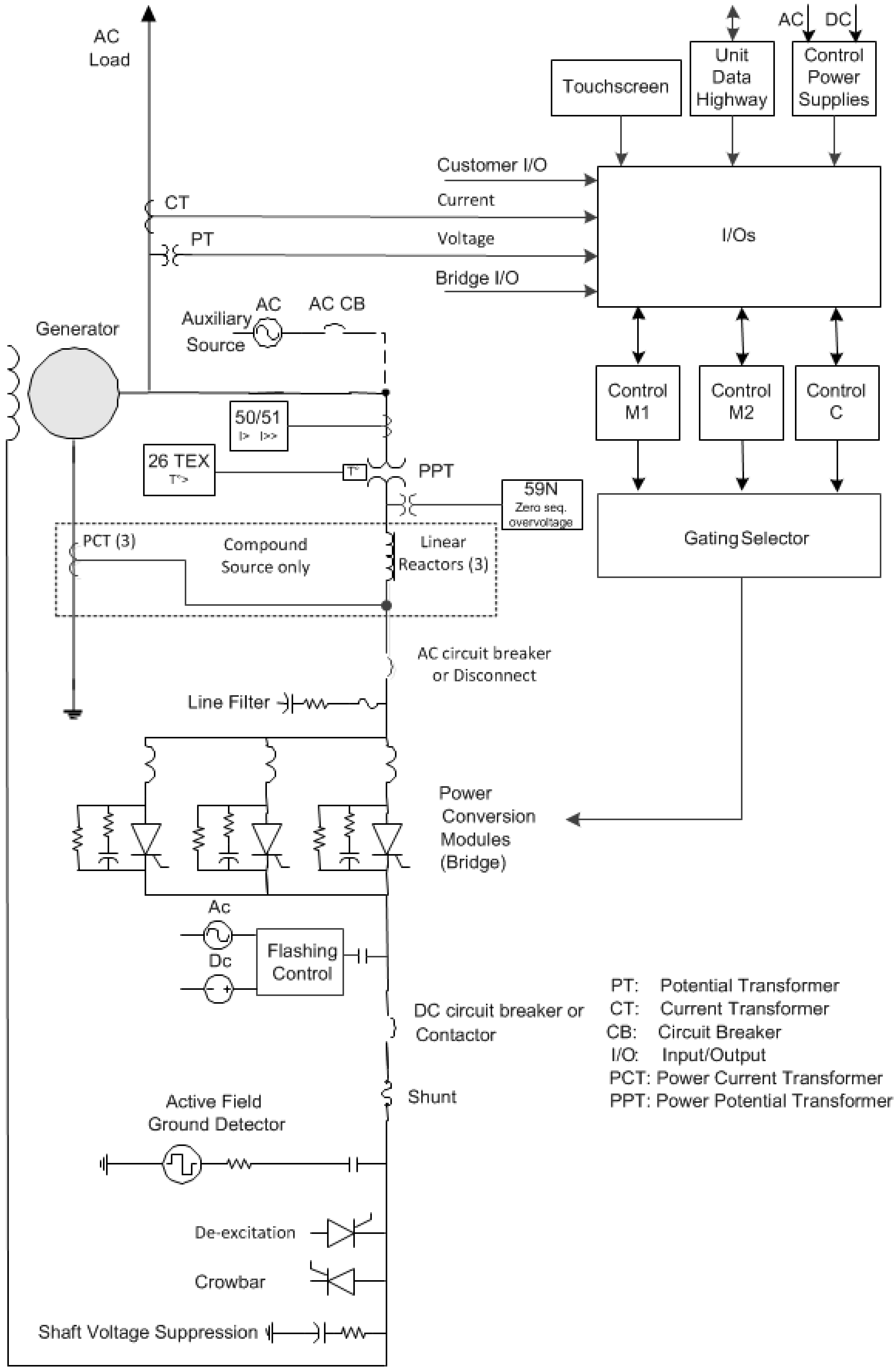
Any reference in this document to the UCSB controller infers the applicable form of the Universal Stand-alone Controller (UCSB or UCSC) or the module assembly UCEC, in the user's system. For more information, refer to the *Mark VIe and Mark VIeS Control Systems Volume II: General-purpose Applications System Guide* (GEH-6721_Vol_II), the chapter Controllers and Unmanaged Switches.
Unless otherwise stated, any reference to the UCSx controller can indicate the UCSB, UCSC, UCSB/CSLA or UCEC.



Turbine Generator and EX2100e Excitation Control System

Excitation control results from phase-controlling the output of the Silicon-controlled Rectifier (SCR) bridge circuit. The SCR firing signals are generated by digital regulators in the controller. In the redundant control configuration, either Master 1 (M1) or Master 2 (M2) can be the active master control, while Controller (C) monitors both to determine which should be active and which should be the standby controller. Dual independent firing circuits and automatic tracking are used to ensure a bumpless transfer to the standby controller.

The following figure is a simplified one-line diagram showing the power source, generator current and voltage measurements, control module, power conversion module (PCM), and protection circuits. In the potential source system, the secondary of the PPT is connected to the input of a 3-phase, full-wave, inverting thyristor bridge. The inverting bridge provides both positive and negative forcing voltage for optimum performance. Negative forcing provides fast response for load rejection and de-excitation.



EX2100e Excitation Control One-line Diagram
(some option depends on project configuration)

1.1 Safety Precautions

Warning

This equipment contains a potential hazard of electric shock or burn. Only personnel who are adequately trained and thoroughly familiar with the equipment and the instructions should install, operate, or maintain this equipment, or have access to the location where it is installed.

Warning

To prevent electric shock or burn while servicing the equipment, personnel must understand and follow all safety requirements for working around dangerous voltages. Obey local site lockout/tagout (LOTO) procedures, wear appropriate personal protective equipment (PPE), and follow GE instructions when performing any adjustments, services, or other tasks requiring physical proximity or contact with the circuit boards, electrical components, or wiring of the exciter.

Warning

Due to the large amount of energy passing through the exciter power converter, failure to properly reinstall shields or to completely latch doors and covers compromises these safeguards and places personnel at higher risk when within the environs of the exciter. Understand and follow the safety procedures and warning labels.

Shock and burn hazard boundaries for the Excitation Control Equipment are dependent upon the specific site application conditions, including Power Potential Transformer (PPT) voltage, the mega volt-ampere (MVA) and impedance ratings, and fault overcurrent clearing time of the power sources feeding the exciter. It is the responsibility of the customer to perform an arc flash analysis of the system, understand the hazard boundaries that exist, and employ adequate safeguards to protect personnel who may be in the proximity of the exciter, whether working on it or not. These safeguards include restricted access for unqualified personnel, prohibition of unsafe online maintenance practices, and use of appropriate LOTO procedures and PPE for qualified personnel who must access the exciter.

Warning

To prevent personal injury or death, personnel must be aware of arc flash hazards, and must maintain safe distances at all times as determined by released energy calculations. The extent of arc flash hazards is not known until the site-specific installation is evaluated; therefore GE recommends that an arc flash assessment be conducted for each installation.

The following table illustrates the Arc Flash Protection Boundary (AFPB) and Hazard Risk Category Number (HRC#) based on assumed installation conditions that might exist in a typical exciter application. These calculations are based on equations published in NFPATM-70E, *Electrical Safety in the Workplace (2012)*. These numbers are illustrative only and must not be interpreted as applicable to any customer site installation. It is the responsibility of the customer to perform an arc flash analysis of his installation and implement appropriate safeguards as mentioned above. Consider modifications to the installation to reduce the hazard levels during periods when maintenance personnel must be present to perform online repair procedures. These modifications might include the use of reduced energy let-through (RELT) circuit breakers, arc flash detection technology, or faster fault clearing time settings used during maintenance periods.

Note This content provides general and example electrical safety information. For TSR system applicable information, refer to the section *Digital Front-end, Kits, and Separated Controls Cabinet Applications*.

Note When the control cabinet is attached to the power converter lineup, the control cabinet may be within the hazard boundaries of the power converter. Appropriate PPE levels to access the control cabinet may therefore be higher than might be expected based solely on hazards within the control cabinet itself.

Exciter Description	Source MVA	Upstream Fault Clearing Time	AFPB	HRC #
100 mm Multi-bridge	15	0.1 sec	2480 mm (98 in)	4
		0.3 sec	4300 mm (169 in)	Extreme Hazard
100 mm Warm Backup (WBU)	6	0.1 sec	1570 mm (62 in)	3
		0.3 sec	2720 mm (107 in)	Extreme Hazard
77 mm	3.25	0.1 sec	1160 mm (45 in)	2
		0.3 sec	2000 mm (79 in)	3
53 mm	1.6	0.1 sec	810 mm (32 in)	1
		0.3 sec	1400 mm (55 in)	3
42 mm	0.45	0.1 sec	480 mm (19 in)	1
		0.3 sec	830 mm (33 in)	1
120 A Regulator	0.075	0.3 sec	340 mm (13 in)	0
		2.0 sec	1240 mm (49 in)	3
35 A Regulator	0.01	0.3 sec	120 mm (5 in)	0

1.1.1 Grounding Balls

Some models of the EX2100e excitation control and LS2100e static starter control may be equipped with grounding balls for temporary grounding of power busses during maintenance, in accordance with site safety and LOTO procedures.

Grounding Balls Specifications

Model	Grounding Ball Part Number	Grounding Ball Diameter	Grounding Ball Rating (per IEC-61230)
EX2100e 100 mm	151X1227RG02PC01	30 mm (1.2 in)	60 kA (250 ms)
EX2100e 77 mm and smaller	151X1227RG01PC01	25 mm (1.0 in)	35 kA (250 ms)
LS2100e 8.5 MVA and 14 MVA	151X1227RG01PC01	25 mm (1.0 in)	35 kA (250 ms)

To safely use the grounding balls within this equipment, site personnel must be properly qualified and aware of site specific installation parameters as follows:

- Before using the grounding balls, verify the available short circuit current and clearing time of the overcurrent protective equipment does not exceed their rating. These parameters are site specific, and not necessarily determined by equipment within GE scope of supply.
- Use grounding clamps and cables that are compatible with the grounding balls and properly rated for the site parameters.
- Comply with site safety procedures and relevant standards such as those provided in the following list.

Refer to relevant standards, including:

- *IEC 61230, Portable Equipment for Earthing or Earthing and Short-Circuiting.*
- *ASTM F855, Temporary Protective Grounds to Be Used on De-energized Electric Power Lines and Equipment.*
- *IEEE 1246, Guide for Temporary Protective Grounding Systems Used in Substations.*

1.1.2 Arc Flash Events

Evaluation of the root cause of arc flash failures in exciters, static starters, and similar power conversion equipment shows that many arc flash events can be prevented with diligent installation and maintenance procedures.

Note This content provides general and example electrical safety information. For TSR system applicable information, refer to the section *Digital Front-end, Kits, and Separated Controls Cabinet Applications*.

Causes and Preventive Practices for Arc Flash Events

Causes	Best Preventative Practices
Loose power bus, bolts, and harnesses (contributed to more than 25% of the events evaluated)	☐ Torque all power connections. ☐ Apply torque marks. ☐ Periodically inspect that marks are aligned. ☐ Verify that all connectors are snug. ☐ Verify that all connectors are free of mechanical stress.
Foreign objects such as tools, animals, loose parts, or moisture left in or ingested into the equipment (caused approximately 25% of the events evaluated)	☐ Verify that all tools and parts are removed after installation and maintenance. ☐ Retrieve and remove dropped fasteners and any chips or shavings from installation. ☐ Do not store spare parts within the cabinets. ☐ Replace all shields and barriers after maintenance work. ☐ Cover openings to keep out water, contaminants, and animals. ☐ Keep cabinet doors securely closed.
Other poor installation practice, such as cable protection and energized part separation distances	☐ Follow installation procedures carefully. ☐ Inspect cables for protection, support, and separation. ☐ Inspect components and assemblies for adequate mounting and voltage clearances.
Poor maintenance practice, such as keeping openings sealed and air filters clean	☐ Follow maintenance guidelines appropriate for site conditions.
Catastrophic component failures, sometimes due to external causes such as inadequate cooling, excessive vibration, damage to insulating mica sheets or sleeves, transient overvoltage, or application beyond ratings	☐ Monitor and mitigate external conditions that can lead to premature failures. ☐ Be careful not to damage new or reused parts during installation procedures. ☐ Do not reuse questionable parts. ☐ Know the equipment ratings and do not exceed them.

1.1.3 Digital Front-end, Kits, and Separated Controls Cabinet Applications

Some EX2100e excitation control and LS2100e static starter control installations may include a control cabinet that is separated from the power converter lineup. Examples include EX2100e and LS2100e DFE applications and some combined EX2100e and LS2100e LCI Exciter Compartment (LEC) installations, which locate the controls in a separate room of the LEC from the power converters, to isolate personnel in the controls area from the arc flash hazards of the power converter. While such an arrangement greatly reduces the risks of shock, burn, and injury from arc blast pressures, personnel should understand that hazardous voltage and energy levels are present in the vicinity, and are exposed when the control cabinet door is opened.

Note This content may be considered applicable for TSR systems and TSR/SEDC, with the exception of references to power converters.

Personnel should perform the following safety practices:

- Wear appropriate PPE for the equipment. Fora separated EX2100e control cabinet, this is typically PPE-0. Fora separated LS2100e control or pump panel, this is typically PPE-1.
- Field installation of harnesses for separated control cabinets or field mounted kits can introduce hazards and failure modes if proper procedures are not followed. Failures at wire and cable connections are one of the leading causes of electrical equipment misoperation, including unnecessary trips and failure of protective functions such as the 86 lockout circuit to operate when needed. Watch out for:
  - Open circuits or loose connections.
  - Short circuits.
  - Inadvertent contact and energizing cables with unintended voltages.
  - Insulation damage from installation or abrasion over time.
  - Conductor damage such as kinks, stretching, and stray strands at terminations.
  - Voltages present on harnesses during maintenance due to remote equipment not locked out. Establishing an electrically safe state for work on the controls in some situations may also require lock-out to be performed on the power converter, and vice versa.
  - Poor terminations and stress on connectors. If harnesses are supplied pre-terminated, ensure the terminations and connectors are not damaged during harness installation.
  - Poor routing and protection of harnesses. Where harnesses pass through building or cabinet walls, provide adequate protection against damage and sealing to prevent propagation of contaminants during normal operation and arc blast gases during fault events. Refer to the applicable *Installation and Startup manual*, the section *Cable Damage Prevention* for the equipment.
  - Failure to separate harnesses by voltage and electromagnetic compatibility (EMC) levels. For the equipment, refer to applicable Installation and Startup manual, the section *General Cable Specification and Routing Guidelines.*
- Be sure protective and functional grounding is provided for the detached equipment, per instructions provided in the system elementary diagram. A minimum #2 AWG grounding wire must be provided from the detached control equipment to the building system ground point. The power conversion cabinets must also be bonded to this point. For grounding details, refer to the equipment elementary diagram.
- Look for hazards such as those in the above subsections during inspections following installation and maintenance.

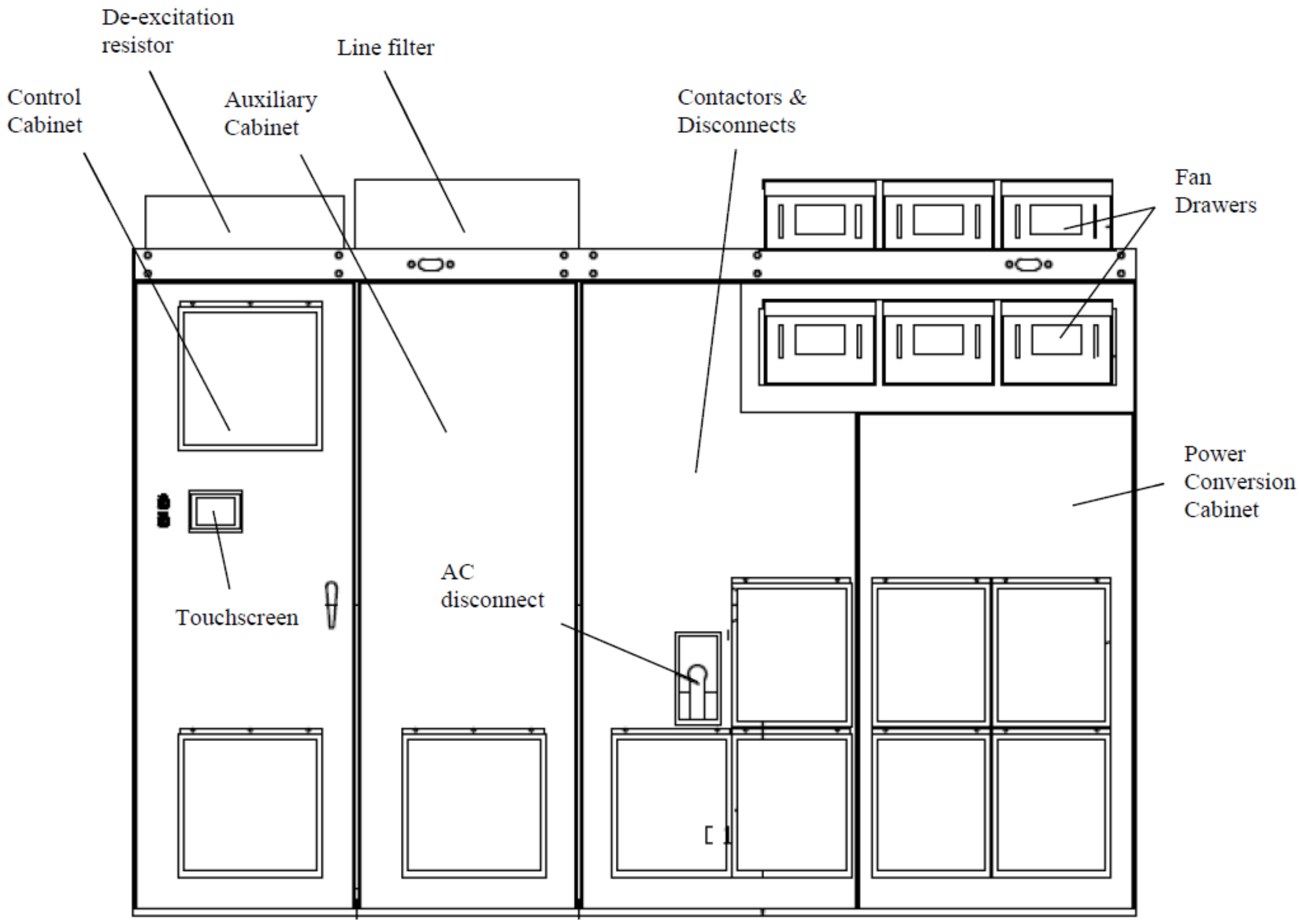
1.1.4 Additional Safety Reminders

- Always know the voltage approach and arc flash boundaries for the equipment you work on or are exposed to, and wear appropriate PPE.
- PPE always includes hearing protection. Arc flash events generate high sound levels and blast pressure waves that can cause permanent hearing damage.
- While PPE may provide protection from shocks and burns, it does not provide protection from injuries such as falling or being thrown by an arc blast pressure wave. For example, fora typical 77 mm EX2100e control installation with 300 ms clearing time, the arc blast pressure at 0.9 m (3 ft) from the arc could be 640 kg/m2 (130 lbs/ft2). To avoid such injuries, always de-energize and apply lockout for all maintenance activities in areas where arc flash hazards exist.
- Equipment may be energized from multiple sources, including unintended or inadvertent sources. Never assume any conductor is safe to touch.
- Electromechanical devices such as relays and contactors are not suitable lockout devices, since they can be re-energized electrically.
- When equipment is installed in rooms with small volumes, consider adding room pressure relief vents that open during arc blast events to reduce the blast pressure. The exhaust from these vents must be directed away from personnel and other equipment.
- Consider installing ground fault protection on control power supplies to the equipment, to provide additional safety for site personnel.
- Always be alert to safety. Shock, burns, and other injuries may happen in an unanticipated instant, but can cause a lifetime of impact.

2 Control Hardware

The EX2100e excitation control hardware is contained in the following cabinets.

- *Control cabinet*: contains the control, communication, and I/O modules
- *Auxiliary cabinet*: contains field flashing and protection circuits, such as de-excitation and shaft voltage suppression (SVS)
- *Power Conversion cabinet*: contains the power SCR cells, cooling fans, dc contactors, and ac disconnect and the power converter consists of bridge rectifiers, resistor/capacitor filter configurations, and control circuitry



EX2100e Control Cabinet Lineup for Typical 77 mm or 53 mm WBU

The components and bridge size vary depending on the type of excitation system and the required power output. The power conversion hardware is defined by application requirements, which determine the exciter bridge size. The available bridge sizes are: 100 mm, 77 mm, 53 mm, and 42 mm (equivalent). The available bridge configurations are: simplex or single bridge, WBU or redundant bridge, multiple parallel bridges (up to four total), and N+1 or N+2 online maintainable versions. The 42 mm thyristor bridge is available in both inverting and non-inverting topologies. The larger bridge sizes are always supplied as inverting bridges.

Note Bridge sizes are referenced to the size of the SCR device used.

The EX2100e excitation control is also available without a power converter, Digital Front-end (DFE) control only, for bridge upgrade applications. The 42 mm power modules are available as separate modules to facilitate upgrades into existing power converter cabinets, such as Frame 5 generator control installations. For further details, refer to the *EX2100e Digital Front-end Thyristor Control Systems and Separated Controls Application and Installation Guide* (GEH-6787).

The EX2100e control consists of the following standard components:

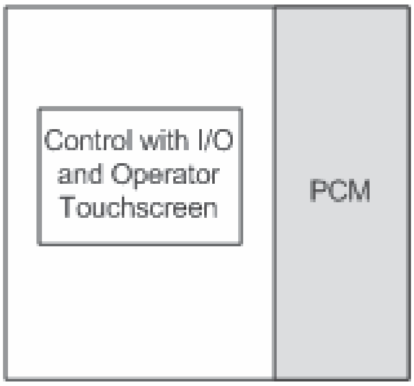
- PCM and cooling fans
- PPT (mounted separate from exciter)
- Line-to-line filters
- De-excitation module
- Controllers and I/O boards
- Control power supplies

Optional components that may be added to the exciter are:

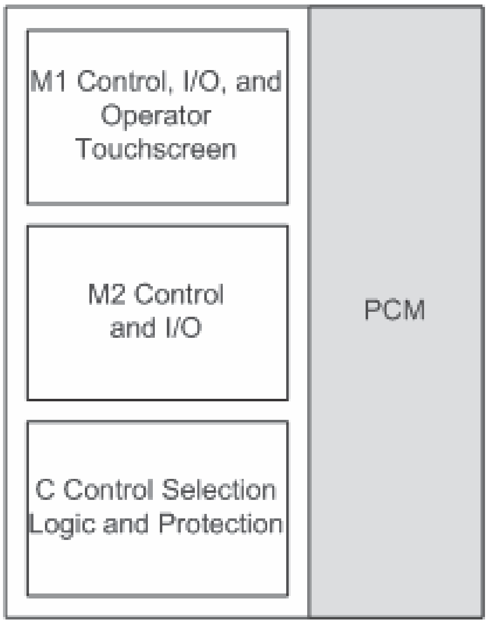
- Diagnostic operator interface (touchscreen keypad)
- Warm Backup (WBU) bridge configuration
- Multi-bridge configuration for high current requirements
- Compound power source (separate from exciter)
- Permanent Magnetic Generator (PMG) power source
- Auxiliary power source (bus-fed)
- DC polarities mechanical reverse mean (for hydro applications)
- Crowbar module (for hydro and other special applications)
- DC disconnect
- Field ground detector
- Redundant ac source for control power supplies
- Redundant cooling fans
- AC disconnect or circuit breaker
- Shaft voltage suppressor (SVS) (not required for brushless exciters)
- Field flashing module
- Boost module (brushless applications)
- Redundant controllers providing a Triple Modular Redundant (TMR) system
- 4-20 mA analog outputs
- I/O expansion through VersaMax® modules or Mark VIe IONet
- RFCT sensors for Collector Health Monitor (CHM)
- Synchronization module

2.1 Control Configurations

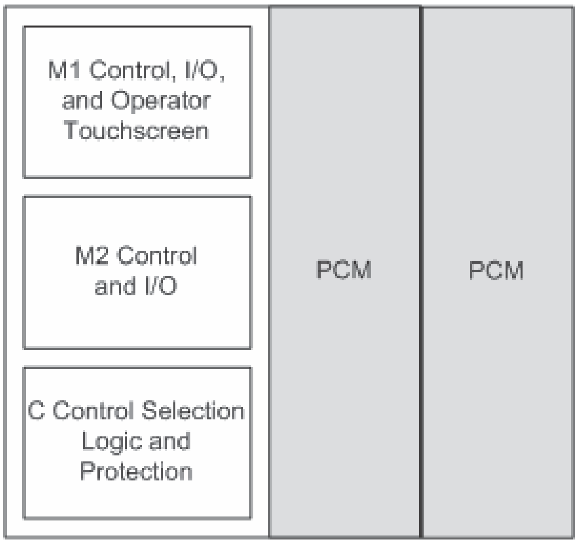
There are two primary versions of the EX2100e control hardware: Simplex control or Redundant control configurations. For simplex control configurations, only a single bridge (only the M1 components) is supplied. A simplex control with multiple bridges is not a supported option. The redundant control includes triple modular redundant (TMR) bridge hardware for the most critical portions of the control. In a TMR control, any one of the three modules can fail but the system remains fully operational. Some components can be replaced online, while the exciter is running. The three redundant control sections are referred to as M1, M2, and C Controller. Multiple PCMs can be supplied with simplex, WBU, or redundant N+1 or N+2 PCMs (with N+1 or N+2 equal to 3 or 4).



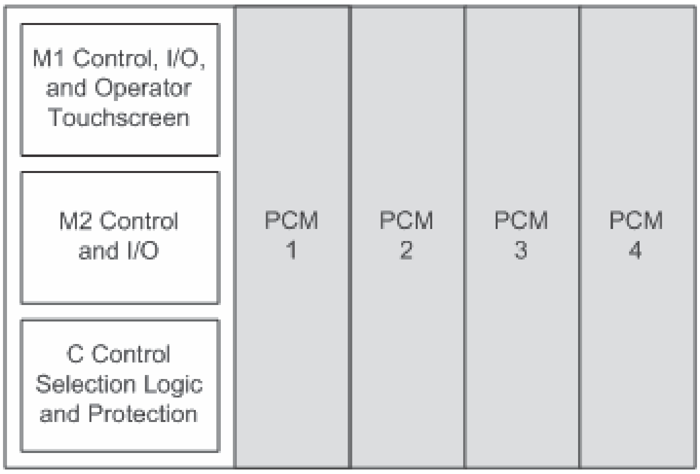
Simplex Control with Single PCM



Redundant Control with Single PCM



Redundant Control with WBU PCMs



Redundant Control with Parallel PCMs

2.2 Control Cabinet

The control cabinet contains the controllers, control power distribution module (EDIS) and power supplies, and I/O terminal boards, and optional touchscreen.

2.2.1 Control Section

The control section consists of the Universal Stand-alone Controller UCSx, connected through High-speed Serial Links (HSSL), to the I/O terminal boards. The control and I/O processor boards are:

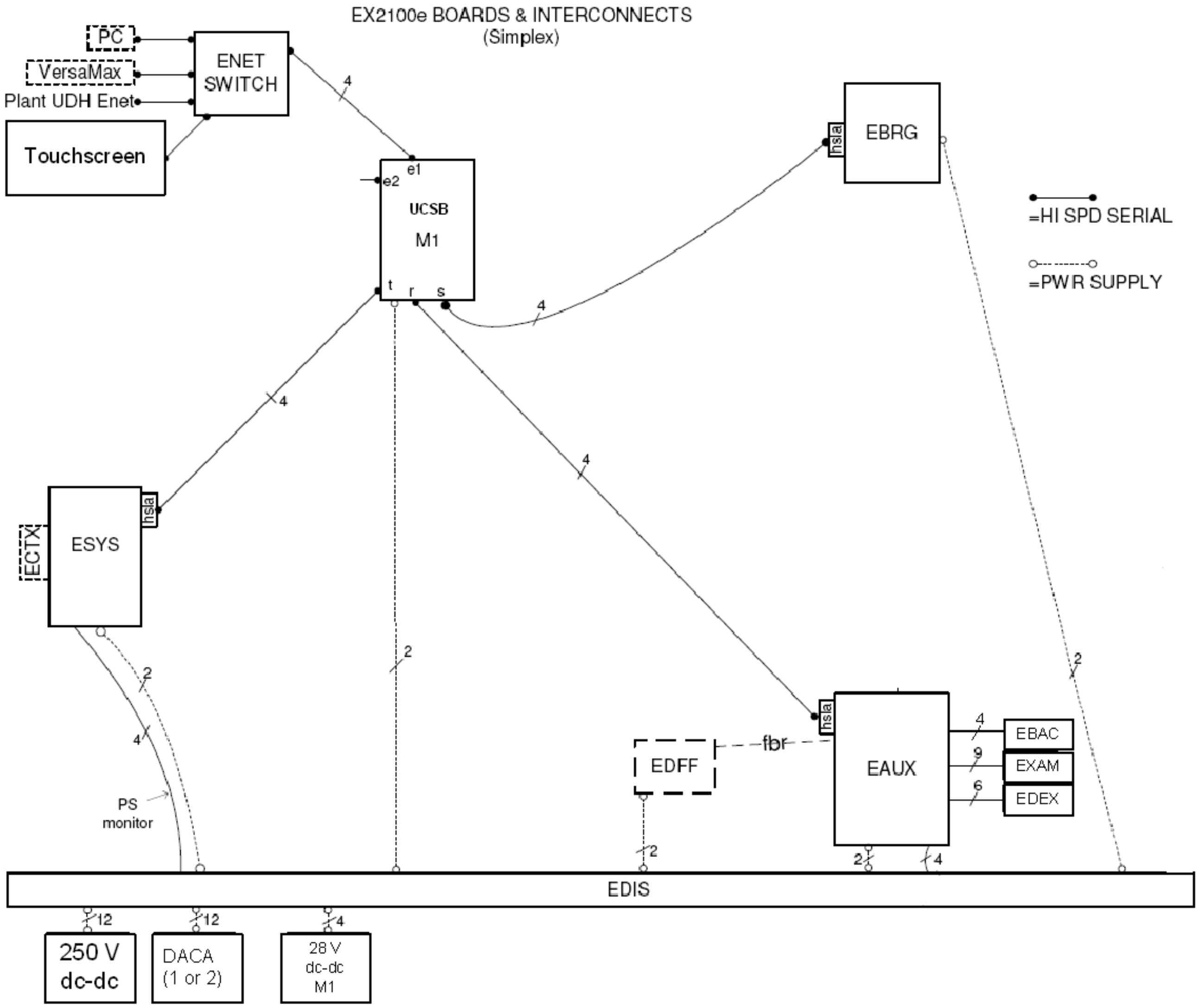
- UCSB or UCSC controller or UCEC module
- Compact High-speed Serial Link Expansion (CSLx) board (depending on the exciter configuration)
- High-speed Serial Link Interface (HSLA) board

There can be three independently powered controllers: M1, M2, and C. Each controller consists of the UCSx controllers and CSLx boards. If the control cabinet contains only the M1 UCSx controller, it is a simplex control system. If it contains all three UCSx controllers, it is a redundant control configuration.

Note The UCEC module integrates the UCSC controller and CSLB expansion board.

2.2.2 Simplex Control

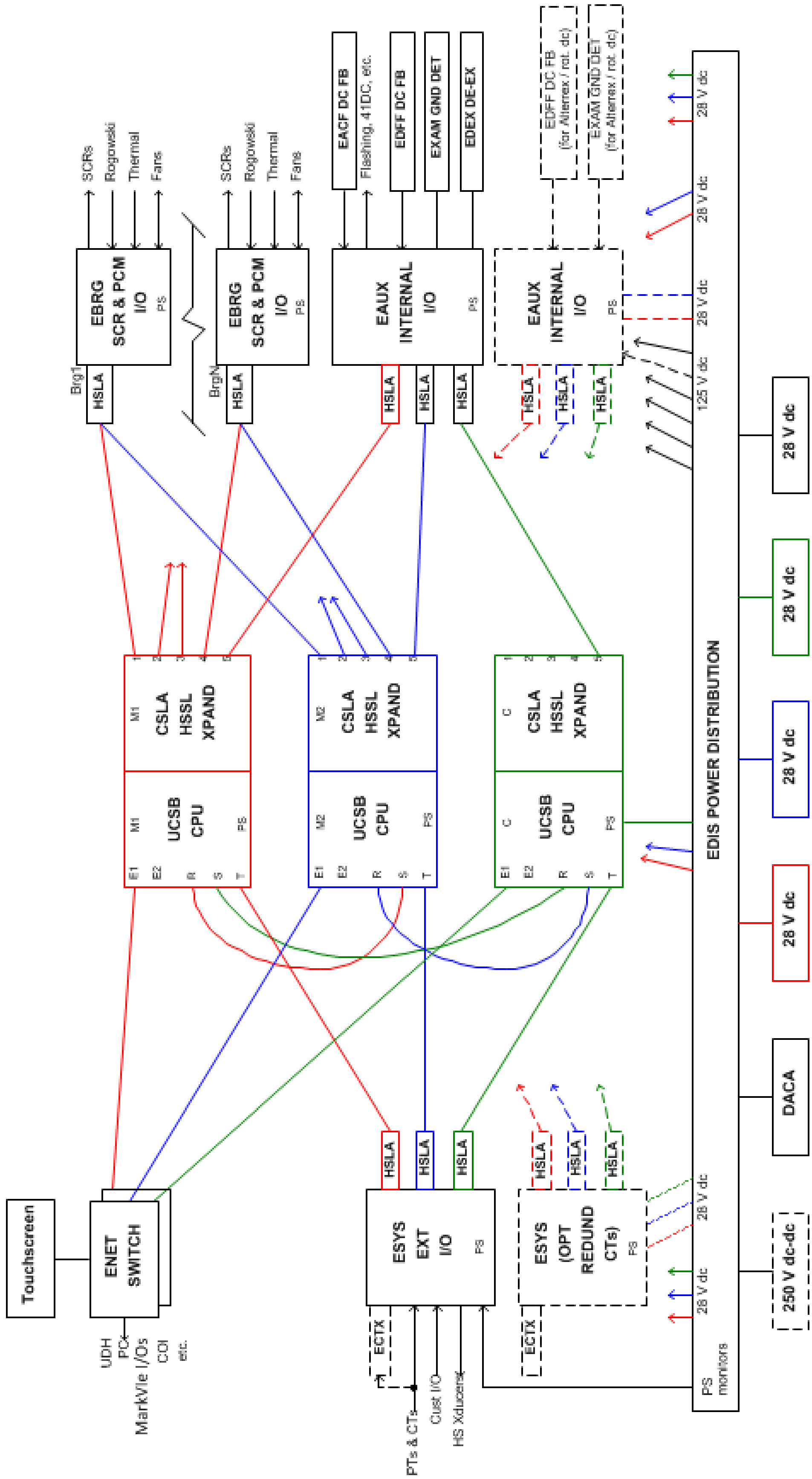
The interconnections between the simplex control system and the I/O terminal boards, generator protection modules, and power supply are displayed in the following figure.



Simplex Control System Cabling

2.2.3 Redundant Control

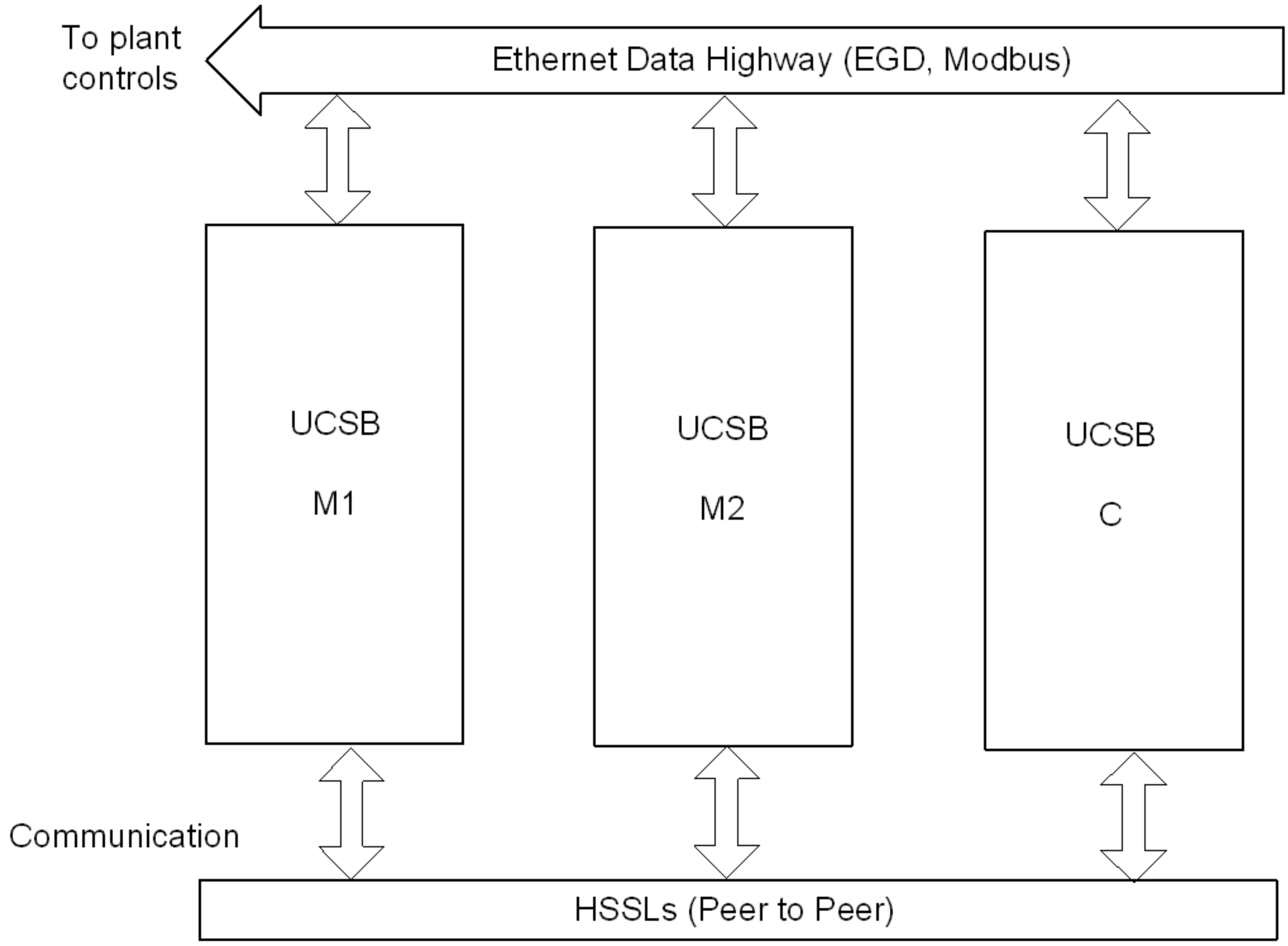
In a redundant control system, Ethernet cables are connected to three UCSx controllers for redundant communication with the turbine control and HMIs. An optional *touchscreen* may be provided on the control cabinet door that connects to M1 or M2 UCSx controller for diagnostic interface.



Redundant Control System Cabling

2.2.3.1 Controller C

Controller C is only used with redundant systems and does not interface to the EX2100e Excitation Control Bridge Interface (EBRG) for bridge firing. It receives the same feedback voltage and current inputs as the other controllers and contains similar software. It monitors the active and backup controllers (M1 or M2), and initiates appropriate protective responses if system conditions exceed the defined regulation boundaries. I/O signal voting takes place in all three controllers, which are linked in a TMR controller configuration. For more information, refer to the *EX2100e Excitation Control Bridge Interface (EBRG) Board Instruction Guide* (GEI-100776).



Communication Between Redundant Controllers

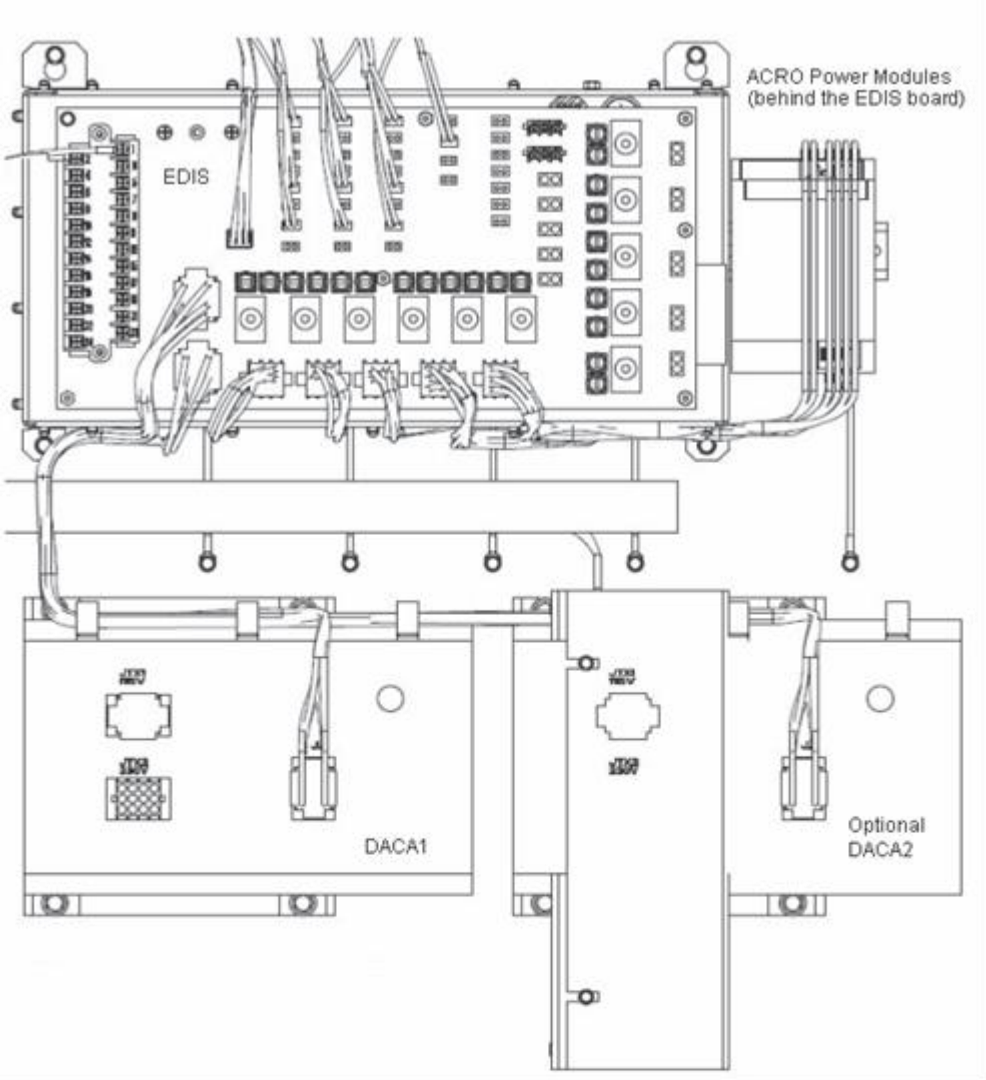
2.2.4 Control Power Supplies

Power for the controls is fed from the EX2100e Exciter Power Distribution (EDIS) module. The EDIS interfaces customer ac and dc power supplies to the EX2100e control system hardware. It is supplied by a 125 V dc source and one or two 115 or 220 V ac sources. The ac source is passed through an ac-to-dc converter (DACA or 120VPS power supply). The resulting 125 V dc is diode-coupled with the other dc sources to create a dc bus that feeds the controllers, I/O boards, and bridge interface boards. Fused outputs from the EDIS feed power to the EBRG, EAUX, and optional VersaMax or Mark VIe IONet modules, and to the 28 V dc power supplies. Each output has a light-emitting diode (LED) indication and an on/off isolation switch. There can be up to five 28 V dc control power supplies connected to the 125 V dc from the EDIS that generate the 28 V dc supplies used in the control cabinet, three of which are dedicated to M1, M2 and C. The remaining two power modules are provided based on job requirements.

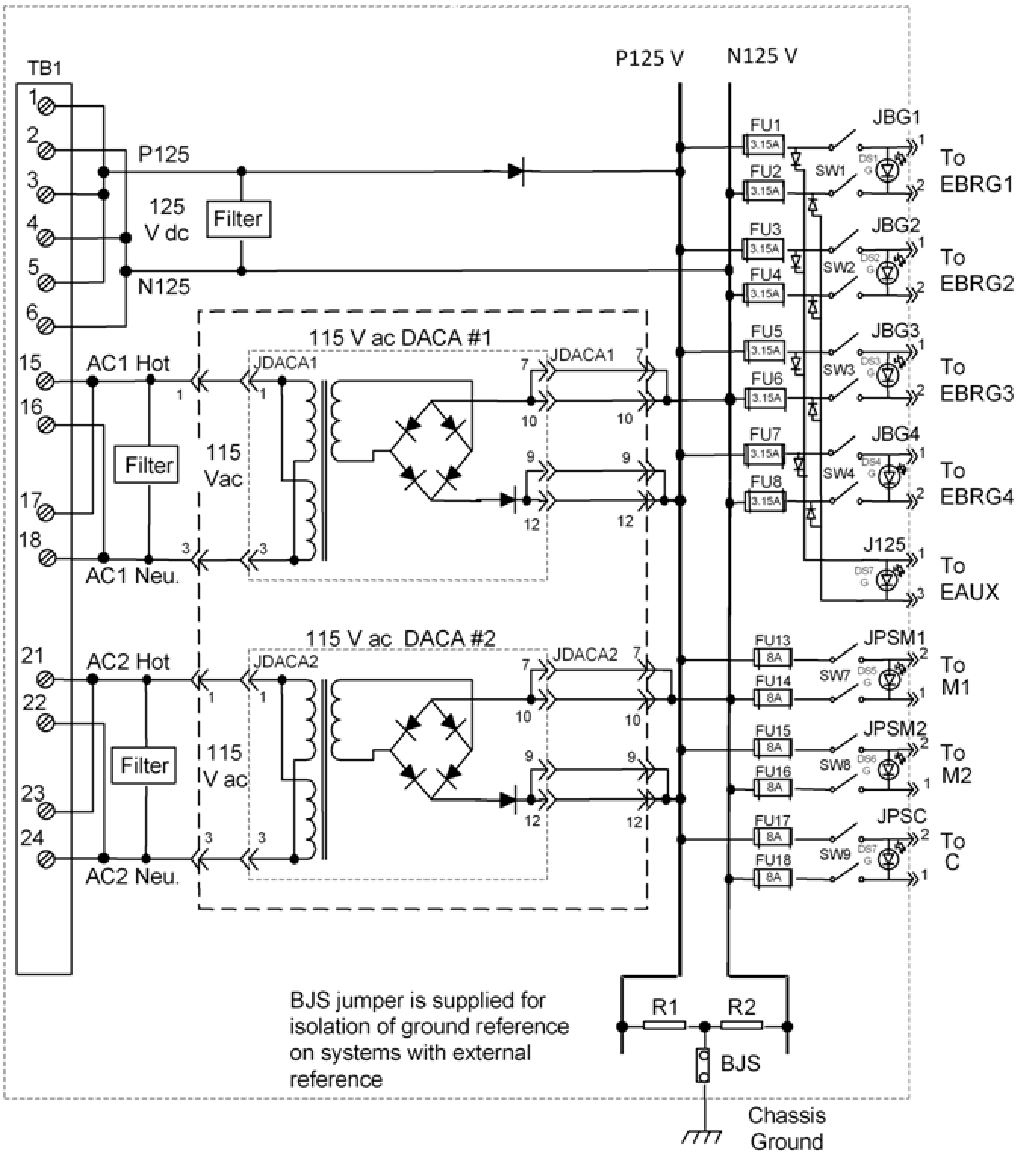
Note In the case of EX2100e DFE (upgrade of EX2100), two power supplies are used to provide redundant power to M1, M2 and C.

The 28 V supplies from the EDIS are used by the UCSx controller and the EDFF, EAUX, and ESYS. For more information, refer to the *EX2100e Excitation Control Power Distribution (EDIS) Instruction Guide* (GEI-100777).

Note T Redundant input supplies provide high reliability.
In a simplex control application, only one controller is provided.



Power Supply and DACA Modules



EDIS Module

2.2.5 Touchscreen

The optional touchscreen is mounted on the control cabinet door and provides full exciter operation. The touchscreen indicates system conditions and diagnostic displays for maintenance and troubleshooting. For further details, refer to the chapter *Touchscreen Operator Interface*.

2.3 Auxiliary Cabinet

The auxiliary cabinet contains the modules that monitor exciter output and provide startup dc power. Also mounted in this cabinet are modules for filtering the incoming ac power, de-excitation, shaft voltage suppression (SVS), and field flashing. In smaller exciter systems, these components are located in the *Power Converter Cabinet*.

2.3.1 AC Line-to-Line Filters

Fuse protected line-to-line series resistance capacitance (RC) filter circuits (snubbers) are provided to dampen the ac system to prevent voltage spikes during SCR commutation. There are several styles of filters employed depending on the voltage, including 300 V PMG, 600 V, 1000 V, and 1400 V. Each contains RC filter components and Metal Oxide Varistors (MOV) transient suppressors, and may also contain peak reverse voltage (PRV) resistors. For further details, refer to the chapter *Terminal Board I/O and Equipment Connections*.

Note In some systems, ac line-to-line filter may be located on top of the exciter.

2.3.2 De-excitation Control and Crowbar Module

During shutdown, the energy that is stored in the generator field must be dissipated. In a normal shutdown, an operator initiates a stop. The inverting bridge is fired at the retard limit and sufficient time is allowed for the field to decay before the field contactors are opened. During a trip, the field contactors are opened immediately and the stored field energy must be dissipated through a separate De-Excitation Control (EDIS) board.

The 42 mm non-inverting bridge provides a free-wheeling diode to carry current during de-excitation. In this topology, a separate EDEX is not required. The dc contactors should not be used since the free-wheeling diode on the bridge must remain connected to the generator field.

For customers requiring rapid de-excitation, an SCR de-excitation module is provided. In the EDEX, an SCR is fired to provide a conduction path through the field discharge resistor (or inductor) for the field current to flow and dissipate the field energy.

Note De-excitation modules can be paralleled for larger excitation systems.

The EDEX has dual independent firing control circuits. Each is activated by a parallel combination of auxiliary contacts representing the status of the field contactor(s), bridge ac supply breaker, and exciter bridge operating state. Any one of these paths can gate the de-excitation SCR, which does not conduct unless the field voltage is inverted. If neither firing control circuit can fire the SCR, it is fired on overvoltage when the anode-to-gate voltage on the SCR exceeds the break over voltage of the break over diode string connected between the anode and gate. For further details, refer to the *De-excitation (EDEX) Control Board Instruction Guide* (GEI-100466).

Some applications may require a crowbar module to limit pole-slip voltages. Crowbar and de-excitation may be combined into a single module.

2.3.3 Shaft Voltage Suppressor

The Shaft Voltage Suppressor (SVS) is a filter that conducts the high-frequency components of the induced voltages to ground and protects the shaft bearings. The SVS is not used in brushless systems and is optional in some static excitation applications.

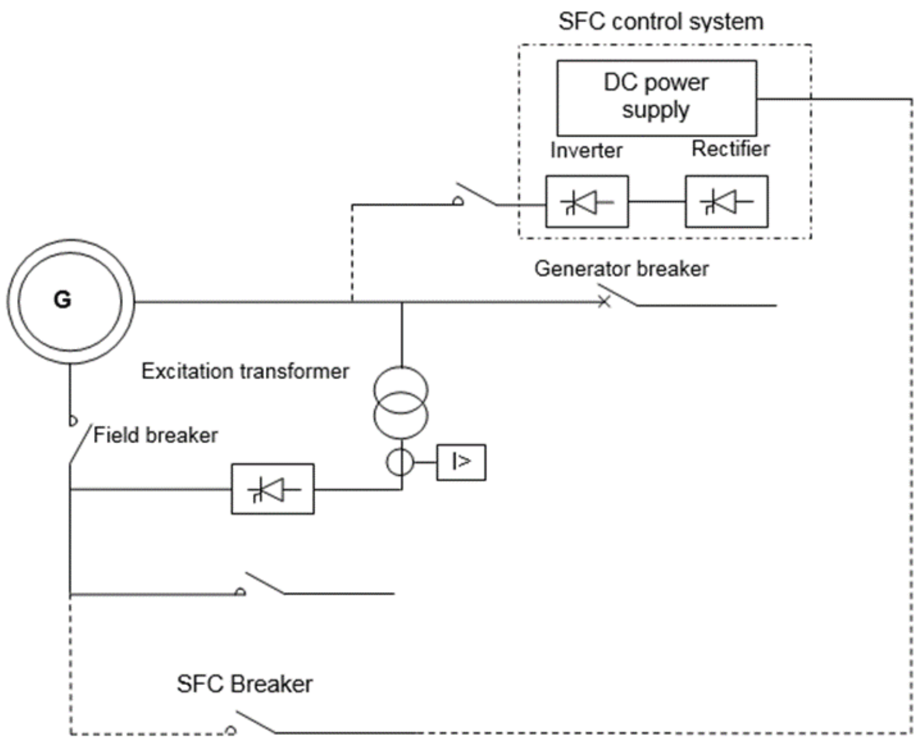
Some SVS modules may include CT sensors used by an external Collector Health Monitor (CHM).

2.3.4 Field Flashing Module

The Field Flashing module is provided on generator, terminal-fed excitation systems. It supplies initial exciter current and builds generator voltage, supplying approximately 10 - 15% of no-load field current from the station batteries during the startup sequence.
AC field flashing modules are used on larger machines requiring significant flashing current. The ac power is supplied through an isolation transformer. Both designs require customer-supplied power.

2.3.5 SFC Starting

Some generator driving engines (especially hydro applications) need an auxiliary device for starting. Instead of an electric motor or a diesel engine, the generator can be used as a synchronous motor for that purpose. In this case a Static Frequency Converter supplies the generator with a variable voltage and frequency, and provides either a field current reference for the excitation system or directly control the field current. An external command signal closes simultaneously the field breaker and the SFC breaker. The generator speed increases following a slope with a constant V/f ratio until the speed required for synchronization is reached. When the unit has reached the synchronous speed, the driving engine is started. The generator can be connected to the network. Then the SFC breaker is opened and the regulator of the excitation system controls the stator voltage of the generator.



SFC starting

2.3.6 Boost Module

The optional Boost module may be provided on terminal-fed, brushless excitation systems. The boost module is used in conjunction with the Field Flashing module to provide exciter current from a station battery under generator fault conditions when the terminal voltage may have collapsed.

The boost module includes a connected bank of resistors that provide the resistance necessary to limit the exciter field current to approximately 150-200% of rated current. Boost current is calculated as follows:
Vbattery / RF + Rboost

Depending on the magnitude of Vbattery compared to rated field voltage, a boost resistor may not be necessary to limit the current to an appropriate value. The module typically becomes active if the PPT voltage drops to 75% of rated, and provides boost current for up to 10 seconds, allowing time for the fault to clear and normal operation to resume.

2.3.7 Field Ground Detector Modules

The generator field winding is electrically isolated from ground. The existence of one ground usually does not damage the rotor. However, the presence of two or more grounds in the field winding path causes magnetic, thermal, and electrical imbalances, as well as localized heating, which can damage the rotor forging or other metallic parts. The field ground detector is an active protection device. It detects a ground path from any exciter component connected to, and including, the main field windings.

The Exciter Attenuation Module (EXAM) drives the electrical center of the field winding with a low frequency ac voltage relative to ground. To detect the current flow, the voltage across a sensing resistor is picked up by the EXAM and measured by the Exciter Auxiliary Interface (EAUX) board. The signal is sent over a high-speed serial link (HSSL) to the controller, where it is monitored and alarmed. For further details, refer to the *EX2100e Excitation Control Exciter Attenuation Module (EXAM) Instruction Guide* (GEI-100509), and the *EX2100e Excitation Control Auxiliary Interface (EAUX) Board Instruction Guide* (GEI-100779).

Also available is a stand-alone version of the ground detector, known as the Digital Ground Detector (DGD). This module provides a separate terminal board user interface. For more information, refer to the *Digital Ground Detector User Guide* (GEH-6715).

2.3.8 High Voltage Interface

The High Voltage Interface (HVI) module contains the ac line filter fuses and several circuit boards. The Bridge AC Feedback (EBAC) board uses transformers to step down and isolate incoming PPT ac voltage used by the control. The Bridge dc Feedback (EDFF) board uses fiber-optics to provide isolated field voltage and current feedback to the control. The EXAM interfaces the field ground detector. All of these boards connect to the EAUX, which interfaces to the controller through the High-speed Serial Link Interface (HSLA) board.

2.4 Power Conversion Cabinet

The Power Conversion Cabinet contains the PCM, the EBRG, ac circuit breaker or disconnect, and the dc circuit contactor. Three-phase power for the PCM comes from a PPT external device to the exciter. The ac supply comes into the cabinet through the ac circuit breaker or disconnect (if supplied), and is filtered by 3-phase line filters.

2.4.1 Manual AC Disconnect or AC Breaker

The optional manual ac disconnect switch serves as a disconnect device between the secondary of the PPT and the static exciter. It is a molded case, 3-phase, non-automatic, cabinet-mounted switch that is manually operated to isolate the ac input supply. It is a no-load disconnect device. For most EX2100e control systems, an ac circuit breaker is also available.

Note For 100 mm systems, a manual 5-pole (3 ac, 2 dc) disconnect for online maintenance is available.

2.4.2 Power Conversion Module

The exciter Power Conversion Module (PCM) includes the bridge rectifiers, dc leg or ac line fuses, thyristor protection circuitry (such as snubbers, filters and fuses) and leg reactor assemblies. The components vary for different bridge ratings based on the power output required.

2.4.2.1 Filters

Three-phase input power is fed to the bridge from the secondary of the PPT, either directly or through an ac breaker or disconnect, and a line-to-line filter. With inverting bridge designs, the bridge is capable of negative forcing voltage, which provides fast response for load rejection and de-excitation. The dc current output of the bridge is fed through a shunt, and, on some designs, a contactor (41A or both 41A and 41B) to the generator field. The bridge uses dc leg or ac line fuses to protect SCRs from overcurrent.

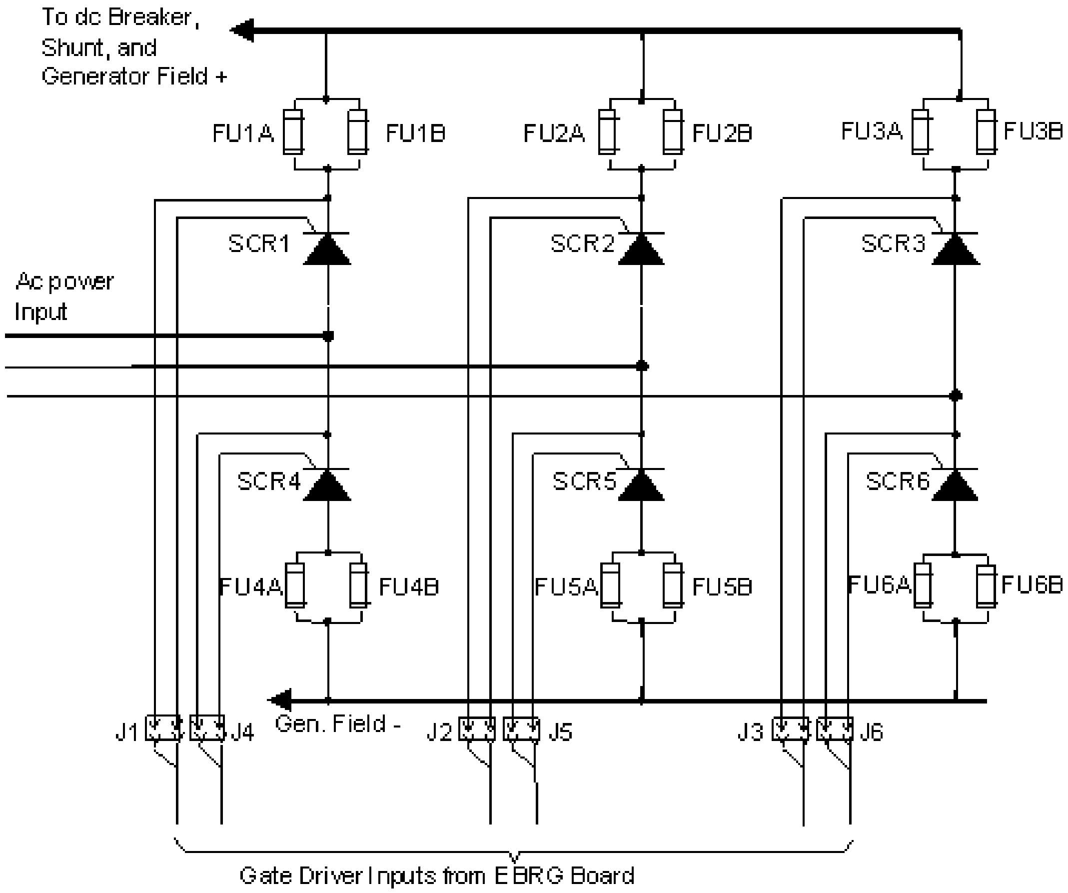
Some exciter PCMs may contain leg commutating reactors, SCR snubbers, and voltage balancing PRV resistors. Other EX2100e control systems integrate these filter components with the ac line filter.

2.4.2.2 Current Shunt

A dc shunt provides the bridge output current feedback signal. The mV output signal is input to a differential amplifier on the EDFF board. The EDFF provides dc current and voltage feedback to the controls. The amplifier output voltage controls the frequency of an oscillator that generates a fiber-optic signal sent to the control module. The bridge output voltage feedback signal is generated in a similar way.

2.4.2.3 Bridge Rectifier

Each bridge rectifier is a 3-phase, full-wave, thyristor bridge. It has six SCRs (thyristors) controlled by the EBRG. Optionally, the 42mm thyristor bridge may be supplied as a non-inverting bridge with an integral free-wheeling diode. Heat is dissipated through large aluminum or copper cooling fans and forced airflow from fans.



Typical Power Bridge

2.4.2.4 Rogowski Coils

Some of the EX2100e control bridges include Rogowski coil current feedback. This is used for SCR diagnostics, current measurement on a per-bridge basis, or for compound source applications.

2.4.3 Bridge Interface

The EBRGH2 (or EBRGH1 for 100 mm excitation systems) interfaces the control to the power bridge. The EBRG takes the gate commands from the UCSx controller and generates the gate firing pulses for six SCRs. It is also used for interface for current conduction feedback, cooling fan control, analog outputs (DAC) and bridge airflow, and temperature monitoring.

Note The gate pulse amplifiers directly control the SCRs.

A thermistor monitors the bridge temperature and generate alarms. Additional sensors are actuated by rotation to monitor cooling fans that send airflow across the bridge. On retrofit excitation controls, the exciter may have provisions for accepting feedback from two thermal switches mounted on the SCR heatsink assemblies. One thermal switch opens at the alarm level (76°C, 170 °F) and the other at the trip level (87°C, 190 °F). These switches are wired to the EBRG and may require upgrade into the existing bridge. If either switch opens, a bridge overtemperature alarm is generated. If both switches open, an alarm and a trip are generated.

2.4.3.1 Cooling Fan Assembly

The SCR bridge module is cooled with forced air.

Only the 42 mm systems can be supplied without cooling fans. All other systems require forced cooling to meet the published product current ratings. One to six fans are used, depending on the bridge rating and redundancy requirements:

- In 42mm configuration, 1 or 2 fans are mounted under each bridge.
- In 52/77 mm configuration, the fans are mounted on the top of the power converter cubicle: ventilation is designed at the power converter cubicle level not at the bridge level. In case of simplex configuration (1 bridge), there are: 2 fans in non-redundant ventilation configuration, 4 fans in case of ventilation redundancy. In case of WBU configuration (2 bridges), there are: 3 fans in non-redundant ventilation configuration, 6 fans in case of ventilation redundancy.
- In 100mm configuration, the fans are mounted on the top of each bridge cubicle. Each bridge can be cooled by 1 or 2 fans (in case of redundant ventilation).

On 77/53mm and 42mm systems, cooling fans are powered by single-phase AC power (115V or 230V) supplied by the customer. On 100mm systems, three-phase fans (operable at 480V / 60Hz or 400V / 50 Hz) are used.

Note In redundant fan applications on the 100mm and 77/53mm, a fan can be replaced while the exciter is running. Because the exciter may present some risk of arc-flash hazard when energized, personnel must wear appropriate PPE when performing a fan replacement.

Only the 42 mm systems can be supplied without cooling fans. All other systems require forced cooling to meet the published product current ratings.

2.4.4 Main DC Contactors

The optional main dc contactor (41A or 41A/41B at the output of the PCM) provides a disconnect between the PCM and generator field. The contactor picks up when the running mode is selected and no fault exists in the excitation. The contactor is normally actuated using pilot relays on the EAUX driven by the controller. The auxiliary contacts from the contactor are routed back through the EAUX as feedback signals.

The dc contactor control is electrically interlocked to the customer 86G lockout. This ensures the exciter is disconnected from the field during lockout or emergency situations, even if the exciter control software is not operating correctly.

2.5 Operator Interface

Operator and engineering workstations, such as the Human-machine Interface (HMI), communicate with the exciter to allow operator control and monitoring of the exciter, as well as engineering access to system diagnostics and control block configuration. Operator interface options include:

- Turbine control HMI
- ToolboxST application
- Control operator interface
- Touchscreen operator interface

2.5.1 Turbine Control HMI

The EX2100e control shares the HMI on turbine generator sets that include Mark* VIe turbine controls. The HMI has a Windows®-based operating system with CIMPLICITY* operator display software and communication drivers for the unit data highways (UDH). Using an HMI, the operator can initiate commands and view real-time data and alarms on the CIMPLICITY graphic display screens. It contains exciter and turbine graphic displays and can be mounted in a control console or on a tabletop. An HMI can be configured as a server or viewer, and may contain tools and utility programs.

The UDH connects the exciter with the HMI or HMI/Data Server. For further details, refer to the *NetworkST 3.1 for Mark Vie Controls Application Guide* (GEH-6840).

Note Redundant Ethernet cable operation is optional and, if supplied, operation continues even if one cable fails.

2.5.2 Standalone Configuration

The EX2100e control is also available in standalone configuration, meaning DCS is a third-party system.
The excitation system can then integrate a separate workstation that provide the excitation HMI views. The HMI has a Windows®-based operating system with CIMPLICITY* operator display software and communication drivers for the unit data highways (UDH). Using an HMI, the operator can initiate commands and view real-time data and alarms on the CIMPLICITY graphic display screens.

2.5.3 ToolboxST Application

The ToolboxST application is used to configure and maintain the exciter. The software runs on an HMI server or a separate maintenance computer on the UDH. Using the application configuration tools, control blocks and diagrams can be modified and loaded to the EX2100e control. With the exciter online, the ToolboxST screen displays real-time data, including control system diagnostics that can be used for troubleshooting.

2.5.4 Control Operator Interface

The control operator interface provides more functionality than the touchscreen operator interface (keypad). The operator can use a control operator interface for exciter control and status display, to collect Sequence of Events (SOE) data, and to run the WorkstationST* application.

graphEX-OI

The graphEX-OI is an optional door-mounted or remote-mount operator interface with a touchscreen that displays and controls EX2100e signals. It connects directly to the control system through the UDH; however, it is less functional and more cost-effective than an HMI control interface. The graphEX-OI uses a solid-state drive (SSD) for storage, has a Windows-based operating system and has a display screen that is optimized for touchscreen use that is available in a 396 mm (15.6 in) wide-screen format. The display screen includes critical operation values, key control functions, full alarm monitoring and acknowledgement, and generator capability curve (where applicable).

graphEX-OI Operator Interface

Legacy Control Operator Interface (COI)

Attention

The legacy COI is obsolete, and units are no longer available. GE recommends using the graphEX-OI in place of the COI

Legacy versions of the COI are an optional cabinet door-mounted remote touchscreen interface that displays and controls EX2100e signals (if remote control was needed). It connects directly to the control system through the UDH; however, it is a less-functional, more cost-effective control interface than an HMI. The COI configuration uses a hard disk drive, Windows®-based touchscreen interface, with either a 254, 305, or 381 mm (10, 12, or 15 in) liquid crystal display (LCD) touchscreen. The screen displays operation status, alarms, and COI configuration.

COI

2.5.5 Touchscreen Operator Interface

The optional touchscreen operator interface displays operational status and provides exciter control operation. For further details, refer to the section *Touchscreen Operator Interface* and the *EX2100e Excitation and LS2100e Static Starter Control Systems Touchscreen Local Operator Interface Instruction Guide* (GEI-100787).

Notes

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. For more information, refer to the *ToolboxST User Guide for Mark Controls Platforms* (GEH–6700), the sections related to the EX2100e Excitation Control.

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.

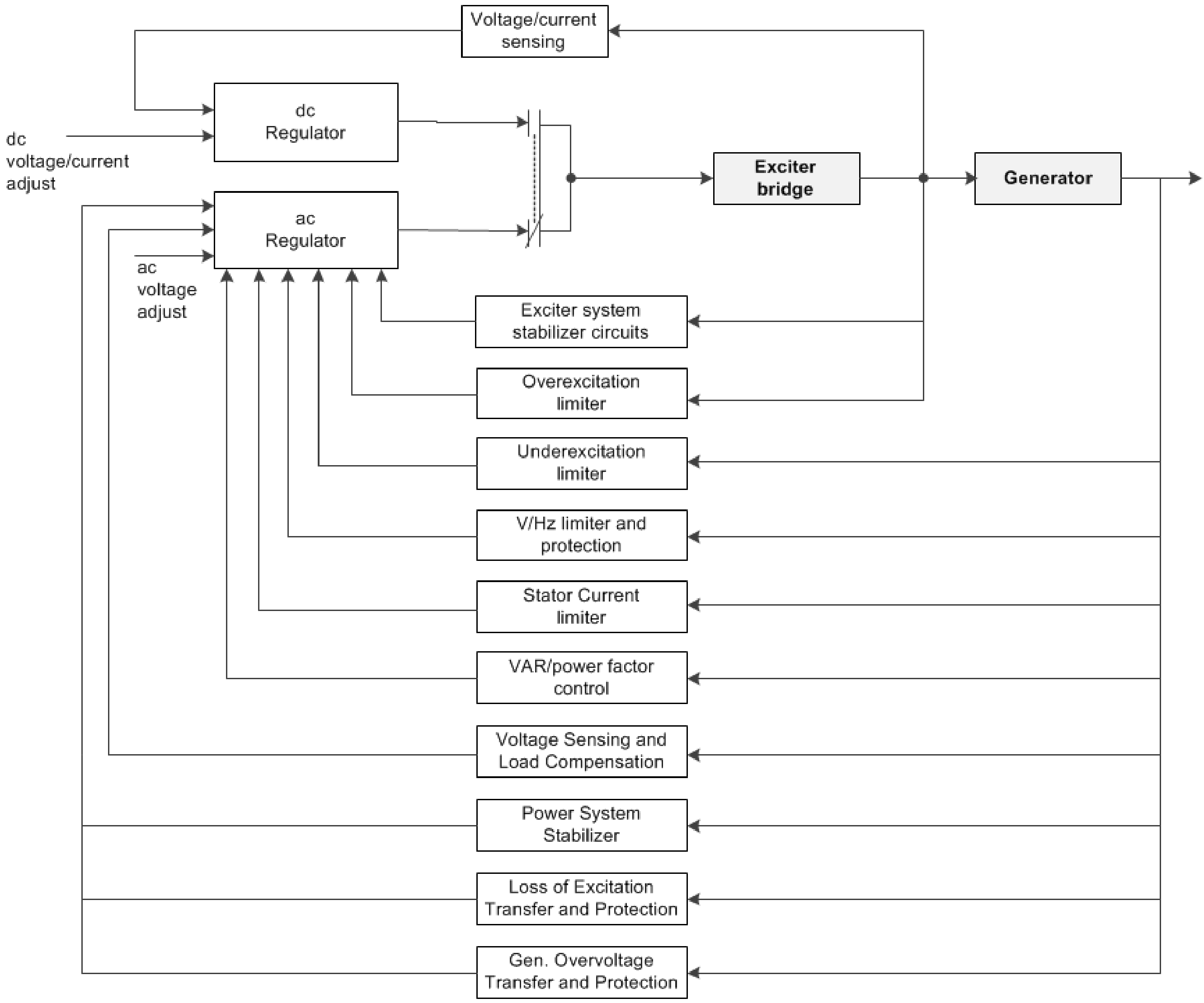
The output of the software transducer system includes the following:

- Generator voltage
- Generator current
- 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)

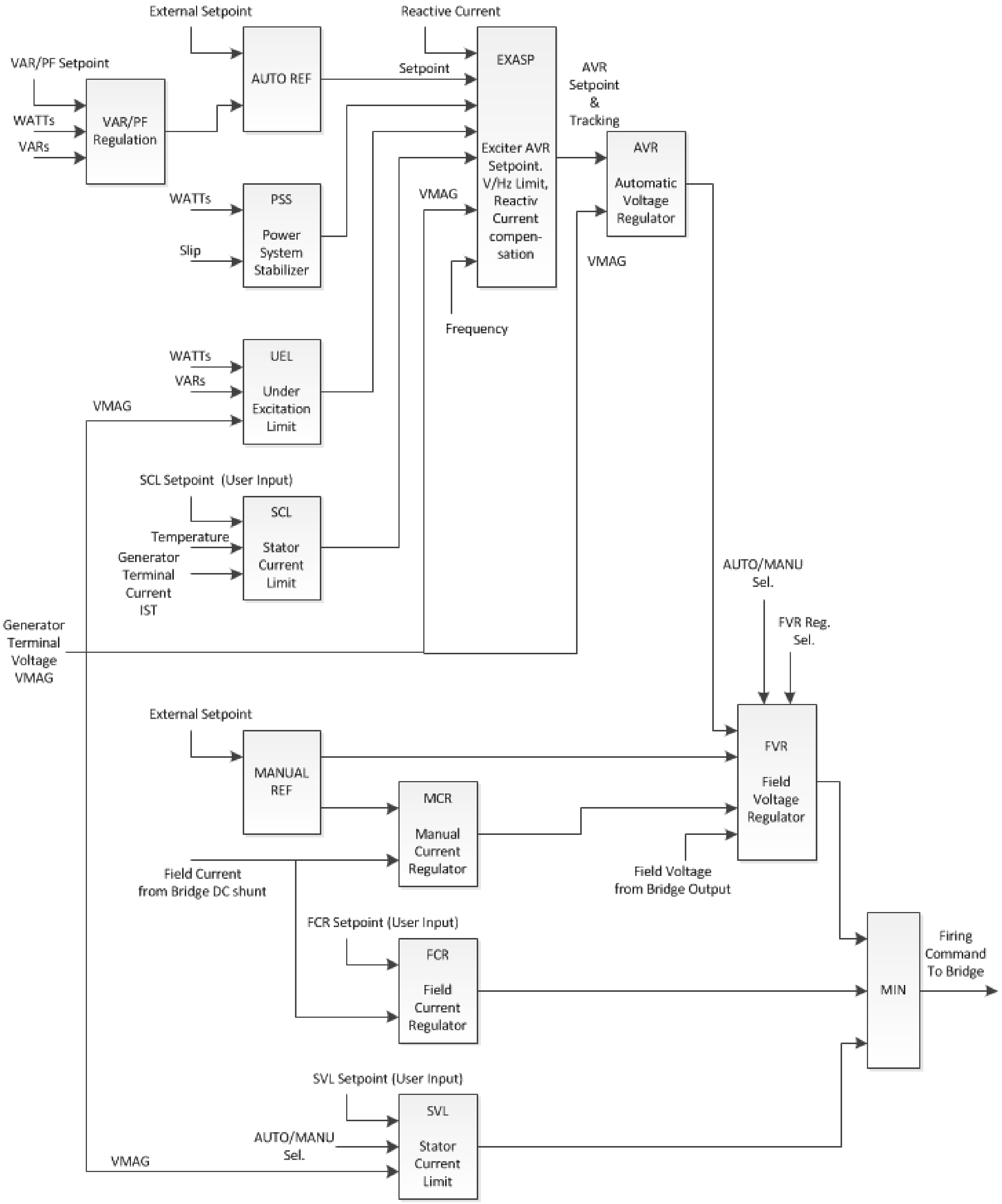
The transducer system uses the output to calculate the following:

- 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)

3.1 Control Blocks

The application software emulates traditional analog controls. It uses an open architecture system with a library of existing software control modules (blocks) that are configured using the ToolboxST application. For further details, refer to the *ToolboxST User Guide for Mark Controls Platforms* (GEH-6700). The control blocks are combined to create required system functionality. Block definitions and configuration parameters are stored in flash memory, while variables are stored in random-access memory (RAM). From the ToolboxST application, control blocks can be interrogated while the exciter is running.

Note The *UCSx controller* runs the exciter control code.

Individually, the blocks perform specific functions such as logic gates, proportional integral (PI) regulators, function generators, and signal level detectors. The EX2100e control selects one of two modes: generator voltage regulation (Auto Regulation), or direct control (voltage or current, depending upon the application). Generator protection functions are integrated into the control, including overexcitation limiting (OEL) and underexcitation limiting (UEL), power system stabilization (PSS), stator current limiter (SCL) and V/Hz limiting.

3.1.1 Auto Reference Block

The Auto Reference (AUTO REF) block generates an auto control set point for the Automatic Voltage Regulator (AVR) based on user-supplied parameters and conditions. Either raise and lower inputs or absolute set point value to AUTO REF are received from the other devices on the data highway, such as the turbine control, HMI or external I/O modules. A variable rate integrator generates the output set point within preset limits. The set point is combined with other auxiliary stabilizing and protective signals in the *Exciter AVR Set point (EXASP) block* to form the reference to the AVR block.

Note The dynamically changing I/O module values of each block can be observed in operation, which is valuable during startup or troubleshooting.

3.1.2 Exciter AVR Setpoint Block

The Exciter AVR Set point (EXASP) block combines a number of functions to produce the internal voltage set point (reference input) to the AVR and provide the AVR tracking value. The AVR set point and tracking value are the inputs to the *Automatic Voltage Regulator (AVR) block*.

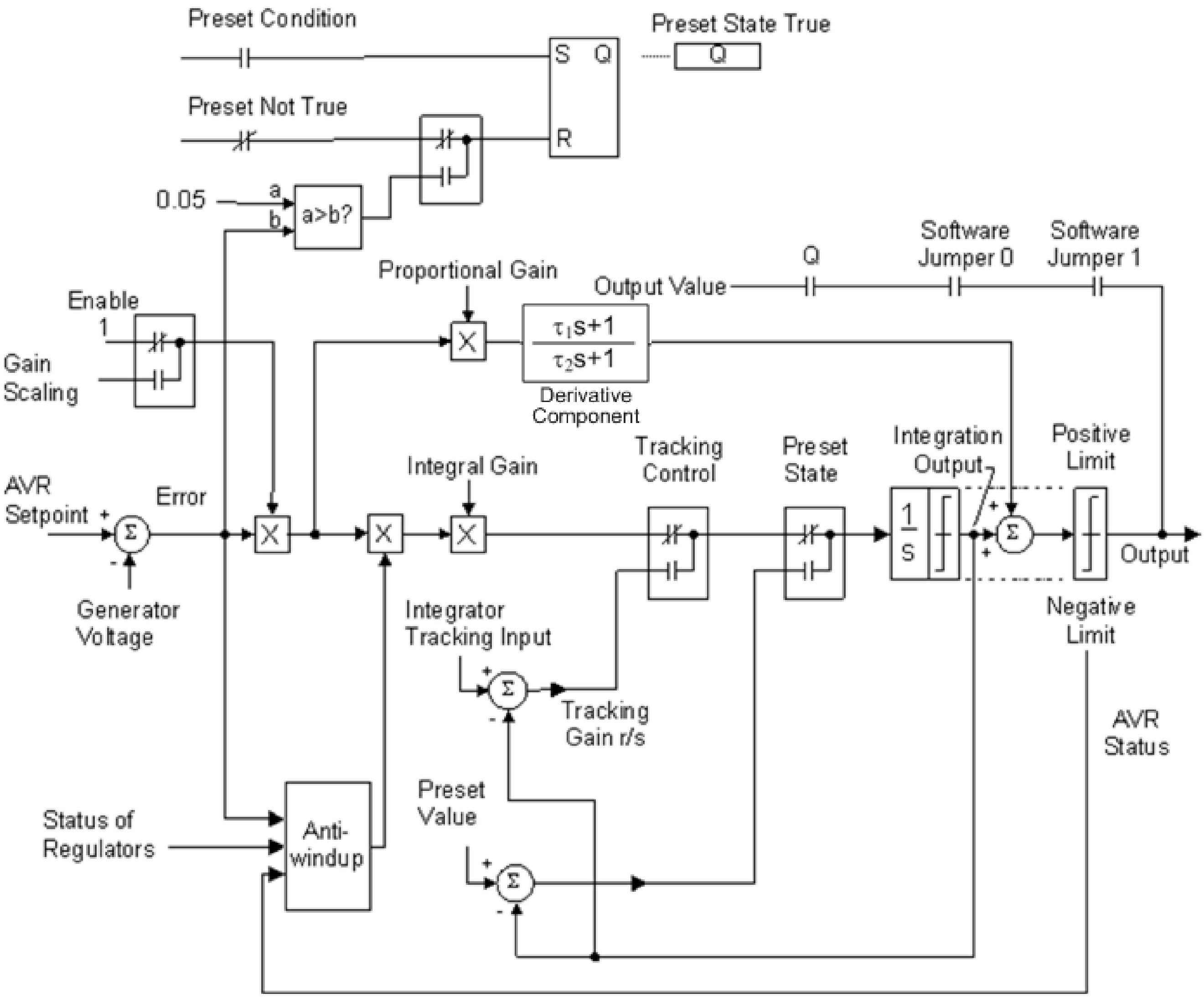
The internal voltage set point integrates in the following priority order (higher priority to lower priority):

- Reference higher value saturation
- Stabilizing signal from the *Power System Stabilization (PSS) block*
- Over fluxing limitation output
- Stator current limiter output
- Droop compensation (based on reactive current input (feedback))
- Control signal generated by the *Under-Excitation Limit Control (UEL) block*
- Output from the *AUTO REF block*
- External test signal

A Power Factor or Reactive Power regulation loop can also be implemented in option to drive the internal voltage set point (reference input) to the AVR.

3.1.3 Automatic Voltage Regulator Block

The Automatic Voltage Regulator (AVR) block controls the generator terminal voltage. The set point (reference) comes from the *EXASP* block, and the feedback is the generator voltage. The error value is input to a PI regulator with integrator windup protection that produces an output signal. When the AVR is enabled, the output is passed directly from the track input to the output of the *Field Voltage Regulator (FVR) block*.



AVR Block

3.1.4 Manual Reference Block

The Manual Reference (MANUAL REF) block generates a manual set point for the *Field Voltage Regulator (FVR) or Field Current Regulator (FCR)* based on user-supplied parameters and conditions. Raise/Lower inputs to MANUAL REF come in from other control devices on the data highway, such as the turbine control, HMI or external I/O modules.
The block integrates a simple under excitation limit that prevent decrease of the manual set point when the limit is reached.

3.1.5 MANU Mode Regulation

The excitation solution application offers 2 possibilities for MANU mode regulation. They are not possible simultaneously. The selection is a user defined parameter. In the application, the configuration is either FVR (Field Voltage regulator) or MFCR (Manual Field Current Regulator).

3.1.5.1 Field Voltage Regulator

The Field Voltage Regulator (FVR) is one possibility offered by the excitation system as manual regulator. It uses the generator field voltage as the feedback input. While FVR permits the current to vary as a function of the field resistance, it makes the manual regulator completely independent from the overexcitation limiter (OEL). The FVR uses the voltage from the generator field as feedback, with a set point from the *MANUAL REF block*. A PI regulator with integral windup protection generates the output. During operation in AUTO mode, the output of the AVR is passed directly to the FVR output with no signal conditioning. On units that operate with an inner FVR loop, such as compound exciters and some high ceiling exciters, the FVR uses a set point from either the *AVR block* or the *MANUAL REF block* and is always operational whether in manual or automatic operation.

3.1.5.2 Manual Field Current Regulator

The Manual field Current Regulator (MCR) is the second possibility offered by the excitation system as manual regulator. It uses the generator field current as the feedback input. The current set point is from the *MANUAL REF block*. A PID regulator with integral windup protection generates the output. In this case, during operation in MANU mode, the output of the MCR is passed directly to the FVR output with no signal conditioning.
The Manual field Current Regulator allows the control of the flux during transient operation like electrical breaking, SFC starting, back to back starting…

3.1.6 Bridge Firing Command

The bridge firing command is the smallest of the FVR (Field Voltage Regulator), FCR (Field Current Regulator – Overexcitation limiter) and the SVL (Stator Voltage Limiter – only in MANU mode) outputs.

3.1.7 Under excitation Limit Block

The Under-Excitation Limit (UEL) block is an auxiliary control to limit the AVR demand for under excited reactive current (or reactive power). The UEL prevents reduction of the generator 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 limiter action on the generator capability curve. There is both a set point section and regulator section of the UEL. The two key inputs are generator terminal voltage and real power.

3.1.8 Stator Current Limit Block

The Stator Current Limiter (SCL) block is an option auxiliary control.
This function is designed to keep the stator current within its limits and thus to avoid overheating of the stator. As an option, this limitation might be temperature dependent (two slopes to approximate generator temperature capability curve).
The limitation provides an over excitation signal when VARs < 0 and a de-excitation signal when VARs > 0. The stator current limitation reference presents an "Inverse time" behavior, following recommendations of the international standards (especially ANSI C50.13 recommendation). That means that the set point decreases per the overheating of the stator.
When VARs approaches zero, the limitation is disabled (dead band). Inside the dead band the limitation function is no longer operating. The only way to limit the stator current is then to send a signal to limit the power of the turbine.

3.1.9 Power System Stabilization Block

The Power System Stabilization (PSS) block provides an additional input to the automatic regulator to improve power system dynamic performance. A number of different quantities may be used as inputs to the PSS, such as shaft speed, frequency, synchronous machine electrical power, accelerating power, or some combination of these. When used with the exciter, the PSS is multi-input 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. The input signal is derived entirely from generator terminal quantities without the need for shaft speed transducers. No additional external hardware is required. For further details, refer to the *Power System Stabilizer for an EX2100 and EX2100e Excitation Control User Guide* (GEH-6676).

Note To implement a Power System Stabilizer (PSS), the EX2100e control requires, at a minimum, a 3-phase PT and a 1-phase CT, although it is preferred to have two 1-phase CT inputs.

3.1.10 V/Hz Limiting

The V/Hz limiter is an auxiliary control to limit the AVR demand for generator terminal voltage proportional to generator speed. A V/Hz limiter prevents excessive fluxing of the generator and associated equipment, such as auxiliary transformers and PTs. Typically, the generator is considered to be adequately operating within ±5% of generator rated terminal voltage at rated frequency. The protection settings are an inverse time characteristic, which approximates the overexcitation capability of the generator.

3.1.11 Droop Compensation

The reactive compensation function allows to operate several generators either connected directly in parallel (negative compensation gain), or to compensate the line voltage drop (positive compensation gain) through the Main Transformer. This function generates a corrective term added to the voltage set point, proportional to the actual reactive stator current. The correction gains can be set from 20% to +10%.

3.1.12 Stator Voltage Limiter Block

As an option a stator voltage limitation function may be available in manual mode.
It prevents stator over voltage during MANU mode operation.

3.1.13 Overexcitation Trip and Overexcitation Limiter

The Overexcitation Limiter (OEL) protects the generator field from damage by events that require or produce abnormally high field currents. Over an extended time, these high currents can overheat the field and cause damage. Generator fields are designed to ANSI® Standard C50.13, which specifies an overvoltage as a function of time that the field is allowed to follow. This standard uses curves to describe the field overheating as a function of time and current. The OEL design approximates the curve of field current versus time. A maximum current reference prevents the excitation current to increase above the ceiling current of the machine.

The Overexcitation Trip (OET) is a backup protection in the event of OEL failure. It also approximates the curves in ANSI C50.13, with suitable times at appropriate current levels before generating an excitation trip signal.

3.1.14 Loss of Excitation

A Loss of Excitation (LOE) protection function is available with the WBU control scheme. It detects a loss of excitation on synchronous machines and provides the GE-recommended settings that require two separate relay characteristics. The LOE function is performed within software code and can accommodate offset settings and two diameter settings. The recommended offset settings are both equal to one-half the machine transient reactance (X'd/2). The small diameter setting is equal to 1.0 per unit on the machine base, and the large diameter setting is equal to the machine synchronous reactance (Xd). The small diameter setting has no time delay and the large diameter setting has an adjustable time delay. Each of the two relay's characteristics (offset, diameter and time delay) are independently adjustable and initiate a transfer to the backup controller, as well as a trip signal if the condition persists.

3.1.15 Generator Overexcitation Protection

The Generator Overexcitation protection (59G) prevents an overvoltage on the machine that may arise from a load rejection that causes an overspeed while the regulator is in manual mode, or an overspeed that may occur while the unit is offline and the voltage regulator is in manual mode.

3.1.16 Excitation Transformer Over Current Protection

50 – Instantaneous overcurrent relay.
51 – AC inverse time overcurrent relay.

As an option, a Micom P14N can be integrated in the excitation system.
The relay monitors the excitation transformer primary current.
The first stage fault causes an alarm generation when the excitation current exceeds a reference threshold.
The second stage fault protects the excitation transformer in case of short circuit and gives a tripping order immediately when the excitation current exceeds a reference threshold.

3.1.17 Excitation Transformer Over Temperature Protection

26 – Apparatus thermal device.

The function used 3 temperatures measurements to monitor the temperatures transformers. The 3 temperatures are acquired by RTD probes connected to excitation system I/Os modules.
The function realized the following treatments:

- Definition of maximal temperature from the 3 measurements
- Tests its value against a first threshold to signal an alarm
- Tests its value against a second threshold to generate a trip

The function is an option of the excitation system.

3.1.18 Excitation Transformer Zero Sequence Overvoltage Protection

59N – Zero-sequence Overvoltage relay.

As an option, a Micom P921 can be integrated in the excitation system.
The relay monitors the excitation transformer neutral voltage and detects, when exists due to unbalance of the transformer primary voltages, a homopolar voltage.
The function realized the following treatments:

- Tests the voltage against a first threshold to signal an alarm
- Tests its value against a second threshold to generate a trip

It protects the excitation system in case of insulation defects to the ground.

3.2 Password Protection

With Mark VIe controller firmware V06.00, a password security feature restricts access to the controller. This password has an eight-character limit and other requirements. Refer to the *ToolboxST User Guide for Mark Control Platforms* (GEH-6700) for instructions on password configuration.

Notes

4 Ratings and Specifications

Note The following tables indicate a range of possible product offerings but not necessarily the capability of the exciter. Refer to the exciter data nameplate for the actual equipment rating.

Ratings and Characteristics

EX2100e SCR	Approximate Exciter Current Capability	PCM Type	Number of PCMs	Number of Shipping Sections	Approximate Weight (lb)	Approximate Dimensions (l x w x h)
42 mm	165 A dc	Simplex or WBU, Convection	1 or 2	1	850.5 kg (1875 lb) (simplex) 1451.5 kg (3200 lb) (WBU)	1803.4 x 800 x 2654.3 mm (71 x 31.5 x 104.5 in) (simplex)
42 mm	500 A dc 200 A dc (PMG)	Simplex or WBU, Forced Air	1 or 2	1	850.5 kg (1875 lb) (simplex) 1451.5 kg (3200 lb) (WBU)	3009.9 x 800 x 2654.3 mm (118.5 x 31.5 x 104.5 in) (WBU)
53 mm	1000 A dc	Simplex or WBU	1 or 2	1	1814.4 kg (4000 lb) (simplex) 2540.1 kg (5600 lb) (WBU)	2844.8 x 800 x 2654.3 mm (112 x 31.5 x 104.5 in) (simplex, no auxiliary)
77 mm	2000 A dc	Simplex or WBU	1 or 2	1	1814.4 kg (4000 lb) (simplex) 2540.1 kg (5600 lb) (WBU)	3606.8 x 800 x 2654.3 mm (142 x 31.5 x 104.5 in) (WBU)
100 mm	2800 A dc	Simplex or WBU	1 or 2	2	7892.5 kg (17400 lb) (2 PCM)	5042 x 1231.9 x 2692.4 mm (198.5 x 48.5 x 106 in) (2 PCM)
100 mm	6000 A dc	N+1 or N+2	3 or 4	2	9491.4 kg (20925 lb) (3 PCM)	5994.4 x 1231.9 x 2692.4 mm (236 x 48.5 x 106 in) (3 PCM)
100 mm	8000 A dc	N	4	2	11090.3 kg (24450 lb) (4 PCM)	6997.7 x 1231.9 x 2692.4 mm (275.5 x 48.5 x 106 in) (4 PCM)

Specifications

<table>
<tr><th>Item</th><th colspan="2">Description</th></tr>
<tr><th colspan="3">PCM</th></tr>
<tr><td>Forcing requirements</td><td colspan="2">150% of design amperes (EDA) for 30 sec at 40°C (104 °F) standard
Other requirements available with evaluation</td></tr>
<tr><th colspan="3">Power Sources</th></tr>
<tr><td>Power for the PCM – Voltage source</td><td colspan="2">Auxiliary bus (potential source)
Generator terminals (potential source)
Compound source (generator terminals and PCTs)
PMG source (300 V ac) 600 or 1000 V or 1400 V versions available</td></tr>
<tr><td>Power for the PCM - Frequency</td><td colspan="2">3-phase 50/60 Hz (up to 480 Hz for 42 mm PMG source)</td></tr>
<tr><td>Power to the Cooling Fans:
42 mm
53 mm and 77 mm
100 mm</td><td colspan="2">40 W per fan at 115 V ac, 1-phase, 50/60 Hz
400 W per fan at 125 V ac 1-phase, 50/60 Hz
1700 W per fan at 480 V ac, 3-phase, 50/60 Hz</td></tr>
<tr><td>Flashing power</td><td colspan="2">125-250 V dc battery source, with up to 200 A for at least 10 s
380-480 V ac, 50/60 Hz 1-phase auxiliary source</td></tr>
<tr><td>Control power (redundant with 2 bridges, WBU)</td><td colspan="2">For two ac sources, or one ac and one dc source:
Nominal 120 or 220 V ac ±15%, with 1 DACA, 8 A rms max
Optional 220 V ac ±15%, with 1 DACA, 6 A rms max
Battery source, 125 V dc, range 80 – 140 V dc, 10.6 A dc max</td></tr>
<tr><td>Control power (simplex controls and bridges)</td><td colspan="2">For two ac sources, or one ac and one dc source
Nominal 120 V ac ±15%, with 1 DACA, 4 A rms max Optional 220 V ac ±15%, with 1 DACA, 3 A rms max Battery source 125 V dc, range 80 - 140 V dc, 4 A dc max</td></tr>
<tr><td>Heat loss in single PCM cabinet</td><td colspan="2">Specific to requisition provided on unit outline drawings</td></tr>
<tr><th>Item</th><th>QTY</th><th>Description</th></tr>
<tr><td>PTs</td><td>2</td><td>3-phase standard, 1-phase available 120 V ac nominal 1 V A nominal burden</td></tr>
<tr><td>CTs (1 or 5 A)</td><td>3</td><td>Any two phases standard, 1-phase or redundant available
1 VA nominal burden</td></tr>
<tr><td>86G dedicated contact input</td><td>1</td><td>Open for trip</td></tr>
<tr><td>52G dedicated contact input</td><td>1</td><td>Closed for online</td></tr>
<tr><td>Trip rated contact outputs</td><td>2</td><td>At 125 V dc with relay break characteristics:
Resistive load 0.5 A Inductive load 0.2 A Normally closed to trip</td></tr>
<tr><td>General-purpose contact inputs</td><td>7</td><td>Customer contacts, 55 V dc supplied by EX2100e System Interface (ESYS)</td></tr>
<tr><td>General-purpose Form C contact outputs</td><td>4</td><td>At 125 V dc with relay break characteristics:
Resistive load 0.5 A Inductive load 0.1 A</td></tr>
<tr><td rowspan="2">±10 V differential amplifier input
Isolated 4-20 mA analog outputs</td><td>2</td><td>For LS2100 or LS2100e control reference or customer use</td></tr>
<tr><td>4</td><td>Optional for monitoring or metering through DIN-rail mounted signal conditioners: Bandwidth 1 kHz
Output load up to 500 Ω Accuracy 5% full scale</td></tr>
<tr><th colspan="3">Thermal</th></tr>
<tr><td>Base controls cabinet</td><td colspan="2">Continuous operation in a 0 to 40°C (32 to 104 °F) ambient environment
with 5 to 95% humidity, non-condensing</td></tr>
<tr><td>Base power conversion and auxiliary cabinet</td><td colspan="2">Continuous operation in a 0 to 40°C (32 to 104 °F) ambient environment
with 5 to 95% humidity, non-condensing</td></tr>
<tr><th colspan="3">Control</th></tr>
<tr><td>Automatic ac Voltage Regulation</td><td colspan="2">Proportional + Integral, software implemented ±0.25 % over full voltage range</td></tr>
<tr><td>Manual dc Voltage regulator</td><td colspan="2">Proportional + Integral, software implemented ±2.0 % over full voltage range</td></tr>
<tr><td>Protection Features</td><td colspan="2">UEL
Overexcitation protection (76)
Generator Field Ground detection (64F) Generator Overvoltage protection (24G) Loss of Excitation protection (40)
V/Hz limit (24) and trip (24T) Bridge Over Temperature (26) Field Over Temperature (49)
Phase Unbalance (22)
PT Failure (60)</td></tr>
</table>

Specifications (continued)

Item	Description
Environmental Control and Protection	
Operating Temperature	Continuous operation in a 0 to 40°C (32 to 104 °F) ambient environment. Operation to 50°C (122 °F) with 0.85% per °C (100 mm, 77 mm, 53 mm), 1% per °C for fan cooled 42 mm, 1.5% per °C convection cooled 42 mm
Storage Temperature	-40 to 70 °C (-38 to 158 °F)
Humidity	5 to 95% humidity, non-condensing
Altitude	Normal operation at 0 to 1000 m. Derate 6% per 1000 m above 1000 m
Cooling	Forced-air cooling required for all PCM cabinets except 42 mm when supplied convection cooled.
Contaminants, withstand 10 PPB of these:	Reactive Sulfur, Reactive Chlorine, Hydrogen Sulfide, Sulfur Dioxide, Chlorine Dioxide, Sulfuric Acid, Hydrochloric Acid, Hyrdogen Chloride, Ammonia
Cabinet Enclosures	
Cabinet type, control and auxiliary	NEMA 1 (IEC IP 20 or IEC IP 31), convection cooled Optional NEMA12 IP54 control cabinet
Cabinet type, power conversion	NEMA 1 (IEC IP 20 or IEC IP 31), forced air cooled or convection (42 mm)
Power and Control Cable Access	Entrances from the top and/or bottom
Cabinet Enclosures	
Mean Time Between Failures (MTBF)	Simplex system 25,000 hrs
Mean Time Between Failure Outages (MTBFO)	Redundant system 175,000 hrs
Mean Time to Repair (MTTR)	Any subsystem 4 hrs
PSS Input Requirements	
Potential Transformer (PT)	One 3–phase PT
Current Transformer (CT)	One 1–phase CT (preferable to have two 1–phase CTs)
Generated Acoustic Noise	
42 mm Convection	Average 60.1 dB
42 mm Fan cooled (2 fans)	Average 77.2 dB
53 mm Fan cooled (4 fans)	Average 76.4 dB simplex, Average 78.4 dB redundant
77 mm Fan cooled (6 fans)	Average 76.6 dB simplex, Average 79.6 dB redundant
100 mm Fan cooled, 60 Hz, 480 V rms	Average 82.7 dB wbu, Average 83.2 dB (3 bridge), Average TBD dB (4 bridge)
100 mm Fan cooled, 50 Hz, 380 V rms	Average 78.2 dB wbu, Average 78.9 dB (3 bridge), Average TBD dB (4 bridge)
100 mm Fan cooled, 50 Hz, 400 V rms	Average 78.4 dB wbu, Average 79.0 dB (3 bridge), Average TBD dB (4 bridge)
Vibration	
Seismic	IBC 2006 / UBC 1997 – Seismic Code section 2312 Zone 4
Sinusoidal	0.075 mm displacement from 10 to 57 Hz and 1 g from 57 to 150 Hz in each of three mutually perpendicular axes

Specifications (continued)

Item	**Description**
Codes and Standards	
Safety	
UL 508C	Power Conversion Equipment
CSA C22.2 No. 14	Industrial Control Equipment
CSA C22.2 No. 0.4	Grounding and Bonding of Electrical Equipment
IEC 60529	Enclosure Degrees of Protection/IP20/NEMA 1
IEEE 421.3	High-potential Test Requirements for Excitation Systems
Circuit Boards	
UL 796	Circuit boards
ANSI / IPC / EIA	Guidelines
Electromagnetic Compatibility Directive (EMC) 2004/108/EC	
Attention	**Equipment is not approved for use in a residential, commercial, or light industrial environment, and should not be connected to a residential electric power network.**
EN 61000-6-4:2001	Generic Emissions Industrial Environment
EN 61000-6-2:2001	Generic Immunity Industrial Environment
EN 61000-4-2:1995	Electrostatic Discharge Susceptibility
EN 61000-4-3:2006	Radiated RF Immunity
EN 61000-4-4:2005	Electrical Fast Transient Susceptibility
EN 61000-4-5:2006	Surge Immunity
EN 61000-4-6:1996	Conducted RF Immunity
EN 61000-4-11:2004	Voltage Dip, Interruptions and Fluctuations
Low Voltage Directive 2006/95/EC	
EN 50178	Electronic Equipment for use in Power Installations

5 Circuit Boards

This chapter describes the EX2100e printed circuit boards and their operation. The boards fall into four functional groups: controller boards/modules, I/O terminal boards, bridge control and protection modules, and power supply modules.

5.1 Controller Boards/Modules

The controller boards/modules are located in the control module. The controller used depends on the system configuration. The available controllers are as follows:

- IS420UCSB Microprocessor-based Universal Controller Stand-alone Version B controller
- IS200CSLA Compact High-speed Serial Link Expansion (CSLA) board (configuration dependant)
- IS420UCEC Microprocessor-based Universal Controller Stand-alone Version C controller with seven Compact HSSL Expansion ports.
- IS200HSLA High-speed Serial Link Interface Board for Host Application (HSLA) board

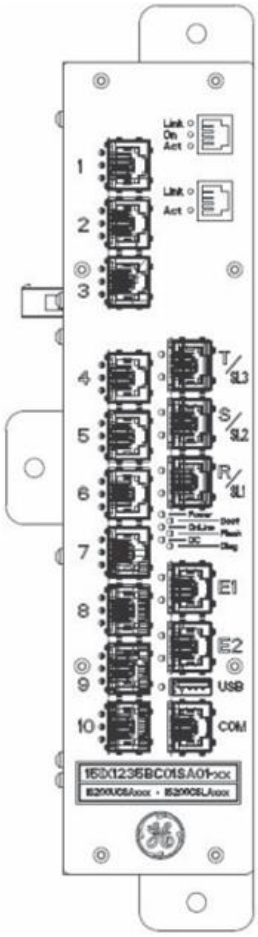
5.1.1 UCSB Controller

The UCSB controller is a stand-alone, single-board controller with scalable processing power. It requires 18-32 V dc (12.5 W typical) power, no fans, no batteries, and no jumper settings. It performs the bridge firing circuit control, I/O processing, and peer-to-peer communications with the other controllers, Ethernet communications with turbine control, Static Starter and HMI, and runs inner and outer loop control functions as follows:

- AVR
- PSS
- UEL
- SCL
- VAR/power factor (VAR/PF) regulator
- FVR
- FCR/MCR
- SVL
- SCR gating signals to the EBRG
- Start/stop function
- Field flashing control
- Protection functions, alarms, and trip logic
- Generator instrumentation processing
- Generator simulator
- Network communications
- HSSL interface to I/O boards

The UCSB controller is available in two platform configurations: UCSBH1A and UCSBH4A. For a comparison between these configurations, such as microprocessor speed and power requirements, refer to the *Mark VIe and Mark VIeS Control Systems Volume II: General-purpose Applications System Manual* (GEH-6721_vol_II), the section *Mark VIe, Mark VIeS, and Mark Stat UCSB Controllers,* the table *UCSB Specifications*.

UCSB Controller (Simplex)



UCSB Controller (Redundant)

5.1.1.1 CSLA

The CSLA is an I/O expansion board used with the UCSB controller to provide 10 HSSL interface ports. This allows the UCSB controller to communicate with the I/O module and bridge interface boards. Refer to the *EX2100e Excitation Control Compact High-speed Serial Link Expansion (CSLA) Board Instruction Guide* (GEI-100788) for further details.

CSLA Board

5.1.2 UCSC Controller

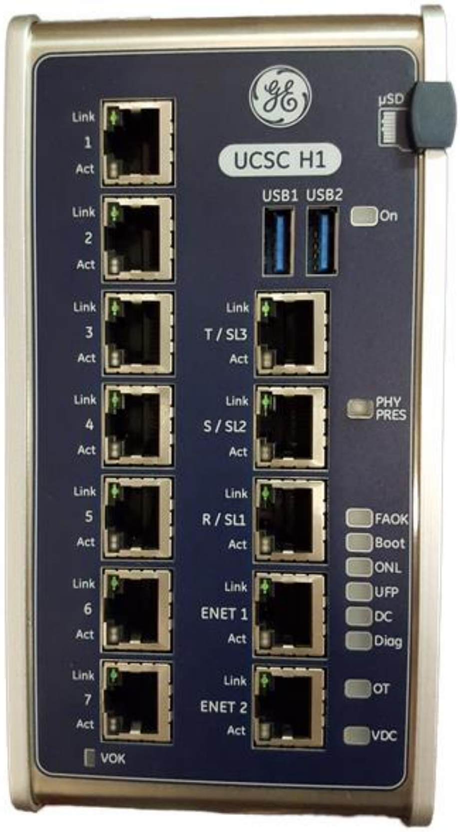
The UCSC controller is a stand-alone, single-board controller with scalable processing power. It requires 18-30 V dc (14 W typical) power, no fans, no batteries, and no jumper settings. It performs the bridge firing circuit control, I/O processing, and peer-to-peer communications with the other controllers, Ethernet communications with turbine control, Static Starter and HMI, and runs inner and outer loop control functions as follows:

- AVR
- PSS
- UEL
- SCL
- VAR/power factor (VAR/PF) regulator
- FVR
- FCR/MCR
- SVL
- SCR gating signals to the EBRG
- Start/stop function
- Field flashing control
- Protection functions, alarms, and trip logic
- Generator instrumentation processing
- Generator simulator
- Network communications
- HSSL interface to I/O boards

The UCSC controller is available in two platform configurations: UCSCH1B and UCSCH3A. For a comparison between these configurations, such as microprocessor speed and power requirements, refer to the *Mark VIe and Mark VIeS Control Systems Volume II: General-purpose Applications System Manual* (GEH-6721_Vol_II), the section *UCSC Controllers*, the table *UCSC Specifications*.

In a redundant configuration, the UCSC controller is coupled with an I/O expansion board to provide seven HSSL interface ports, called the UCEC module. The UCEC module enables communication between the UCSC controller and the I/O module and bridge interface boards. For more information, refer to GEH-6721_Vol_II, the section *UCECH1x I/O Port Expansion Module.*

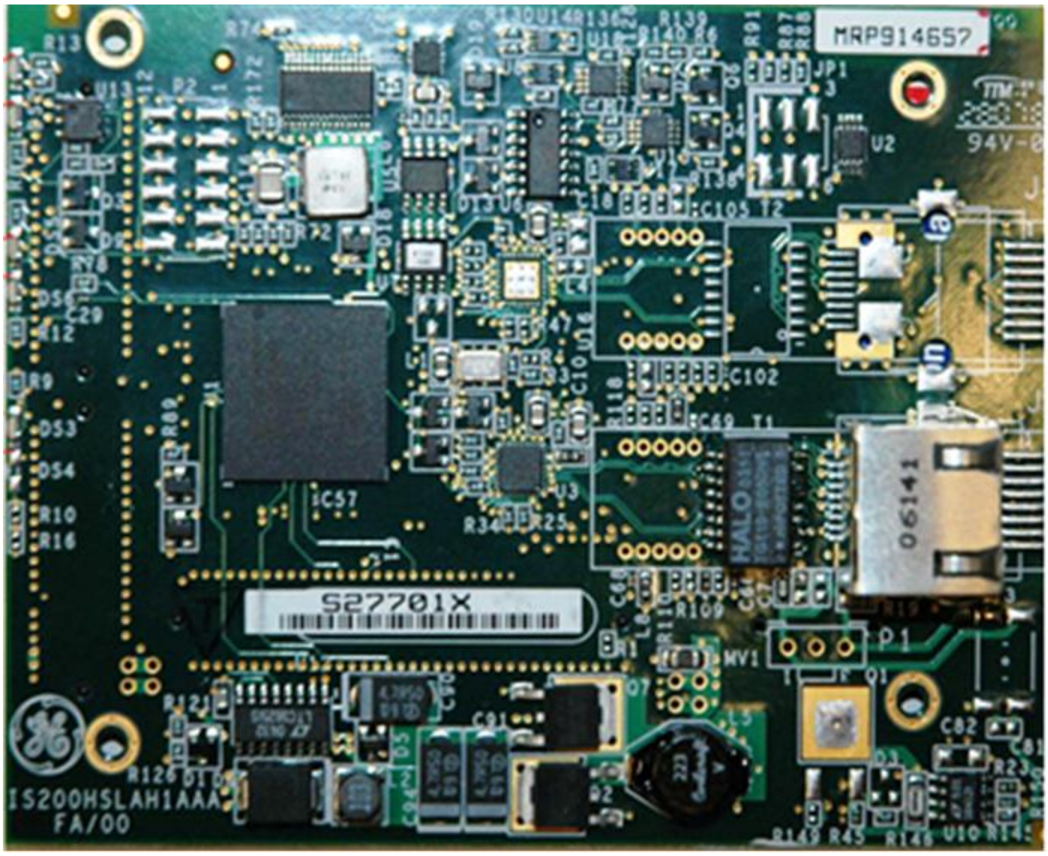
UCSC Controller (Simplex)



UCEC Module (Redundant)

5.1.3 HSLA

The HSLA is a single or dual-port HSSL interface board. The HSLA HSSL daughterboard provides interface to the UCSx controller. A key feature of the HSLA board is the Field Programmable Gate Array (FPGA), which provides the digital control logic functions for the HSSL. Refer to the *High-speed Serial Link Interface (HSLA) Board Instruction Guide* (GEI-100782) for further details.



HSLA Board

5.2 I/O Terminal Boards and Modules

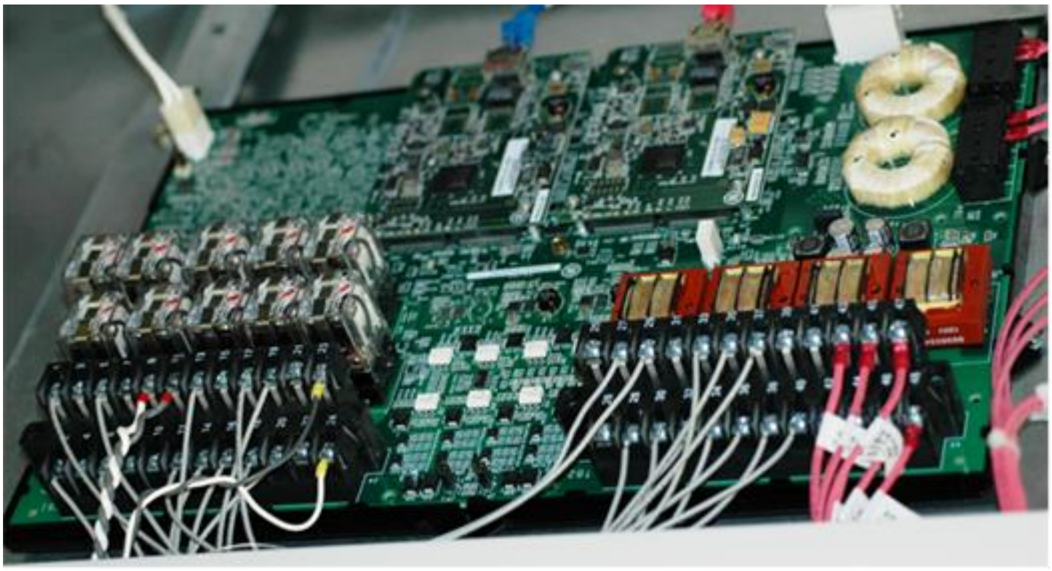
The EX2100e control I/O terminal boards and modules are as follows:

- IS200ESYS EX2100e System Interface (ESYS) module for customer I/O
- IS200EAUX EX2100e Auxiliary Interfaces (EAUX) board
- IS200EAUDEX2100e Excitation Control High-speed Contactor Driver (EAUD) board
- IS200EDFF EX2100e DC Fanned Feedback (EDFF) board
- IS200EBAC EX2100e Bridge ac Feedback (EBAC) board
- IS200ECTX Excitation Control CT Expansion (ECTX) board
- IS200ERGT EX2100e Control Regulator Third-party Ground Detector Terminal (ERGT) board
- IS230SNCIH2A Mark VIe Digital Input module (IO pack PDIAH1B + terminal board STCIH2A)
- IS230SNRLH2A Mark VIe Digital Output module (IO pack PDOAH1B + terminal board SRLYH2A)
- IS230SNAIH2A Mark VIe Analog Input module (IO pack PAICH1B + terminal board STAIH2A)
- IS230SNAOH2A Mark VIe Analog Output module (IO pack PAOCH1B + terminal board STAOH2A)
- IS230SNRTH2A Mark VIe RTD Input module (IO pack PRTDH1B + terminal board SRTDH2A)

Note Mark VIe IO Modules are described in *Mark VIe Control Volume II System Guide* (GEH 6721 Vol II).

5.2.1 ESYS Module

The EX2100e Excitation Control System I/O Interface (ESYS) module interfaces basic I/O external to the exciter with the control system. It handles most of the system I/O interfaces, including PT and CT inputs, digital control inputs, customer analog I/O, general-purpose relays, and trip relay outputs. The interface to the customer I/O is through pluggable screw terminal boards and interface to the EX2100e control system is through HSLA high-speed serial link (HSSL) daughter boards that are mounted on the ESYS. The ESYS module is used in both the static and regulator systems.



ESYS Module

Note Status information from the I/O modules is provided to the UCSx controllers through the HSLA boards.

The ESYS module contains isolation transformers for critical generator voltage and current measurements. Two 3-phase generator PT voltage inputs can be connected for generator voltage feedback. Two generator CT inputs with a current rating of 1 A or 5 A provide current feedback to the ESYS. Provisions for two 4–20 mA or ±10 V analog inputs can be used for specific applications. The ESYS also provides the interface for four 12-bit analog outputs driven by M1 and M2.

The ESYS supports excitation contact inputs and contact outputs. It contains two trip relay outputs for driving a customer lockout device based on 2-of-3 hardware voting output. Additionally, it supports four general-purpose form-C relay contact outputs and seven auxiliary contact inputs powered (wetted) with 55 V dc. The ESYS processes 52G and seven general-purpose contact inputs.

ESYS Groups

Group	Redundancy	Control Sections
H1	TMR (not used in EX2100e Regulator systems)	M1, M2, C
H2	Dual Control	M1, M2
H3	Simplex Control	M1

5.2.2 EAUX Board

The EAUX board uses a HSSL to interface the UCSx controller to the following modules and functions:

- 41DC contactors
- 53A and 53B field flashing relays
- 86G contact input
- De-excitation and crowbar functions
- Field voltage and field current feedbacks
- Field ground detection interfacing with the EXAM
- Bridge ac input feedbacks
- Conditioning of signals from power source monitors

Crowbar and de-excitation status signals from the EDEX are conditioned on the EAUX. Three contact inputs from the 41DC contactor and 53A and 53B relays are powered (wetted) by 125 V dc on the EAUX. Power for the contacts is supplied from the M1 and M2 power supplies or only the M1 (simplex). The EAUX interfaces with the EXAM to support the field ground detector functionality. The EXAM senses the voltage across the ground resistor and sends the signal to the EAUX through a nine-conductor cable. The EAUX and EXAM work together to detect field ground leakage current. The EXAM is located in the auxiliary cabinet. Refer to the *EX2100 and EX2100e Excitation Control Exciter Attenuation Module (EXAM) Instruction Guide* (GEI-10509).

The EAUX interfaces with the M1, M2, and C CSLA control boards through HSLA boards. The EAUX is available in two groups (versions). Both groups accept the EAUD daughterboard, which converts the 41DC interface from a standard 125 V dc coil driver mode to a high-speed contactor interface used in some EX2100e control systems. For further details, refer to the *EX2100e Excitation Control Auxiliary Interfaces (EAUX) Board Instruction Guide* (GEI-100779).

Board Groups

Group	Redundancy	Control Sections
H1	TMR	M1, M2, and C
H2	Simplex	M1

5.2.3 EAUD Board

An IS200EAUD daughterboard is mounted on the EAUX board when high-speed contactors are used for the 41DC function. The EAUD provides approximately four times the voltage forcing for the first 150 ms for faster contactor pickup and regulates coil current for optimum operation. The primary application of the EAUD is with the 2500 A dc high-speed contactor. Refer to the *EX2100e Excitation Control High-speed Contactor Driver (EAUD) Board Instruction Guide* (GEI-100778) for further details.

Note The EAUD is not required for systems using 125 V dc contactors or breakers.

5.2.4 EDFF Board

The EDFF board measures field current and voltage at the SCR bridge and interfaces to the EX2100e Excitation Control Auxiliary Interface (EAUX) over a high-speed fiber-optic link. The fiber-optic link provides voltage isolation between the two boards, as well as high-noise immunity. Field current is measured using a shunt in the dc field circuit. The field voltage feedback circuit provides eight selector settings to scale the bridge voltage, depending on the bridge application. The EDFF scales and converts the field current and voltage at the exciter or regulator output into frequency feedback signals. It consists of voltage-to-frequency (V-F) converter circuits: one for field current feedback and one for field voltage feedback, for up to three redundant control sections M1, M2, and C. The EDFF is available in three groups: H1 for TMR, H2 for dual, and H3 for simplex systems, respectively. For more information, refer to the *EX2100e Excitation Control DC Fanned Feedback (EDFF) Board Instruction Guide* (GEI-100770).

5.2.5 EBAC Board

The EBAC board measures the exciter PPT ac supply voltage. This board contains transformers for a 3-phase voltage measurement to allow the control to synchronize gating of the SCRs to the incoming ac line. The outputs of the voltage circuits are fanned out to the three controllers, M1, M2, and C, through the EAUX. The EBAC is available in two groups, depending on the nominal ac line voltage of the power converter. For more information, refer to the *EX2100e Excitation Control Bridge AC Feedback (EBAC) Board Instruction Guide* (GEI-100774).

EBAC Board Groups

Group	Voltage
G1	651 to 1400 V ac
G2	Up to 650 V ac

5.2.6 ECTX Board

The ECTX board contains a single isolation current transformer (CT) for generator current measurements. It provides an optional third CT interface between a customer generator CT and the EX2100e static excitation control. The ECTX mounts as a daughterboard on the ESYS module, which provides interfaces to two customer CTs as a standard configuration that meets many customer applications. If the customer installation uses a full set of three CTs, the ECTX can be supplied to provide the EX2100e interface to all three CTs. For further details, refer to the *EX2100e Excitation Control CT Expansion (ECTX) Board Instruction Guide* (GEI-100775).

5.2.7 ERGT Board

In EX2100e Regulator simplex or dual control systems, the ERGT supports regulator third-party ground detector options. It is the interface between the EX2100e Control Exciter Regulator Auxiliary I/O (ERAX) board and the third-party ground detector. The ERGT does not require a power supply and can be DIN-rail or base mounted. The ERGT converts the 9-pin connector signals from the ERAX to terminal screw connections for the third-party ground detector. For more information, refer to the *EX2100e Excitation Control Regulator Auxiliary I/O (ERAX) Board Instruction Guide* (GEI-100771). The ERAX supports a single third-party ground detector (interfaced through the ERGT) with up to three outputs:

- Ground alarm
- Ground detector malfunction
- Diode fault monitor

5.3 Bridge and Protection Boards

The exciter bridge and protection boards are as follows:

- IS200EBRG EX2100e Bridge Interface (EBRG) board
- IS200EDEX Exciter De-excitation Control (EDEX) board
- IS200EXAM Exciter Attenuation (EXAM) module

5.3.1 EBRG Board

The EBRG interfaces the EX2100e control to the SCR (power bridge) and related bridge I/O terminal boards. It takes the six gate commands from the UCSx controller and controls the gate firing of up to six SCRs on the bridge. Bridge control passes through the EBRG. One EBRG is required per PCM. It is also the interface for current conduction feedback, Rogowski coil current feedback, bridge analog output (DACs), bridge airflow and temperature monitoring, and to control cooling fans on the EX2100e 100 mm systems. The EBRG can provide automatic start/stop control of a single power converter cooling fan, or lead/lag control of redundant power converter cooling fans.

A nominal 125 V dc power source from the EDIS supplies an on-board dc-to-dc converter that provides power for SCR gating over the full range of input supply voltage. LED indicators provide visual status of the output firing, currents into the bridge, gate power supply, line filter, cooling fan rotation, bridge temperature, and alarm or fault conditions.

The EBRG is compatible with most SCR devices, allowing use over a wide range of SCR ratings and bridge architectures, including simplex, WBU, and parallel bridge converter. For more information, refer to the *EX2100e Excitation Control Bridge Interface (EBRG) Board Instruction Guide* (GEI-100776).

EBRG Board Groups

Group	Use
EBRGH1	100 mm Thyristor systems
EBRGH2	77 mm or smaller Thyristors systems

5.3.2 EDEX Board

The EDEX is the main board in the de-excitation module. It is also used in the crowbar module. The EDEX provides de-excitation SCR firing, conduction sense feedback of the de-excitation module, and voltage retention to ensure operation in the event of a power failure. The EAUX opens the 41DC contactor (41A/41B) or breaker, and transfers de-excitation signals from the auxiliary contacts to SCR firing circuits on the EDEX. For further details, refer to the *De-Excitation Control (EDEX) Board Instruction Guide* (GEI-100466).

Note The EDEX is usually controlled by the EAUX. However, it can self-initiate de-excitation if the control fails.

5.3.3 EXAM Module

The EXAM provides attenuation between the EX2100e control and the EAUX. It is mounted on a bracket with the EDFF board in the auxiliary cabinet and contains a sense resistor that is connected to a resistor network across the field. The EXAM applies the low frequency ±50 V square-wave signal that is supplied from the EAUX to one end of the sense resistor. The resulting current, due to a field ground, generates a voltage across the resistor that is sent back to the EAUX for the Field Ground Detection (FGD) function.

In a redundant system, the test signal can come from either controllers, M1 or M2. The EXAM has a relay that switches between the two under the control of C. A single cable carries the control and sense signals between the EAUX and EXAM.

Alterrex applications may use two EXAM and two EAUX to provide two simplex ground detectors. One is used for the exciter field circuit and the other for the generator field circuit. For more information, refer to the *EX2100e Excitation Control Exciter Attenuation Module (EXAM) Instruction Guide* (GEI-100509).

5.4 Power Supply Modules

The exciter power supply modules are as follows:

- IS200EDIS EX2100e Power Distribution (EDIS) module
- DACA module
- 120VPS power supply module
- 125-28 V dc power supply module

5.4.1 EDIS Module

The EDIS module interfaces customer ac and dc control power sources to the EX2100e control power supplies and the control system hardware. The EDIS accepts *125 V dc power supply* from the station battery, and one or two 115 or 220 V ac 50/60 Hz supplies connected through a pluggable screw terminal board. All supply inputs are filtered and each ac supply is rectified to 125 V dc in a DACA module. It is also possible to add as an option a second dc power supply. The resulting two or three dc voltages are diode-coupled together to create the dc source supply, designated as P125V and N125V. With the center grounded (option), these voltages are nominally 62.5 V and –62.5 V to ground.

Note The DACA module must be set correctly for the supply voltage level.

The 125 V dc and 28 V dc power supplies are the outputs from the EDIS for distribution to the controls. The module also provides interfaces to the PCMs, including DACA, 120VPS power supply and 125 V dc to 28 V dc converters. Individual supply outputs to the exciter boards are fused. They have an on/off toggle switch, and a green LED indicator to display supply power availability. These outputs supply up to five EBRG boards, two EAUX boards, and optional I/O modules and 28 V dc outputs are provided for each of the three control sections; M1, M2, and C. Additionally, the EDIS supports either simplex or redundant outputs for auxiliary functions, such as VersaMax or Mark VIe IONet I/O packs and Ethernet switches, and provides a redundant 28 V dc power supply for the optional touchscreen.

The EDIS provides power supply monitoring feedbacks to the controllers for the ac and dc power source inputs and the auxiliary 28 V dc supplies. Any of the exciter power supply modules can be switched off from the EDIS. For more information, refer to the *EX2100e Excitation Control Power Distribution (EDIS) Instruction Guide* (GEI-100777).

5.4.2 DACA Module

The DACA (or DACB) module is an ac-to-dc converter that is powered by a 115 or 220 V ac source and produces 125 V dc. The DACA and battery source provide a redundant 125 V dc supply for the EDIS. Two DACAs may be connected to the EDIS if required for greater power supply reliability.

5.4.3 120VPS power supply module

The standard DACA module can also be replaced by a standard large input power supply range module 120VPS power supply. The inputs of the module can be AC (100 to 240VAC) or DC (90 to 250Vdc). This will allow the availability for a second DC power supply source.

5.4.4 125-28 V DC Power Supply Module

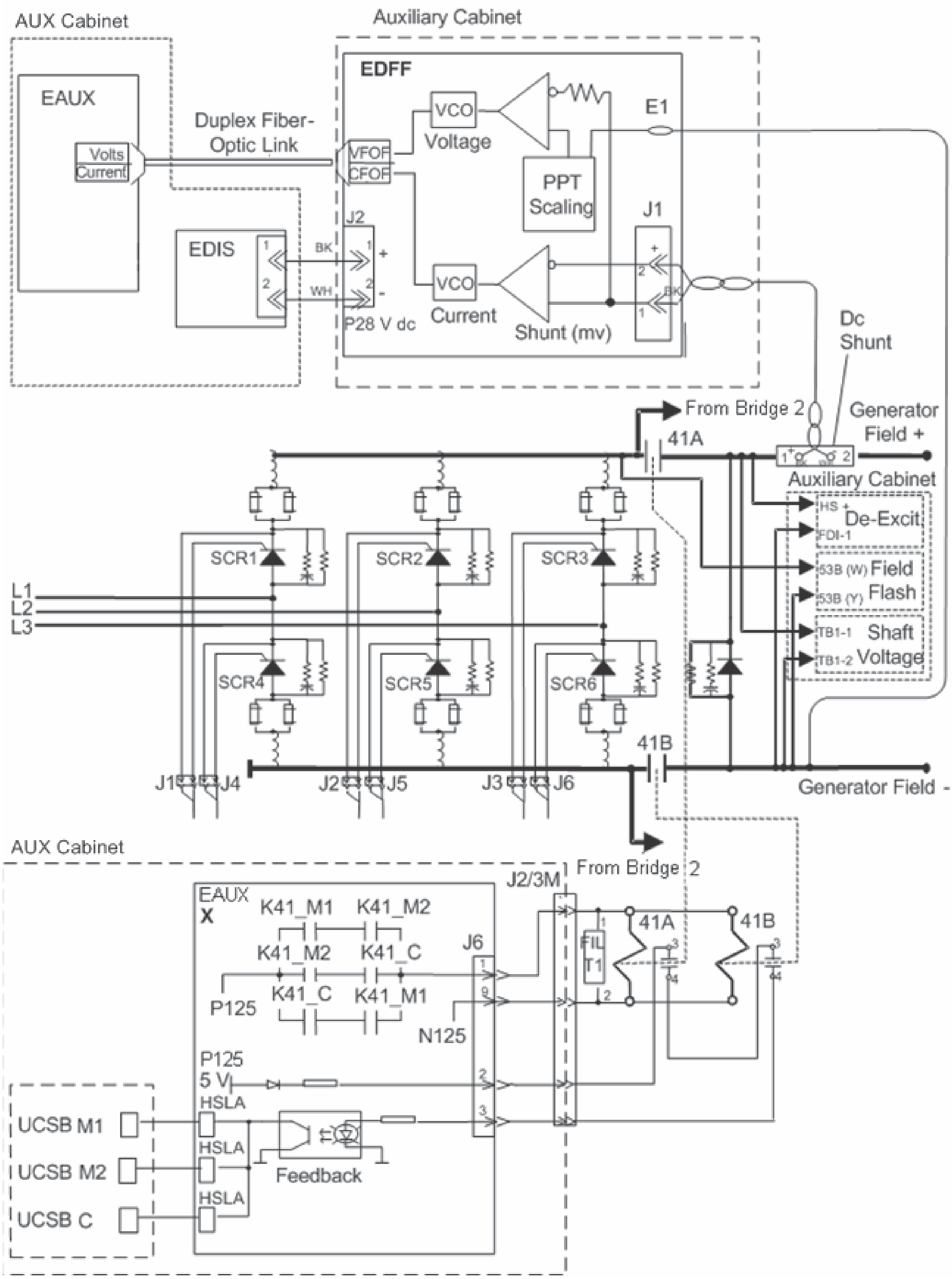
The 125 – 28 V dc power supply module converts 125 V dc from the EDIS into the 28 V dc voltage required for the control system. For redundant control applications, there are three independent power supplies that supply power to each of the controllers (M1, M2, and C). These power supplies are located in the power supply module behind the EDIS.

Note In the case of EX2100e DFE (upgrade of EX2100), two power supplies are used to provide redundant power to each of the controllers (M1, M2, and C). These power supplies are located on the power supply panel below the EDIS.

The module supplies 28 V dc to the controller.

Power is also supplied to other modules, as follows:

- 28 V dc to the EDEX and Crowbar module
- 28 V dc to the EDFF
- 28 V dc to the touchscreen
- Up to two additional 28 V dc modules can supply power for auxiliary functions



EX2100e Control PCM and Interface

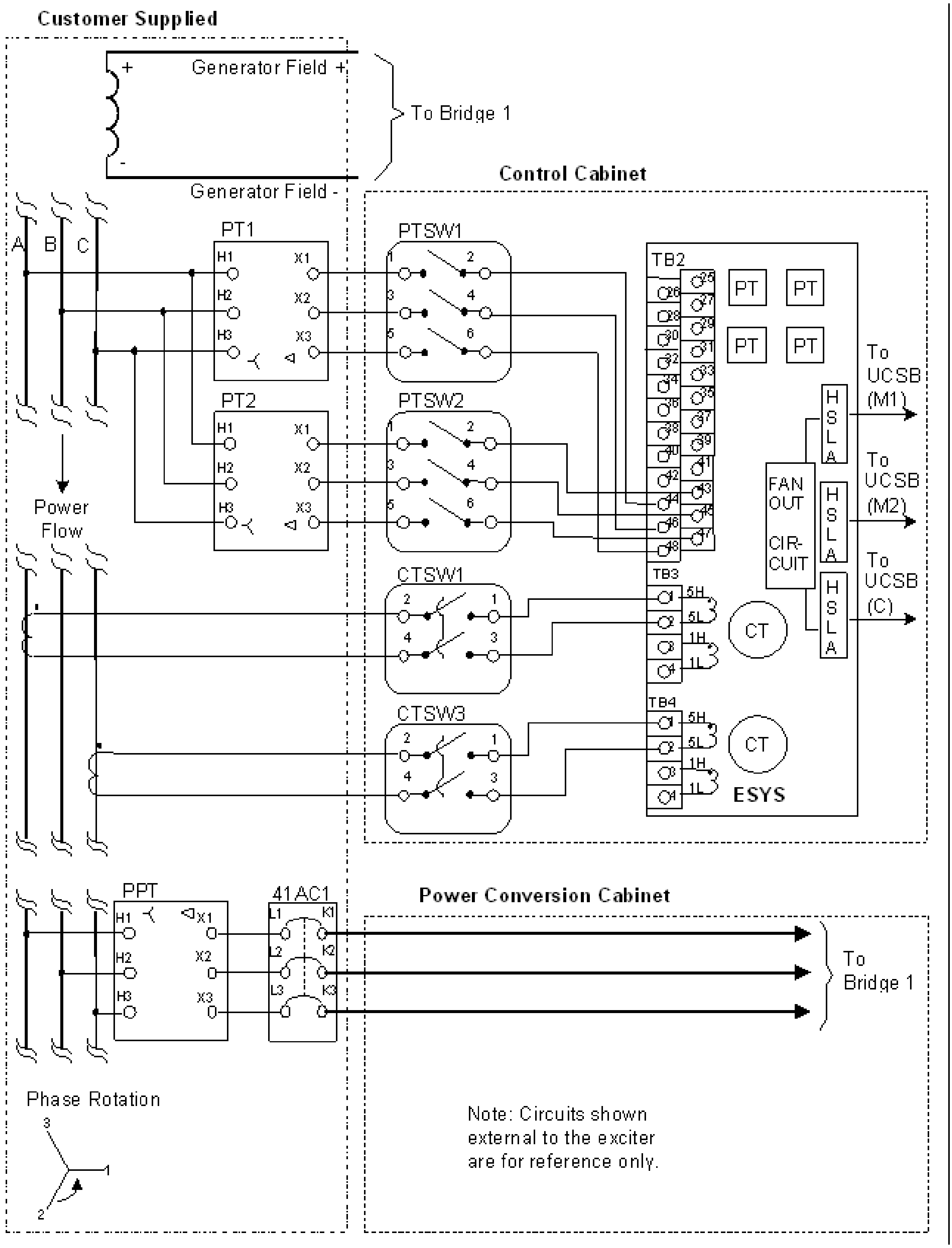
Notes

6 Terminal Board I/O and Equipment Connections

This chapter describes the customer's equipment connections, and I/O modules available through terminal board wiring. System cabling to provide desired functionality is also defined.

6.1 AC Input Power and PT/CT Feedback

The following figure displays a typical connection diagram of the power I/O for an excitation system.



Exciter AC Power Supply and PT/CT Wiring

6.1.1 PPT Inputs

In the EX2100e control system, a 3-phase source of ac power is converted to a controlled dc output. This ac input can be from one of several sources. Most common is a generator terminal connected Y-delta PPT. The primary and secondary voltages, as well as kVA ratings, are sized for the particular application. An auxiliary bus-fed PPT is also commonly used. In industrial applications where forcing is needed for large motor starting, a compound source (current and voltage) input may be used. This ac input is connected to the bus in the Power Conversion Cabinet and can be isolated by the 41AC1 device for maintenance. It is monitored by the controls through the EBAC.

Note For compound source applications, the input is also monitored using Rogowski coils connected to the EBRG boards.

6.1.2 PT and CT Inputs

Customer supplied 3-phase PT and CT inputs are wired to switches in the control cabinet that are wired to the ESYS. High frequency noise suppression near the point of signal entry is provided on all input signals to the ESYS. The two 3-phase generator voltage inputs, nominal 115 V ac, are brought into PT transformers. (Refer to the figure *Exciter AC Power Supply and PT/CT Wiring*.) The resulting low voltage transformer output signals are routed through the HSSL to the UCSx controller. Two generator CT inputs (phases A and C), with either 1 A or 5 A secondaries, are brought into CT transformers.
Optionally, a third CT input can be connected from phase B using a *ECTX daughterboard* mounted on the ESYS. A redundant PT input for PT failure detection is possible, and 1-phase sensing can be supported. Redundant CT inputs are also available.

Note To implement a Power System Stabilizer (PSS), the EX2100e control requires, at a minimum, a 3–phase PT and a 1-phase CT, although it is preferred to have two 1–phase CT inputs.

6.1.2.1 Generator Voltage Measurement

The cable lengths from the generator PTs can be up to 304.8 m (1000 ft) of #14 American Wire Gage (AWG) wire. The PT secondary outputs are connected to ESYS TB2 and are nominally 115 V rms at 50/60 Hz and are fused. On the ESYS, the two transformers make a three-wire open delta voltage measurement, yielding 1.533 V rms for a 115 V rms input.

In a simplex system, the voltage signals are sent through the HSSL to the UCSx controller. In a redundant system, the signals are fanned out and sent to controllers M1, M2, and C through their respective HSLA boards on the ESYS.

PT/CT Generator Voltage Measurement

Item	PT Inputs	CT Inputs
Number of inputs	2, 3 phases each	2, Phase A and C
Volts or current	10 - 200 V rms, 115 V rms nominal	0 - 2 A, nominal 1 A, or 0 - 10 A, nominal 5 A
Frequency	50/60 Hz nominal	50/60 Hz nominal
Burden	< 1 VA	< 1 VA

6.1.2.2 Generator Current Measurement

Two generator current inputs from the CTs are wired to non-pluggable terminal blocks, TB3 and TB4, which support ring terminals. The CTs do not have fused secondaries. The available optionas are 0 - 1 A rms CT input, or 0 - 5 A rms CT input. The cable length from the CT to the ESYS can be up to 304.8 m (1000 ft), and the wire gage can be up to a #10 AWG. The resulting signals are sent to the controller through the same HSSL links as the voltage signals.

6.1.3 Analog Input

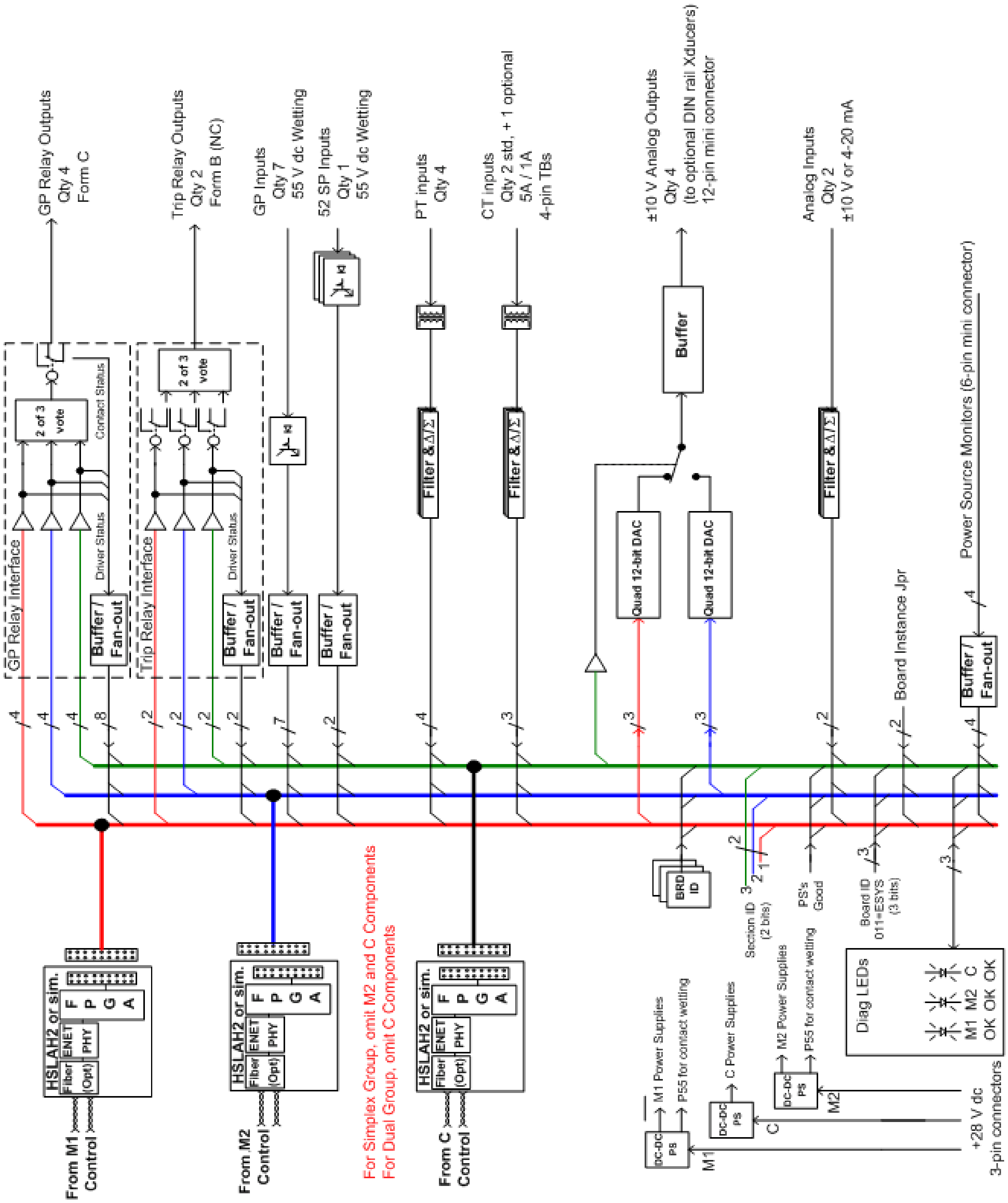
The ESYS provides two analog inputs for customer use. These inputs are jumper selectable for either ±10 V dc or 4 - 20 mA. The controller samples the input at 2000 samples per second, and the accuracy is better than 1% full scale.

6.2 Customer Contact I/O

Customer contact inputs and relay contact outputs are wired to the ESYS. In addition to seven general-purpose contact inputs, one dedicated 52G contact input, wetted by 55 V dc from the exciter, gives the online status of the generator. The ESYS provides four general-purpose form-C and two trip form-B contact outputs controlled by two out of three voting by the three UCSx controllers. These are used for 94EX and 30EX, as well as other outputs. For each relay, the coil current and the status of a relay auxiliary contact is monitored. The feedbacks are provided to the controllers for diagnostics.

General-Purpose and Trip Relay Contact Characteristics

Item	Description		
Customer power	125 V dc nominal (28 V dc min)		
Relay break characteristic	Resistive load	2 A	28 V dc
		0.5 A	125 V dc
	Inductive	1 A	28 V dc 0.0007 s (L/R)
		0.1 A	125 V dc 0.0007 s (L/R)
Suppression	External suppression supplied by customer on induction loads		

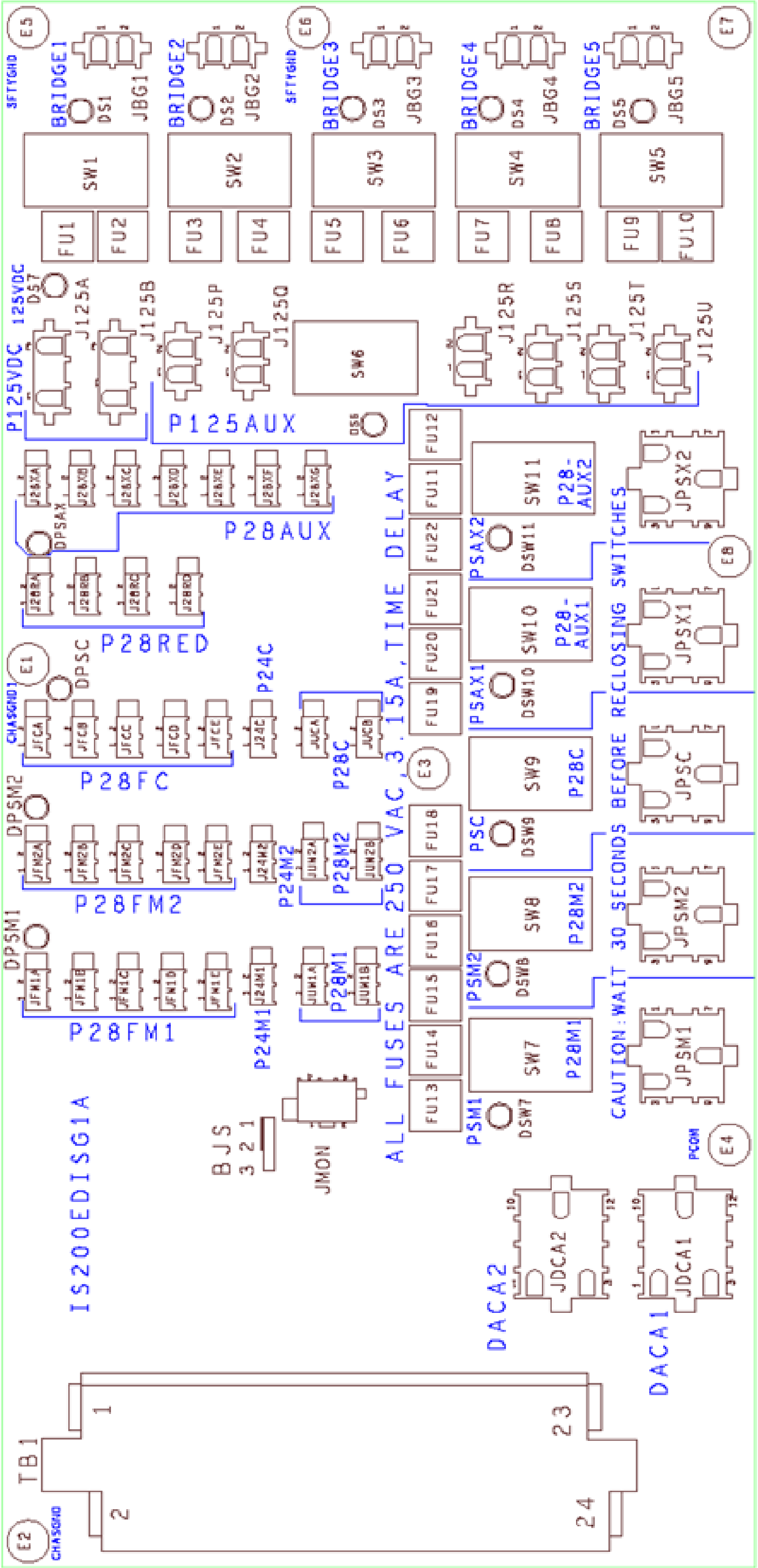


Customer I/O Wired to ESYS Module

6.3 Power Supply Inputs

The customer’s ac and dc control power inputs are wired to the EDIS. The following figure displays the 125 V dc battery source, and the 115 or 220 V ac supply, AC1. A second ac supply, AC2, may also be connected. Other ac inputs, including cooling fan power, convenience lights and outlet, and cabinet heater, are wired to separate terminal blocks, fuse blocks, or circuit breakers.

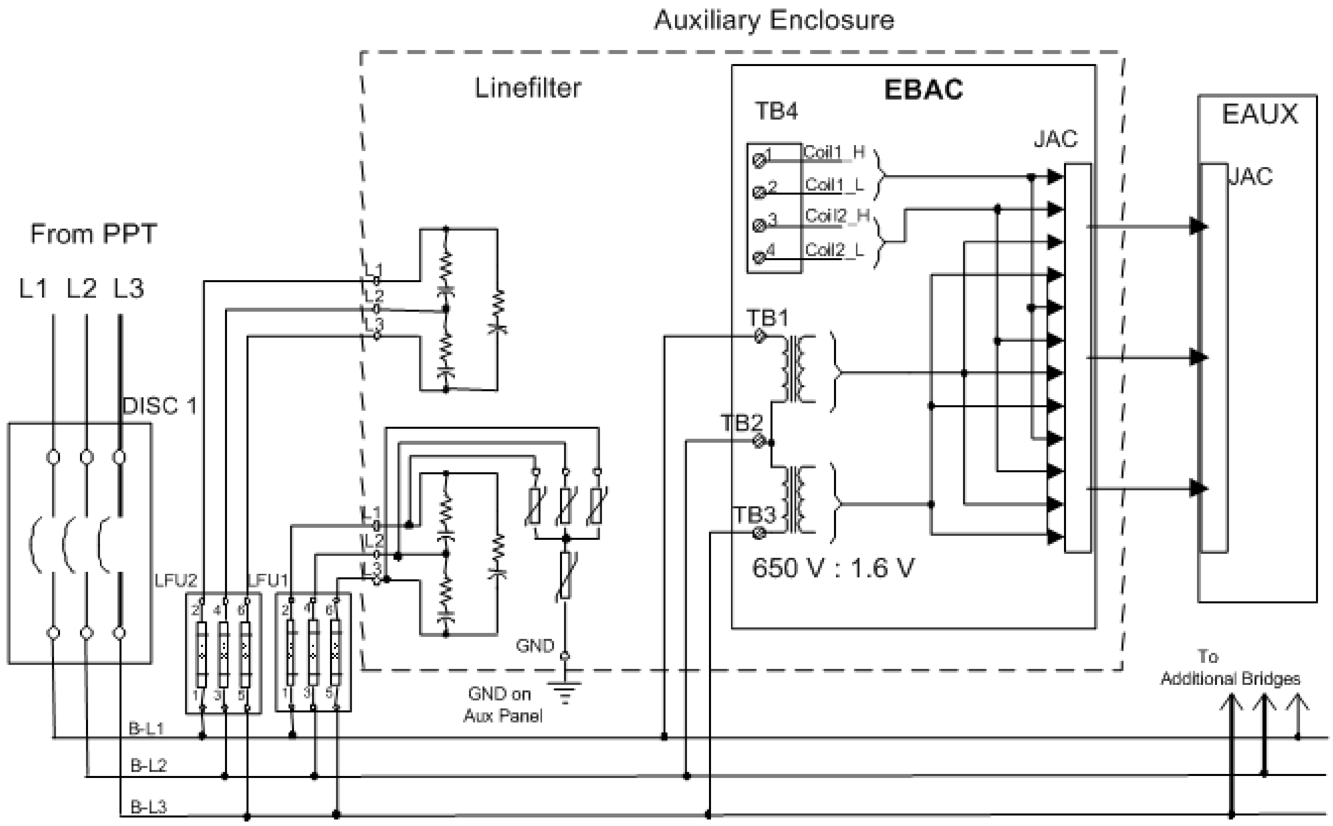
Note The EDIS can accept either 115 or 220 V ac control power inputs. The connector on the face of the associated DACA module must be set to match the input voltage.



Power Wiring Connections to EDIS

6.4 Line Filter Connections

The ac line filter is internally connected to the power converter source bus through one or more fuse blocks, typically located in the exciter auxiliary cabinet. The filters are located at the top of the auxiliary cabinet. In the 100 mm system, the line filters and fuses are located in the ac termination cabinet.



AC Feedback and Line Filters

6.5 Exciter Internal I/O

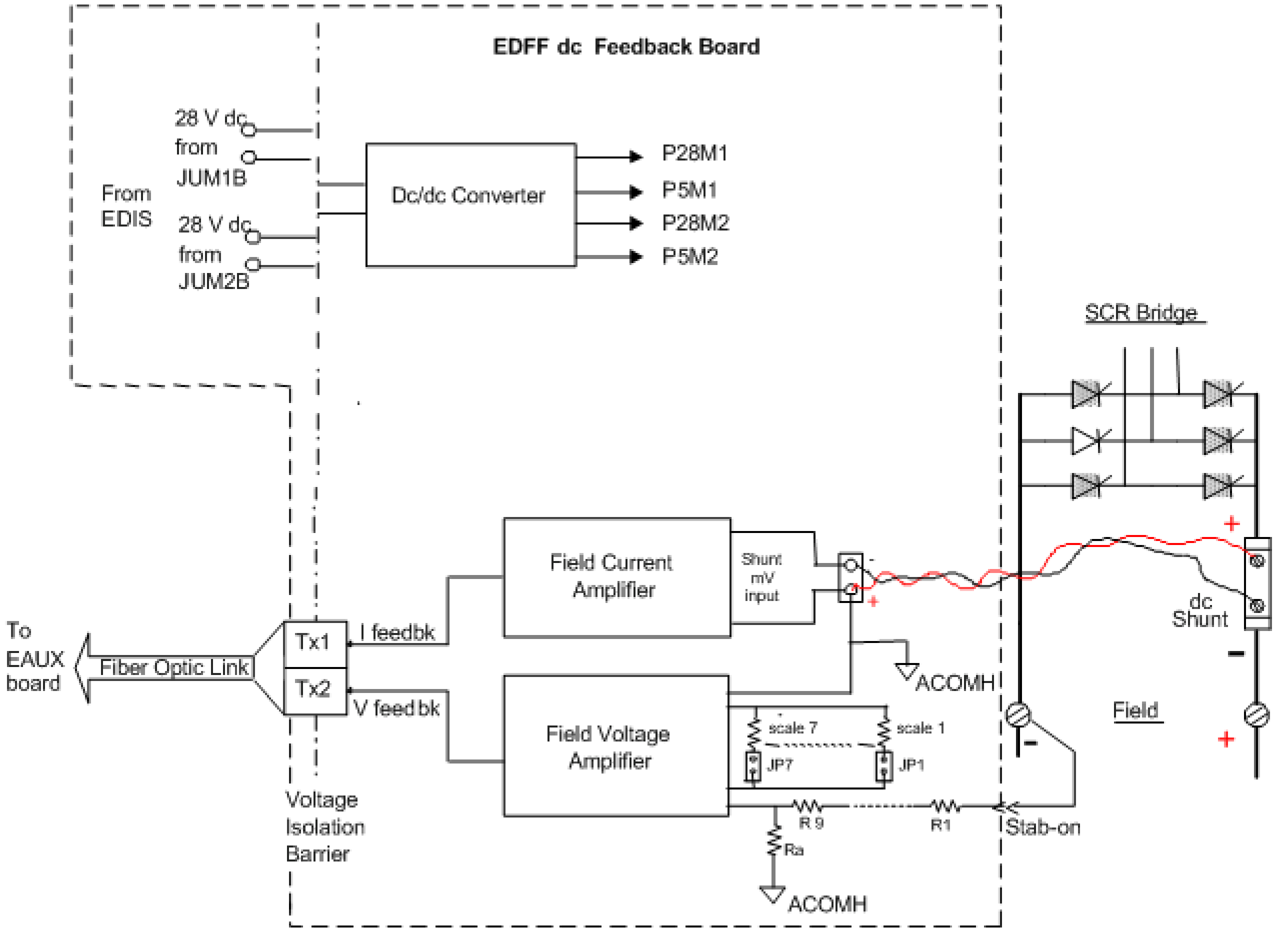
Exciter internal I/O feedback is supplied by the *EBAC* and *EDFF* boards.

6.5.1 Exciter AC Feedback

The EBAC board measures the exciter ac supply voltage and current. The terminal board contains transformers for a 3-phase voltage measurement. For further details, refer the *EX2100e Excitation Control Bridge AC Feedback (EBAC) Board Instruction Guide* (GEI-100774).

6.5.2 Exciter DC Feedback

The EDFF board measures field current and field voltage at the SCR bridge, and interfaces to the EAUX in the control cabinet over a high-speed fiber-optic link. For more information, refer to the *EX2100e Excitation Control DC Fanned Feedback (EDFF) Board Instruction Guide* (GEI-100770).



EDFF DC Field Voltage and Current Measurement

6.6 De-Excitation

During generator shutdown, the stored energy of the generator field inductance must be dissipated. In the EX2100e control, this is the function of the *EDEX* and field discharge resistor or inductor (when supplied).

Standard de-excitation is provided by a thyristor (33, 53, or 77 mm cell size) mounted in an assembly with the attached snubber network and EDEX.

Note In the 42mm optional non-inverting topology, de-excitation is provided through the free-wheeling diode located on the thyristor bridge heatsink.

The EDEX contains Hall effect conduction sensors that are mounted in the air gap of a circular steel ring attached to the board. They sense the magnetic field produced by the field discharge current flowing through the thyristor. Two independent sensor circuits are used. The EDEX fires the SCR when either of two control inputs is true, or when the anode-to-cathode voltage of the SCR exceeds a certain value. The two firing control circuits on the board are powered from separate power supplies and use separate conduction sensors, making them mutually independent.

The actual control logic inputs used are dependent on the application. When the exciter shuts down, a firing control signal is sent to both EDEX firing control circuits, which send gate pulses to fire the EDEX SCR. At this point, the main field polarity reversal has occurred, making the SCR anode positive with respect to the cathode. Therefore, the SCR conducts and dissipates the stored energy of the generator field through the field discharge device.

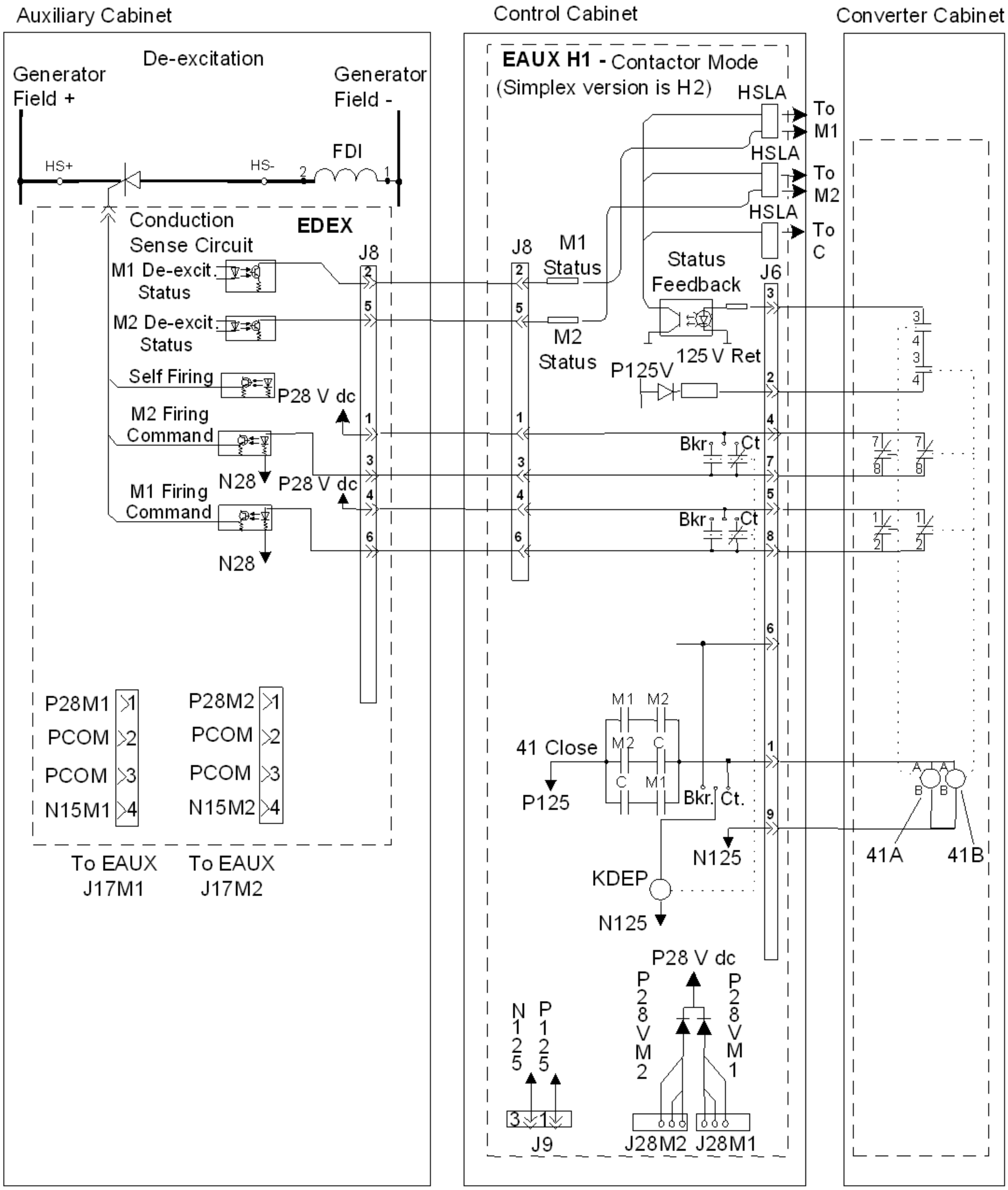
Feedback from either conduction sensor verifies that the discharge circuit has operated successfully. If both independent firing control circuits fail to fire, the SCR is fired by the anode firing circuit when the anode-to-cathode voltage has exceeded the selected level.

For large exciters, it is possible to connect multiple EDEX modules together with one EDEX board configured to be the Master and the others configured to be Slaves. In this case, a firing control signal sent to the master is relayed to the slave modules, firing all modules simultaneously.

The EAUX controls the main breaker or contactor in the field circuit. When this opens, the auxiliary contacts cause an immediate de-excitation commanded by the EDEX.

An alternative to the 41A and 41B contactor is to use a breaker in the excitation ac supply or dc output field circuit.

The 41A dc contactor and the optional contactor 41B in the field circuit are located in the power conversion cabinet (dc exit case for 100 mm). They are driven from the 41 close pilot on the EAUX. Several auxiliary contacts are used to provide status feedback to the control, as well as the firing commands to the EDEX. Normally, the breaker would be a dc field breaker that could break the output while inserting a discharge resistor with the contact, which is generally open. However, an ac breaker with the SCR-based EDEX module may also be applied. The breaker has two coils, 41 close and 41 trip, as well as auxiliary contacts for de-excitation.



DC Contactor Control and Wiring to EDEX Board

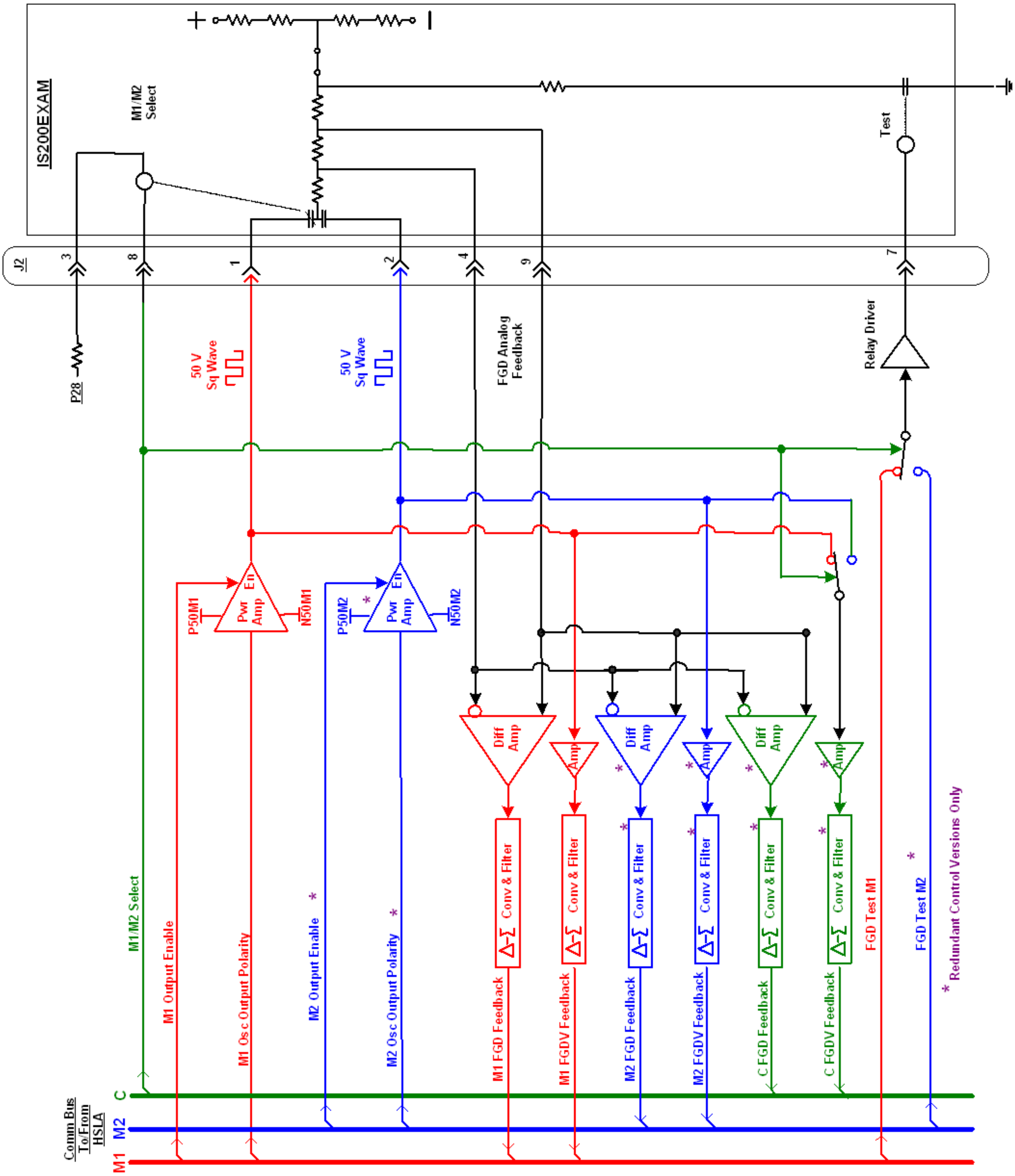
6.7 Crowbar

The optional crowbar subsystem limits high negative voltages that can be inducted into the PCM during a pole slip (loss of synchronization) event. (Refer to the figure *SVS and Crowbar*.) Like the EDEX, the crowbar will self-fire based on selected field voltage limits. It includes a discharge resistor, which may be shared with the de-excitation function when the two are supplied together. This is typically provided only on generators with salient poles (hydro applications).

Note The crowbar and de-excitation functions may be provided as a combined EDEX module in some EX2100e control systems.

6.8 Field Ground Detector

The generator field is an ungrounded system. The ground detector circuit is an active system that applies a voltage to the field circuit. The field ground detector circuit in the EAUX detects field leakage resistance between any point in the field circuit of the generator and ground. The active detection system applies a low-frequency square-wave voltage with respect to ground, and monitors for current flow through a high impedance ground resistor. The square wave is ±50 V dc at 0.2 Hz frequency. If PRV resistors are present, grounds anywhere in the system can be detected, even while the exciter is not gating cells, from the PPT secondary to any point in the generator field. In a redundant control system, if the M1 controller fails, the oscillator in the M2 channel takes over.



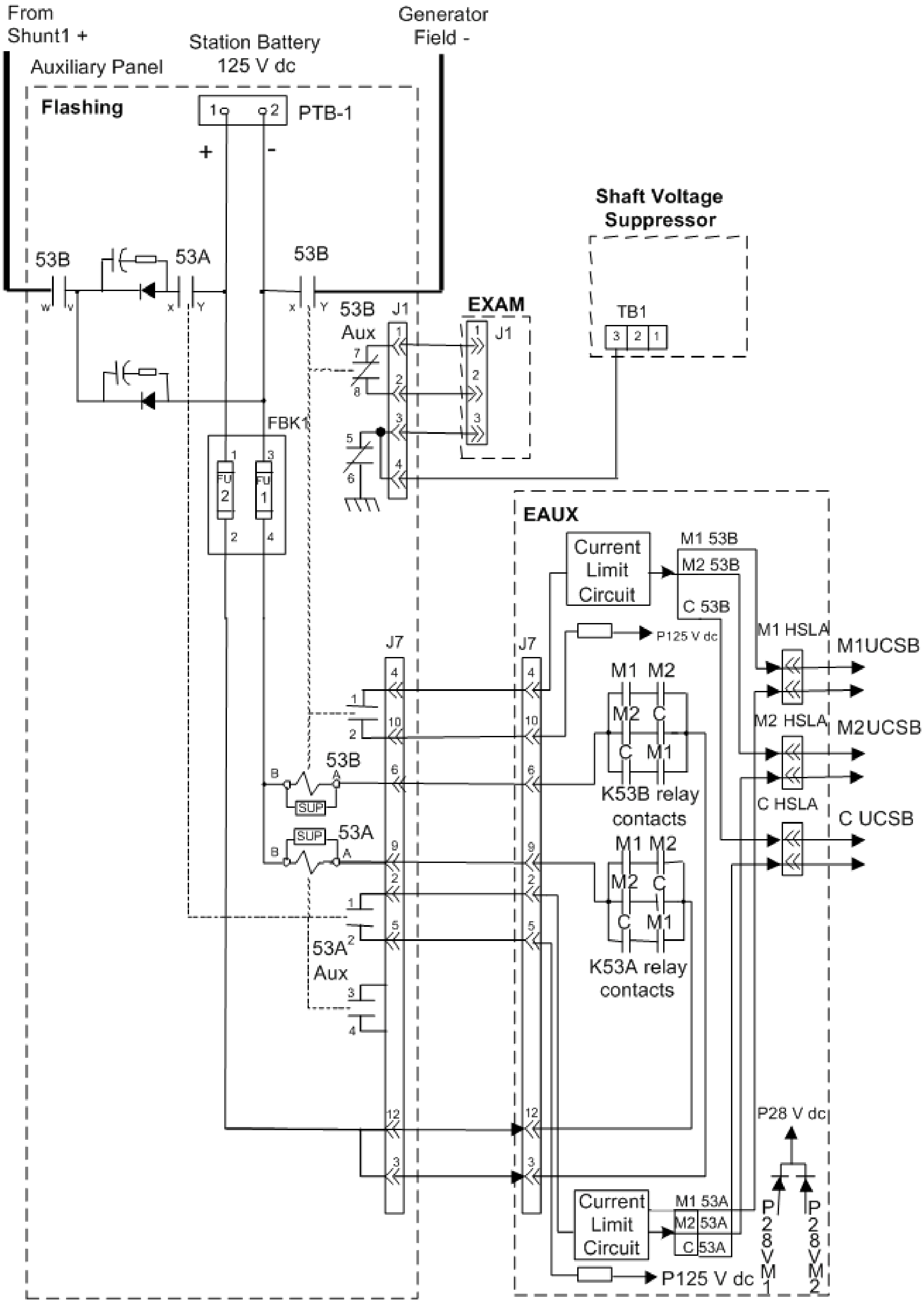
Field Ground Detector Circuit

6.9 Field Flashing

Field flashing relays 53A and 53B are controlled from drivers on the EAUX through pilot relays. (Refer to the figure *Field Flashing Control from EAUX*.) In redundant control, the three driver signals actuate pilot relays on the EAUX, which are contact voted to output a single voltage. These outputs actuate the 53A and 53B relays in the auxiliary cabinet. The 53A and 53B contacts input dc voltage from the station battery across the generator field. The field flashing module supplies approximately 15 - 20% of no-load field amps (AFNL) to the generator field during the startup sequence.

Note The station battery initiates the field current. An auxiliary ac source may also be used.

For ac field flashing, the ac voltage is rectified by a diode bridge and filtered. The startup sequences and logic are the same.



Field Flashing Control from EAUX

6.9.1 DC Field Flashing Settings

Field flashing modules are used to supply a wide range of flashing currents. Configuring a maximum and minimum allowable value in the controller sets the flashing current magnitude required for a generator.

The current values are preset in the factory based on information supplied. These values define the envelope in which the flashing control holds the field current during the flashing sequence.

6.9.2 Flashing Control Sequence

The flashing control sequence begins when an operator issues a start request. The optional field contactor(s) closes, followed by contactor 53B, then 53A. Flashing current flow is monitored by the control through the field shunt. When the field current reaches the maximum allowable field flash value (typically 15 - 20% of AFNL), contactor 53A opens and the field current decays through the freewheeling diodes. If the control has not taken over before the current decays to the minimum field flash current setting (typically 10% AFNL), the sequence is repeated. If the current magnitude exceeds approximately 25% AFNL, or if the control has not taken over after a fixed time delay, the startup is stopped and a diagnostic alarm is issued.

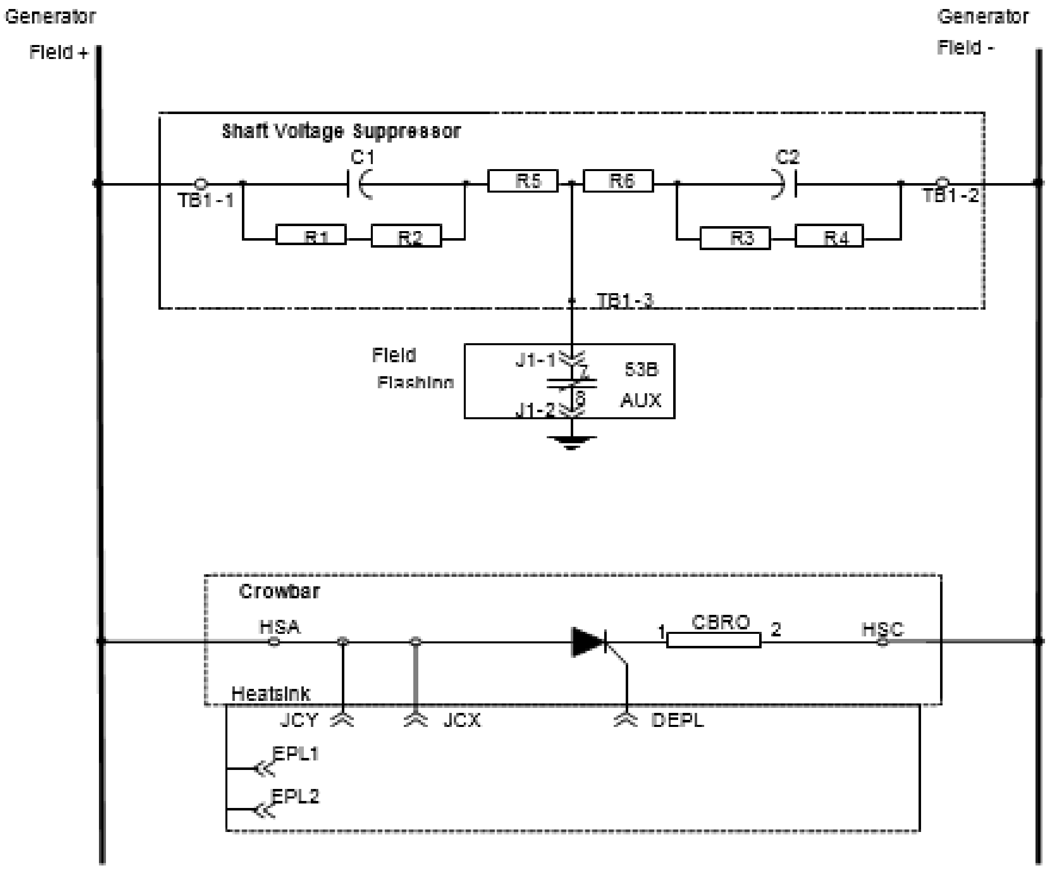
6.9.3 Boost Operation

In brushless applications, the field flashing module may be used to support the boost function, whether or not flashing is required. Boost is used to power the field from the stationary battery when the PPT voltage has collapsed due to a terminal fault condition. A Boost module may be present to limit the current applied. In this case, both flashing current and boost current pass through the boost resistor module. Boost is typically applied for a maximum of 10 seconds should the PPT voltage fall below 75% of rated. Control software is included to protect the boost resistor from overload.

6.10SVS

Excitation systems that produce a dc voltage from an ac supply through a solid-state rectification process cause ripple and spike voltages at the exciter output. Due to their rapid increase and decay times, these voltages are capacitively coupled from the field winding to the rotor body. This creates a voltage on the shaft relative to ground that, if not effectively controlled, may damage both journals and bearings. The Shaft Voltage Suppressor (SVS) is a filter that conducts the high-frequency components of the induced voltages to ground and limits shaft voltage caused by thyristor commutation to less than 5 to 7 V zero to pk.

Note Brushless applications and some static exciters do not require the SVS.



SVS and Crowbar

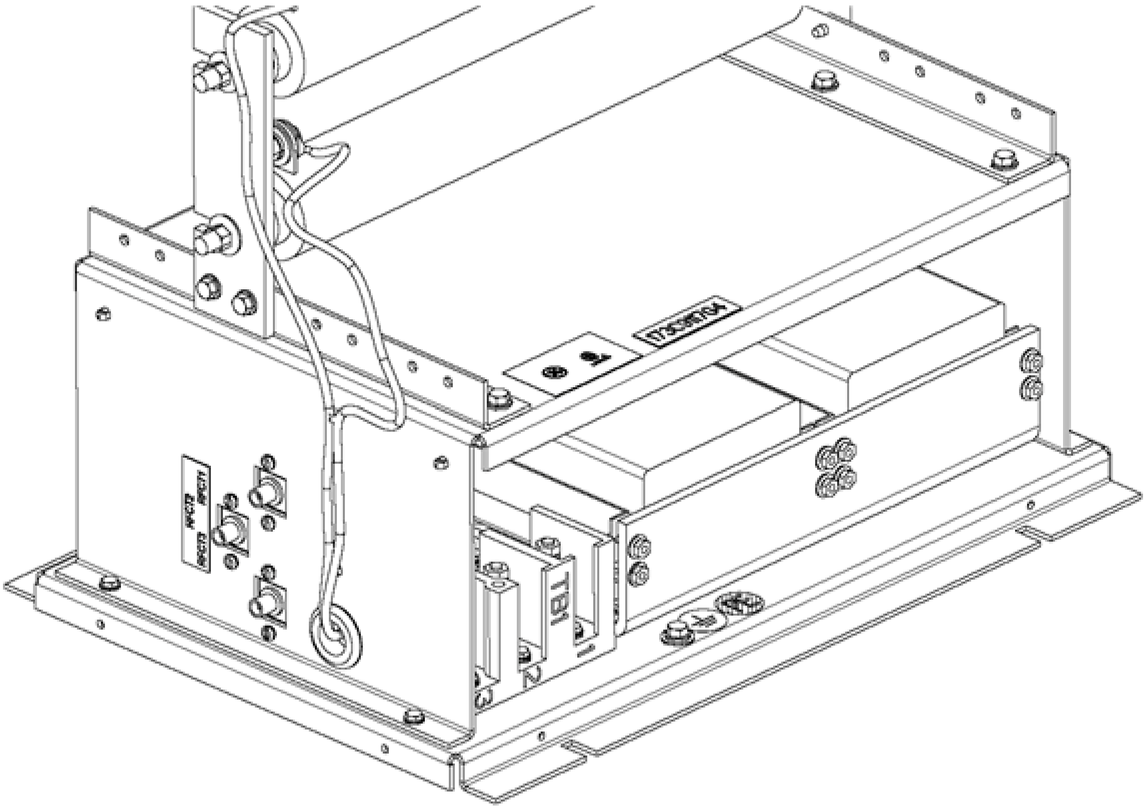
6.11CHM Interface

Some versions of the EX2100e control include an interface to an external GE system, the Collector Health Monitor (CHM). The CHM monitors sparking between the stationary brushes and the rotating collector rings that deliver power from the exciter to the generator field. Over time, brush wear and carbon buildup can lead to increased arcing in the collector assembly, and if timely preventative maintenance is not performed, a damaging flashover can occur. The CHM provides advance warning of the need for maintenance so that flashover can be avoided.

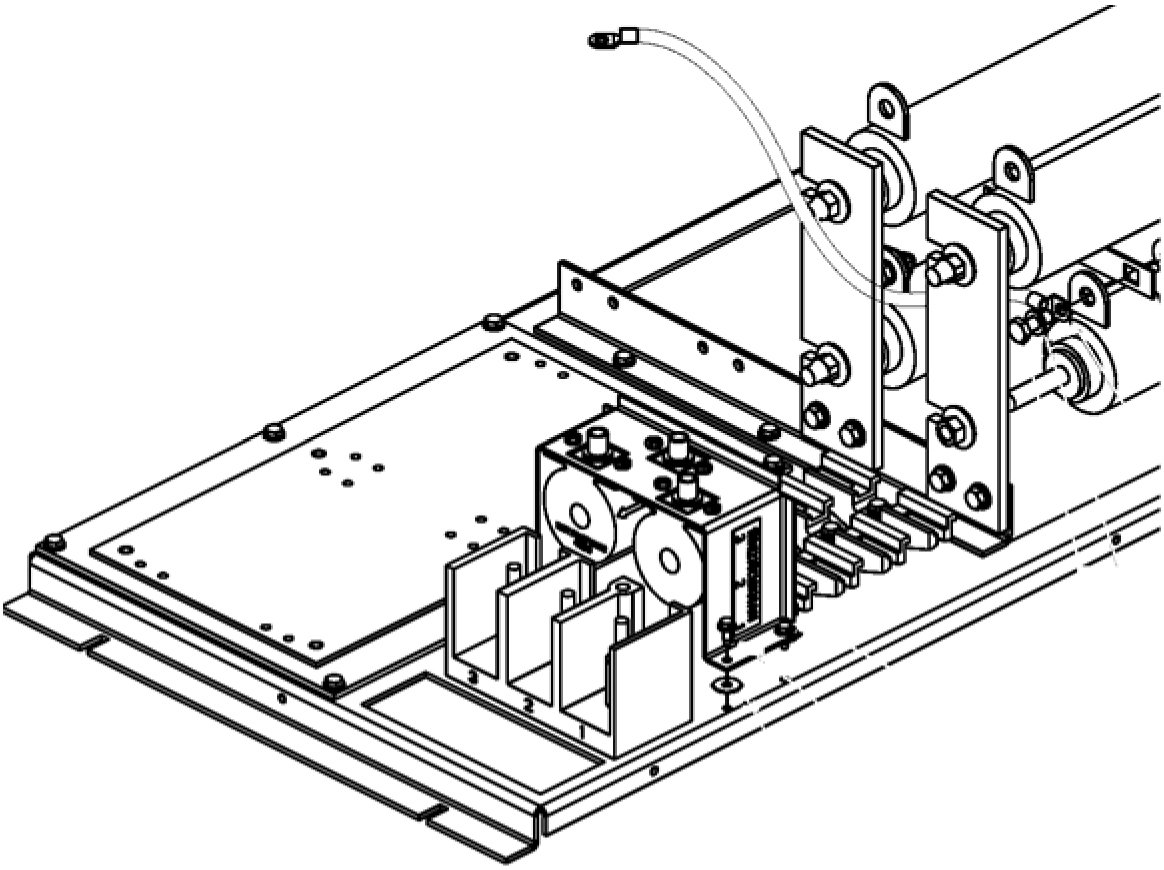
The CHM sensors consist of three high bandwidth radio frequency current transformers (RFCT) that are mounted in the exciter SVS or in the wiring to the SVS. Three coax cables connect from the RFCTs to the external CHM unit. The cables connect directly to the RFCTs, or in some cases to an interposing bracket. For more information, refer to the *Collector Health Monitor (CHM) Operator User Guide* (GEK102858).

Caution

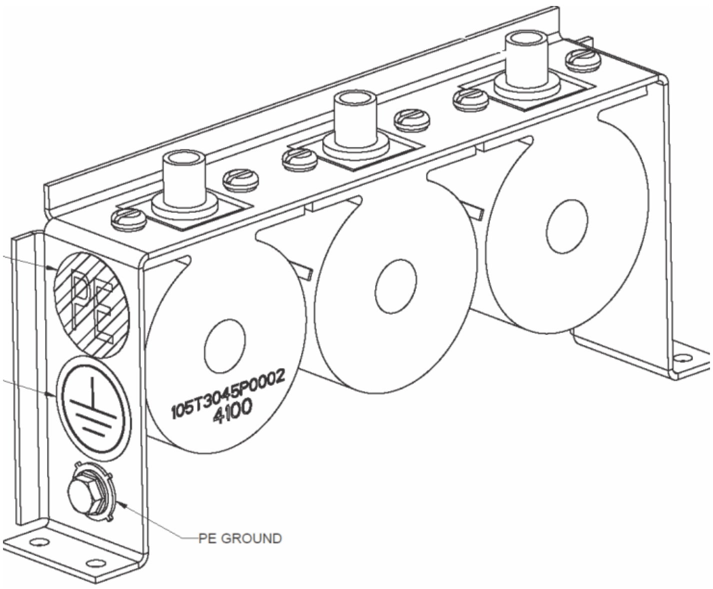
Case must be taken in routing these cables within the exciter to prevent interference due to signal coupling, excessive heating of the cables, and risk of inadvertent high-voltage energization.



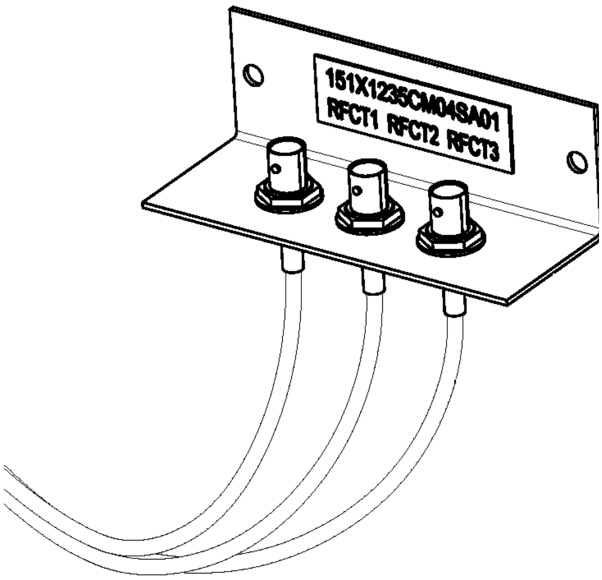
600 V SVS with RFCT Connectors on Sidewall



100 mm SVS with Internal RFCT Interface (Partial Assembly)



RFCT Assembly for Upgrades



Interposing RFCT Cable Interface

6.12Plant Upper Level Connection

6.12.1 Cyber Security concerns

6.12.1.1 Security Definition

Security is the process of maintaining the confidentiality, integrity, and availability of a system:

- ***Confidentiality***: Ensure only the people you want to see information can see it.
- ***Integrity***: Ensure the data is what it is supposed to be.
- ***Availability***: Ensure the system or data is available for use.

GE recognizes the importance of building and deploying products with these concepts in mind and encourages customers to take appropriate care in securing their GE products and solutions.

Note as GE product vulnerabilities are discovered and fixed, security advisories are issued to describe each vulnerability in a particular product version as well as the version in which the vulnerability was fixed. GE Product Security Advisories can be found at the following location:

http://support.ge-ip.com/support/index?page=kbchannel&id=S:KB14607

6.12.1.2 Security Level

Firewalls and other network security products, including Data Diodes and Intrusion Prevention Devices, can be an important component of any security strategy. However, a strategy based solely on any single security mechanism will not be as resilient as one that includes multiple, independent layers of security.

Therefore, GE recommends taking a Defense in Depth approach to security.

6.12.1.3 Defense in Depth Definition

Defense in Depth is the concept of using multiple, independent layers of security to raise the cost and complexity of a successful attack. To carry out a successful attack on a system, an attacker would need to find not just a single exploitable vulnerability, but would need to exploit vulnerabilities in each layer of defense that protects an asset.

For example, if a system is protected because it is on a network protected by a firewall, the attacker only needs to circumvent the firewall to gain unauthorized access. However, if there is an additional layer of defense, say a username/password authentication requirement, now the attacker needs to find a way to circumvent both the firewall and the username/password authentication.

6.12.1.4 General Recommendations

The following security practices should be followed when using GE products and solutions.

- The controllers and supervisory level computers covered in this document were not designed for or intended to be connected directly to any wide area network, including but not limited to a corporate network or the Internet at large. Additional routers and firewalls that have been configured with access rules customized to the site's specific needs must be used to access devices described in this document from outside the local control networks. If a control system requires external connectivity, care must be taken to control, limit, and monitor all access, using, for example, virtual private networks (VPN) or Demilitarized Zone (DMZ) architectures.
- Harden system configurations by enabling/using the available security features, and by disabling unnecessary ports, services, functionality, and network file shares.
- Apply all of the latest operating system security patches, validated and “AUTHORIZED” for the deployment by GE, to control systems PCs.
- Use anti-virus software on control systems PCs and keep the associated anti-virus signatures up-to-date.
- Use whitelisting software on control systems PCs and keep the whitelist up-to-date.

6.12.1.5 Checklist

This section provides a sample checklist to help guide the process of securely deploying the products.

1. Create or locate a network diagram.
2. Identify and record the required communication paths between nodes.
3. Identify and record the protocols required along each path, including the role of each node.
4. Revise the network as needed to ensure appropriate partitioning, adding firewalls or other network security devices as appropriate. Update the network diagram.
5. Configure firewalls and other network security devices.
6. Enable and/or configure the appropriate security features on each module.
7. On each module, change every supported password to something other than its default value.
8. Harden the configuration of each module, disabling unneeded features, protocols and ports.
9. Test/qualify the system.
10. Create an update/maintenance plan.

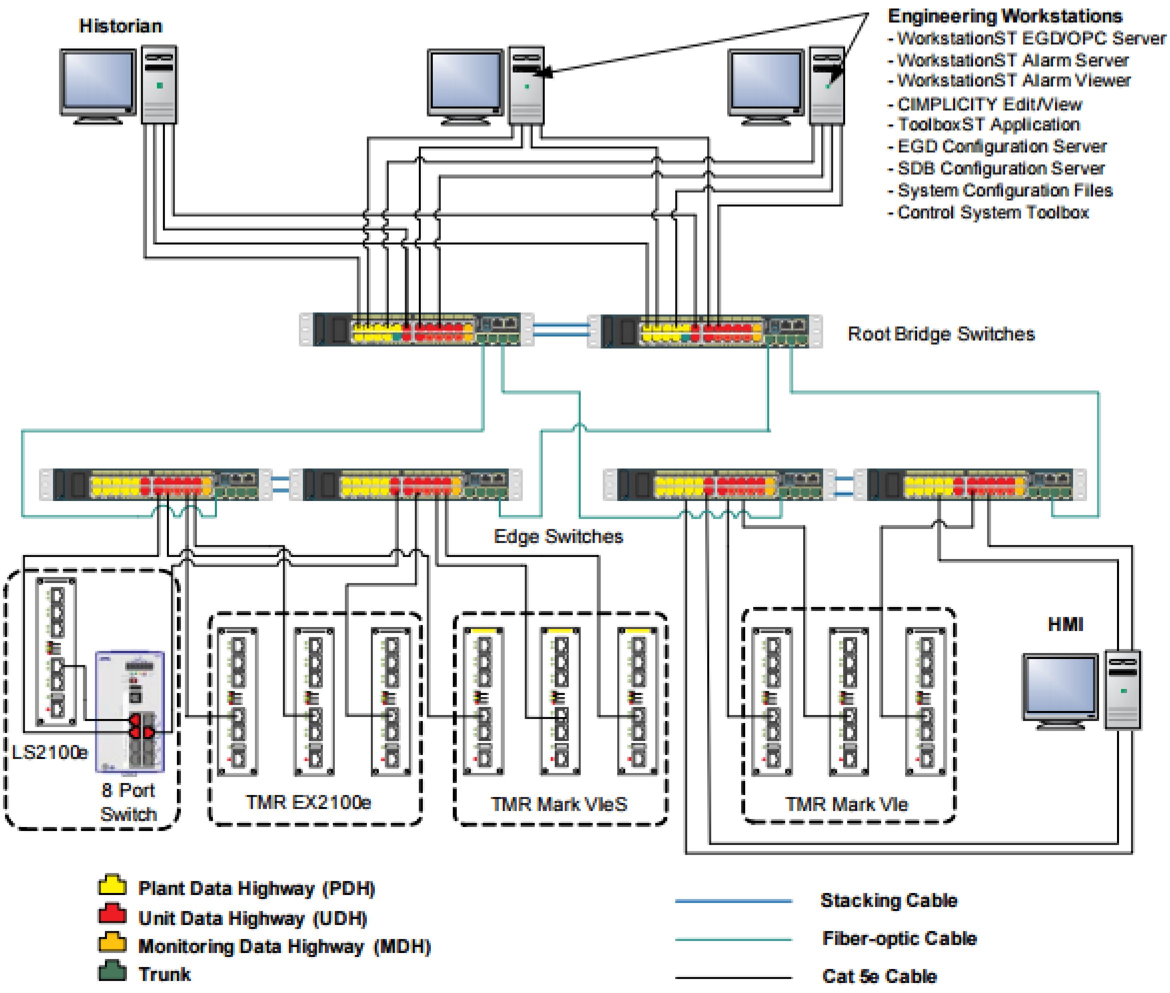
6.12.2 Unit Data Highway Connections

Note The UDH is the designation commonly applied to the Ethernet communications network among GE-supplied control system equipment such as the EX2100e control, LS2100e static starter control, Mark VIe Turbine control, and HMI. In applications where the EX2100e control is used with generator controls from other suppliers, the details of this section may not apply.

Note In no way, the UDH should be connected to another network. The greatest care must be taken if this EX2100 dedicated section of the UDH would like to be connected to the "rest of the plant" section of the UDH.

When in an integrated configuration, the EX2100e control communicates over the same data highway as the Mark VIe turbine control and the HMI. A typical exciter connection to the redundant UDH network is displayed in the following figure. The figure describes the concepts of the redundant Ethernet-based control network used in the NetworkST 3.1 topology. It also describes the concepts of the NetworkST 4.0 topology that can be layered on top of NetworkST 3.1 to provide additional security features.

Note For security deployment, refer to *Mark* VIe Control Systems Secure Deployment Guide* (GEH-6839)
For more information, refer to *NetworkST 3.1/4.0 for MarkVIe Controls Application Guide* (GEH-6840).



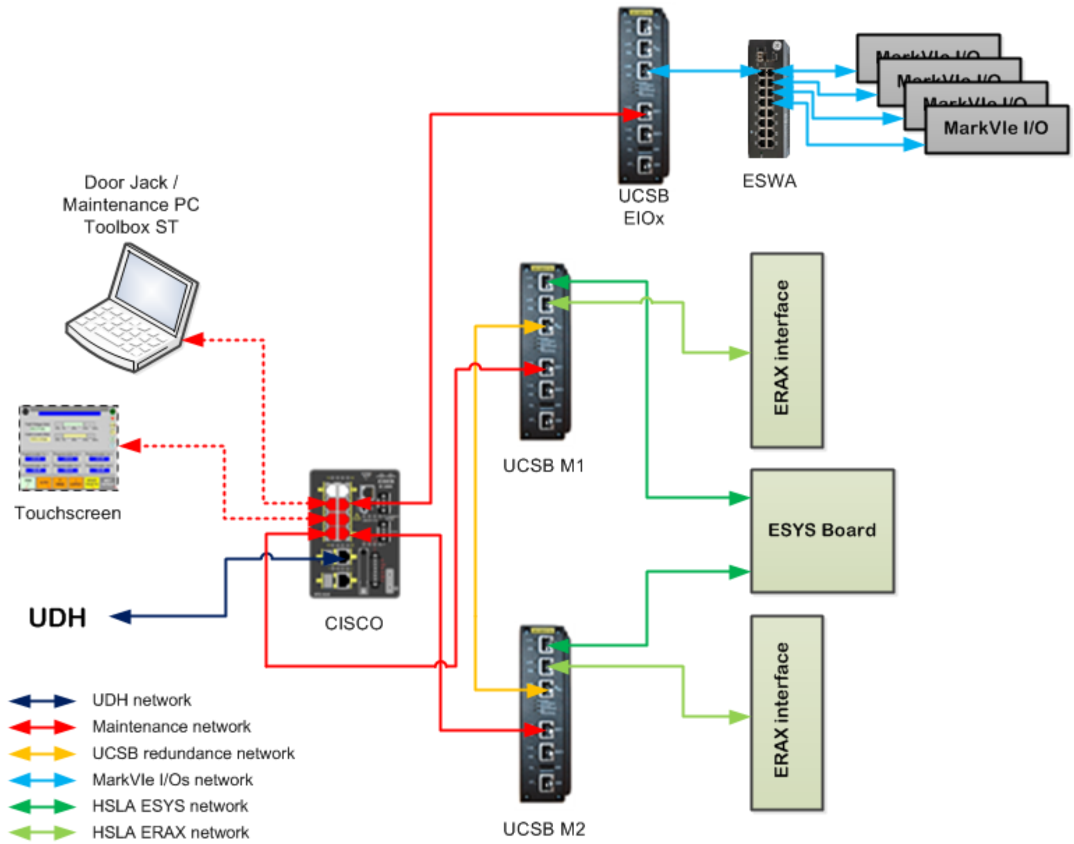
UDH Connections

The detailed architectures of a redundant TMR EX2100e Exciter configuration and of a redundant dual EX2100e Regulator configuration are given on below figures.
10/100BaseT cabling is used for short distances between the controller and the T-switch and any local HMI. The 10/100BaseT ports in the UCSx and the T-switch are for RJ-45 connectors. The maximum distance for local traffic at 10/100 Mbps using unshielded twisted pair cable is 100 m (330 ft). 10/100BaseFX fiber-optics may be used for longer distance communication between the local control area and the central control room.

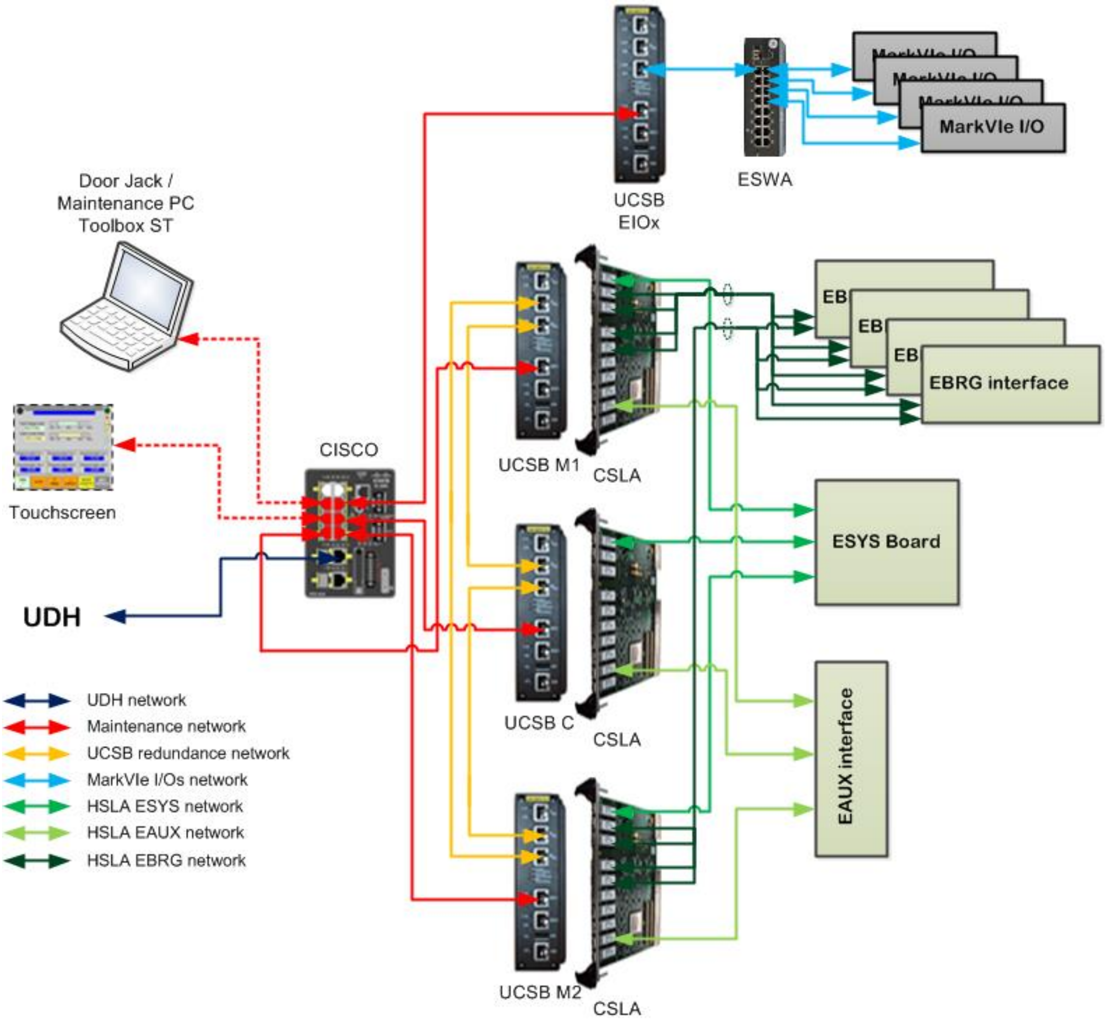
Note For more information, refer to *Mark VIe and Mark VIeS Control Systems Volume I: System Guide* (GEH-6721_Vol_I).

A Cisco Industrial Ethernet 2000 8 ports switch interfaces with UDH network. Redundancy of the switch can be provided. Switches are configured by GE; pre-configured switches should be purchased from GE. The modification of the switch configuration is not authorized without review by GE to keep a good level of cyber protection.

Note Unused Ethernet ports on the switch must remain physically locked.



Redundant Dual EX2100e Regulator Configuration

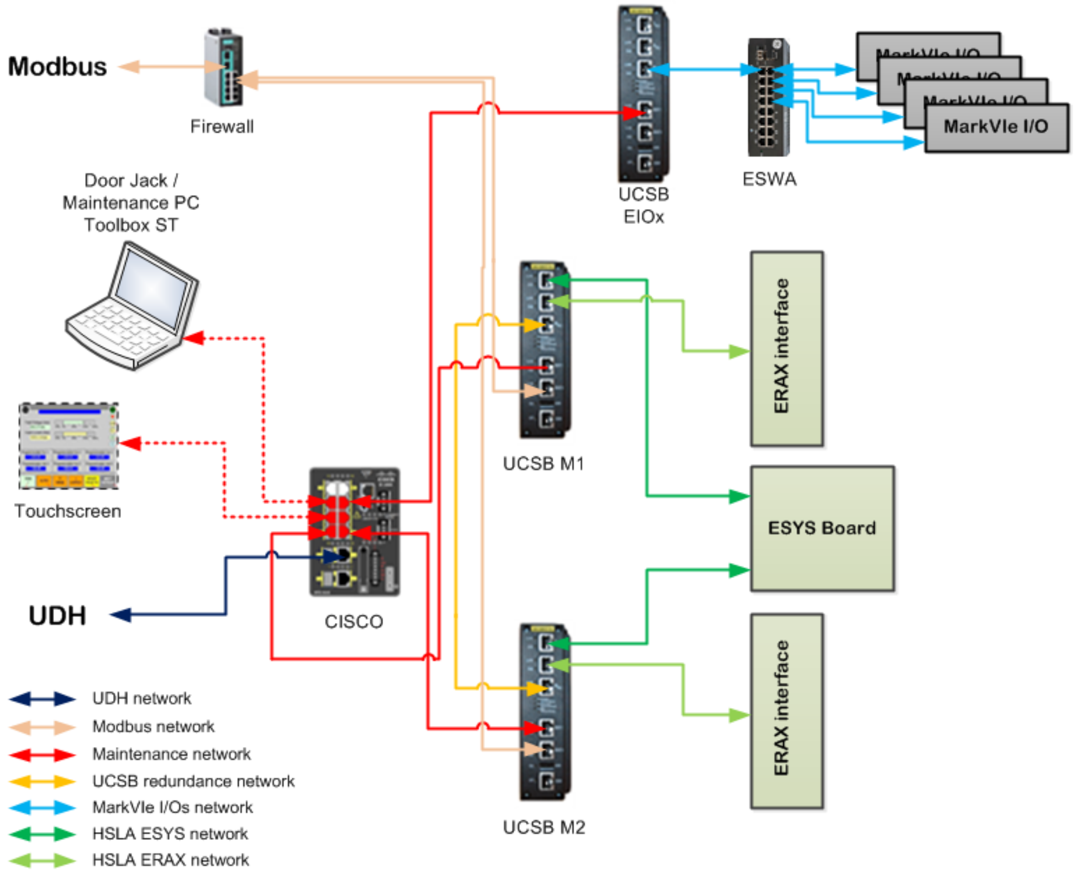


Redundant TMR EX2100e Exciter Configuration

6.12.3 Third-Party DCS Connections

The EX2100e control is also available in standalone configuration, meaning DCS is a third-party system. This is seen often in case of retrofitting units.
The "stand-alone" Excitation solution is compliant with a *Defense in Depth* approach to security. Refer to section Cyber Security concerns for *Defense in Depth* definition.

The detailed architecture of a redundant Dual EX2100e Regulator configuration in standalone is given on below figure to illustrate the function. Similar architecture concept is applied to the redundant TMR EX2100e Exciter configuration.



Standalone Redundant Dual EX2100e Regulator Configuration

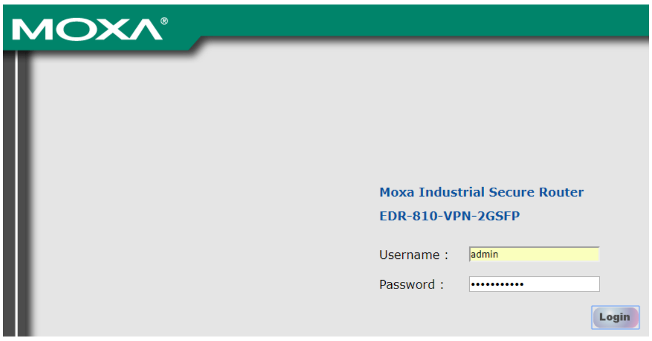
The standalone Excitation Solution requires an external link to 3rd party devices that is used for Modbus protocol communication.
This link integrates an industrial firewall configured with security rules that can protect safely the network segments of the Excitation solution. In Addition, this device handles Deep Packet Inspection on Modbus transmission.
On this industrial firewall: Moxa EDR-810-VPN-2GSFP with dedicated administration port, Customer must change every supported password to something other than its default value.

Managed switches (Cisco IE2000) are used in stand-alone architecture (simplex or redundant) to offer an acceptable level against cybersecurity requirements. Cisco switches are configured by GE; pre-configured switches should be purchased from GE.
The modification of the switch configuration is not authorized without review by GE to keep a good level of cyber protection.

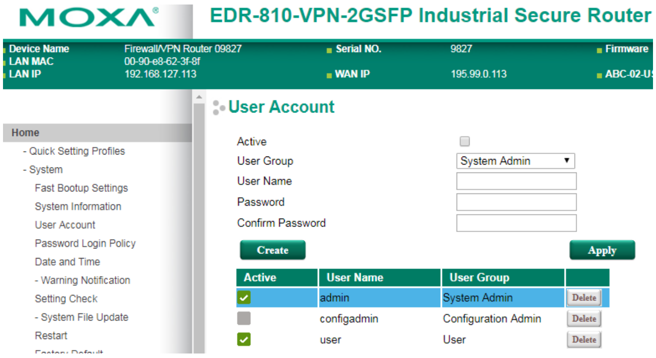
Note Unused Ethernet ports on the switch must remain physically locked.

6.12.3.1 Change default Password on Moxa device

From Lan: ADM, login into Moxa device using Username and Password provided initially by GE.



From the **System** menu, select **User Account**.



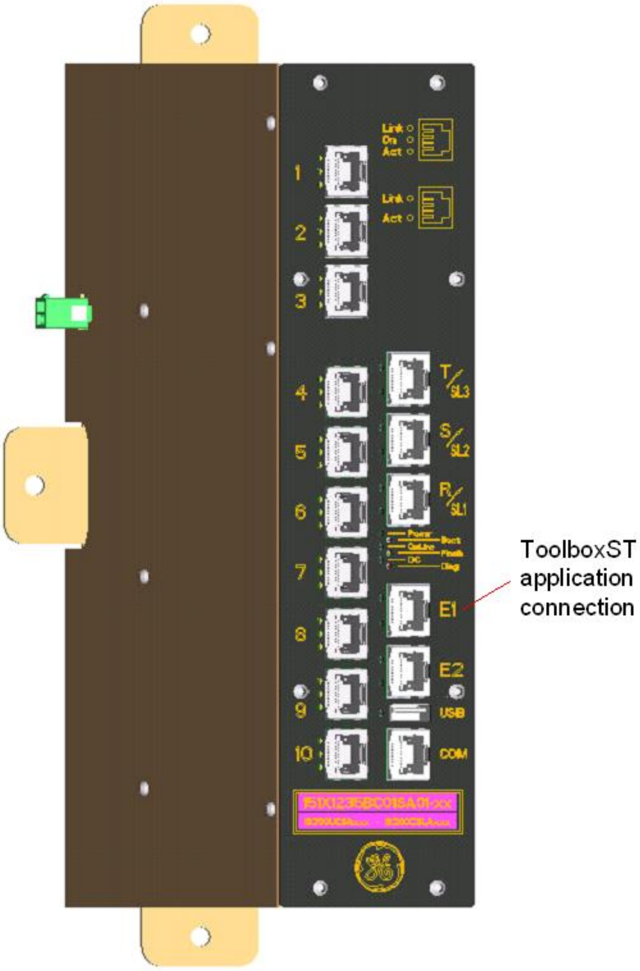
For admin user: Change default password and Apply.

Managed switches (Cisco IE2000) are also used in stand-alone architecture (simplex or redundant) to offer an acceptable level against cybersecurity requirements. A dedicated configuration is associated to each managed switch.

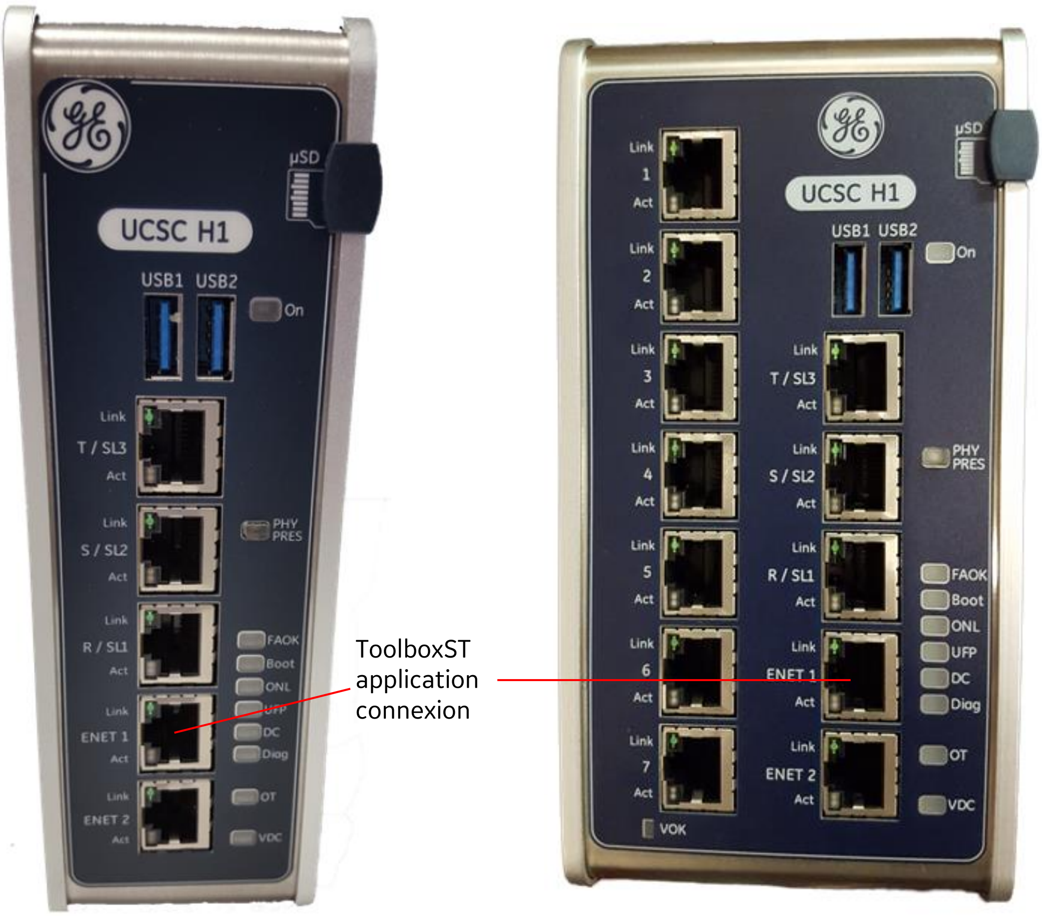
6.13ToolboxST Application Connection

The Ethernet E1 port on the UCSx controller provides the ToolboxST application interface through the UDH. This is a 10/100BaseT port that uses an RJ-45 connector for unshielded, twisted pair cable.

To connect: from the ToolboxST application, connect to the E1 switch on the UDH that is connected to the UCSx controller, and go online with the exciter.



UCSB Controller E1 Connection



UCSC Controller E1 Connection
Simplex configuration

UCEC Assembly E1 Connection
Redundant configuration

7 Touchscreen Operator Interface

The optional touchscreen is mounted on the control cabinet door and provides full exciter operation. The touchscreen communicates with the controller over the UDH, which is the Ethernet local area network (LAN) normally connected to UCSx connector E1. When the touchscreen's heartbeat icon is pulsing, it is communicating with the exciter system.

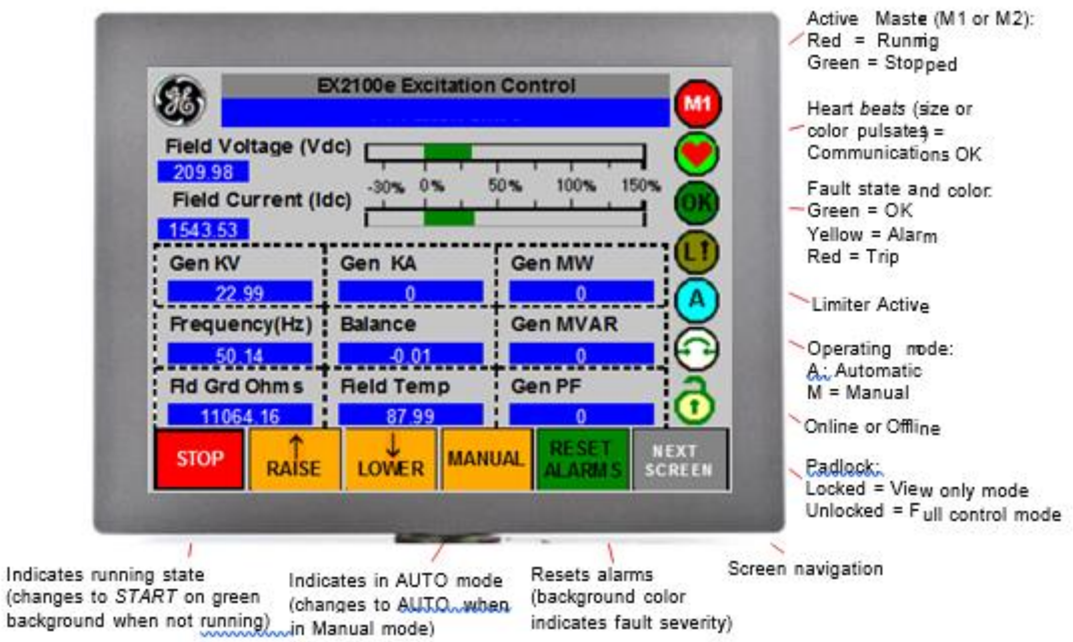
Attention

During startup, the touchscreen displays the IP address of the UCSx controller to which it is connected. This must match the IP address of the M1 controller of the exciter system.

The touchscreen includes bar graph and variable displays to indicate system conditions, such as generator megawatt (MW) and mega volt-amperes reactives (MVARs), field current and voltage, and regulator balance (null balance). Diagnostic displays, such as alarm history, exciter parameters, variables and I/O values, application data, and I/O interface, provide system information for maintenance and troubleshooting. Status indicators on each screen indicate current running or not running state. The touchscreen can be disabled and is password-protected to prohibit local operation. It is shipped from the factory pre-configured. For more information, refer to *EX2100e Excitation and LS2100e Static Starter Control Systems Touchscreen Local Operator Interface Instruction Guide* (GEI-100787).

Using the touchscreen, the operator can issue the following commands:

- Start/stop
- Raise/lower voltage
- Transfer between automatic/manual modes
- View and reset diagnostic alarms



Touchscreen Main Screen with Status Indicators

Note For information on other operator interface options for exciter control, refer to the section *Operator Interface*.

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8 Replacement and Ordering

This chapter helps the user with parts replacement, as well as to identify and order replacement parts.

8.1 Replacement

Replacement parts may contain static-sensitive components. Therefore, GE ships replacement parts in anti-static bags. When handling electronics, make sure to store them in anti-static bags or boxes and use a grounding strap (per the following Caution criteria).

Caution

To prevent component damage caused by static electricity, treat all boards with static-sensitive handling techniques. Wear a wrist grounding strap when handling boards or components, but only after boards or components have been removed from potentially energized equipment and are at a normally grounded workstation.

Warning

To prevent personal injury or damage to equipment, follow all GE safety procedures, Lockout Tagout (LOTO), and site safety procedures as indicated by Employee Health and Safety (EHS) guidelines.

Warning

This equipment contains a potential hazard of electric shock, burn, or death. Only personnel who are adequately trained and thoroughly familiar with the equipment and the instructions should install, operate, or maintain this equipment.

8.2 Replacement Procedures

Troubleshooting should be done at the system component level. The failed system component (least replaceable part) should be removed, returned to GE, and replaced with a known good spare. Do not attempt to repair system components.

Warning

To prevent electric shock, turn off power to the equipment, then test to verify that no power exists in the board before touching it or any connected circuits.

Caution

To prevent equipment damage, do not remove, insert, or adjust board connections while power is applied to the equipment.

Attention

Replacement of the terminal board requires full reconfiguration of the changed component using the ToolboxST application. For this reason, it is generally preferable to replace only the I/O pack unless the terminal board is known to be the point of failure.

8.3 Ordering

Prior to ordering a replacement part for a GE product, the following items should be understood:

- How to accurately identify the part
- If the part is under warranty
- How to place the order

Note Renewals and spares (or those not under warranty) should be ordered by contacting the nearest GE Sales or Service Office, or an authorized GE Sales Representative.

Control system electronics are identified by a 12-character alphanumeric part number and a single revision letter.

HSLA Example

When ordering, be sure to include the following items:

- Complete part number and description
- Serial number
- Material List (ML) number

Note The ML number is provided on the data nameplate.

When ordering, be sure to include the complete part number and revision letter. All digits are important when ordering or replacing any device. The factory may substitute newer versions based on availability and design enhancements, however, GE ensures backward compatibility of replacements.

Data Nameplate

Each exciter lineup, cabinet (panel)/case, and core unit has a unique identifying catalog number, also called the part or ML number. The data nameplate provides the ML number, which links the equipment to its requisition, drawings, components, materials, specification item, and shipping documents. The data nameplate is located on the back of the cabinet door.

EX2100e NAMEPLATE DATA

NAME: DM#:
GEPS PO#/LINE:
DESC: VC:
GEPS PART#:
GEINDSYS: ITEM#:

DRAWINGS:

ELEMENTARY: OUTLINE:

INSTRUCTION MANUAL: GEH-6785, GEH-6786

POWER REQUIREMENTS:

INPUT - VOLTS: 990 AMPS: 1583.4 HERTZ: 50 PHASE: 3
MAX SYM S.C.C. AMPS: 50000 MAX VOLTS: 1000

CONTROL POWER:

125 Volts DC @ 15 Amps ;<ETX>
120 Volts AC @ 15 Amps, 60 Hertz, 1 Phase

OUTPUT - VOLTS: 680 AMPS: 1940.4
Refer to system manual and elementary for detailed requirements

Typical EX2100e Data Nameplate

Glossary of Terms

41DC A contactor used in the exciter.

52G A dedicated contact input.

59G The generator overexcitation protection.

86G A dedicated contact input.

ANSI American National Standards Institute.

Automatic Voltage Regulator (AVR) AVR is controller software that maintains the generator terminal voltage through the Field Voltage Regulator.

Auxiliary source A source of three-phase ac power for the exciter, but not from the generator being controlled.

Baud A unit of data transmission. Baud rate is the number of bits per second transmitted.

Bit Binary Digit. The smallest unit of memory used to store only one piece of information with two states, such as One/Zero or On/Off.

Block Instruction blocks contain basic control functions, which are connected together during configuration to form the required machine or process control. Blocks can perform math computations, sequencing, or regulator (continuous) control.

Board Printed circuit board.

Bumpless No disruption to the exciter when transferring control.

Bus Upper bar for power transfer, also an electrical path for transmitting and receiving data.

COM port Serial controller communication ports (two). COM1 is reserved for diagnostic information and the serial loader. COM2 is used for I/O communication.

Configure To select specific options, either by setting the location of hardware jumpers or loading software parameters into memory.

Crowbar The crowbar limits the high negative voltages that may be induced into the PCM during a pole slip (loss of synchronism) event. It includes a discharge resistor, and is self firing.

CT Current Transformer, used to measure current in an ac power cable.

DACA or DACB Ac to dc converter for power supply, produces 125 V dc.

De-excitation The de-excitation circuit produces a conduction path through a discharge resistor or inductor to dissipate the field current after a unit trip.

Device A configurable component of a control system.

DRAM Dynamic Random Access Memory, used in microprocessor-based equipment.

EGD Ethernet Global Data, a control network and protocol for the controller. Devices share data through EGD exchanges (pages).

Ethernet LAN with a 10/100 M baud collision avoidance/collision detection system used to link one or more computers together. Basis for TCP/IP and I/O services layers that conform to the IEEE 802.3 standard.

EX2100e exciter GE static exciter; regulates the generator field current to control the generator output voltage.

FCR Field Current Regulator.

Field flashing The supply of initial exciter current during startup, usually from station batteries.

Field ground detector
The field ground detector is an active circuit that detects a ground in either the ac or dc sections of the exciter and field wiring.

Field Voltage Regulator (FVR)
FVR is controller software that maintains the generator terminal voltage using inputs from the AVR and the field voltage feedback.

Firmware The set of executable software that is stored in memory chips that hold their content without electrical power, such as EEPROM or Flash.

Flash A non-volatile programmable memory device.

Gating Controlling the conduction of the power SCRs with an input pulse train (or a voltage).

GDG The Digital Ground Detector provides a separate terminal board user interface.

Health A term that defines whether a signal is functioning as expected.

Heartbeat A signal emitted at regular intervals by software to demonstrate that it is still active.

HMI Human-machine Interface, usually a computer running Windows NT and CIMPLICITY HMI software.

HSSL High-speed Serial Link, signals are sent over the HSSL to the controller, where it is monitored and alarmed.

HVI High Voltage Interface, contains the ac line filter fuses and several circuit boards.

I/O Input/output interfaces that allow the flow of data into and out of a device.

I/O drivers Software that interfaces the controller with input/output devices, such as communication networks, sensors, and solenoid valves.

IEEE Institute of Electrical and Electronics Engineers. A United States-based society that develops standards.

IP address The address assigned to a device on an Ethernet communication network.

LAN Local Area Network.

Line filter Filter networks across the three-phase input lines to the exciter to minimize the voltage spikes that result from the abrupt decay of current during SCR commutations.

LOE The Loss of Excitation (LOE) protection function is available with the warm backup control scheme. This function detects a loss of excitation on synchronous machines.

LS2100e Static Starter
Electric power device that runs the generator as a motor to bring a gas turbine up to starting speed.

Mark VIe turbine controller
A control performs turbine-specific speed control, logic, and sequencing.

MTBF Mean Time Between Failures.

MTBFO Mean Time Between Failure Outages.

Multiple bridges Several power producing bridges operate in parallel to produce a high field current. These share the exciter current load to provide redundancy and increased reliability.

MVAR Mega volt-amperes reactive; the touchscreen includes bar graph and variable displays to indicate system conditions such as generator MW and MVARs.

MW Mega watt; the touchscreen includes bar graph and variable displays to indicate system conditions such as generator MW and MVARs.

NEMA National Electrical Manufacturers Association; a U.S. standards organization.

Non-volatile Memory specially designed to store information even when the power is off, for example Flash memory.

Overexcitation Trip (OET)
The OET protects the generator field from damage by events that require or produce abnormally high field currents.

Overexcitation Limit (OEL)
OEL software limits the excitation current to prevent overfluxing the generator.

peak reverse voltage (PRV)
PVR is limited with pole slip resistors, wired across the SCRs.

Permanent Magnetic Generator (PMG) source
Power used by the exciter to excite the main generator field is taken from a PMG connected to the generator shaft. The PMG typically produces 400-480 Hz three-phase output.

Potential transformer (PT)
PT is used for measuring voltage in a power cable.

Power Conversion Module (PCM)
The PCM or Bridge consists of six thyristors connected in a three-phase bridge, with associated protection and control devices, to generate the dc field voltage.

Power current transformer (PCT)
A PCT can be attached to the generator line to provide a portion of the three-phase power for the exciter, part of a compound source.

Power Distribution module (EDIS)
The PDM distributes 125 V dc to the power supplies for the controllers and I/O termination boards.

Power potential transformer (PPT)
A PPT is attached to the generator terminals or an auxiliary bus to provide three-phase power for the exciter; referred to as a potential source.

Power System Stabilizer (PSS)
PSS software produces a damping torque on the generator to reduce generator oscillations.

Radio Frequency Interference (RFI)
This is high-frequency electromagnetic energy which can affect the control system.

Real-time Immediate response, referring to control systems that must respond instantly to changing conditions.

Redundant A system containing of duplicated components (boards or modules), which can transfer functionality from a failed component to one of the duplicate components without loss of the entire system's functionality.

SCR Silicon-controlled Rectifier (SCR) bridge circuit.

Serial loader Connects the controller to the toolbox computer using the RS-232C COM ports. The serial loader initializes the controller flash file system and sets its TCP/IP address to allow it to communicate with the toolbox over Ethernet.

Server A computer, which gathers data over Ethernet from plant devices, and makes the data available to computer-based operator interfaces known as Viewers.

Shaft Voltage Suppressor (SVS)
The SVS is a filter that conducts to ground the high frequency components of the induced voltages in the field current.

Signal The basic unit for variable information in the controller.

Simplex System with only one set of control and I/O modules. Contrast with redundant control systems.

Static Exciter Produces a controlled dc field current without the use of a rotating generator.

TCP/IP Communications protocols developed to inter-network dissimilar systems. It is a de facto UNIX standard, but is supported on almost all systems. TCP controls data transfer and IP provides the routing for functions.

ToolboxST Application
A Windows-based software package used to configure the EX2100e and Mark VIe turbine controller.

Triple Modular Redundancy (TMR)
An operation that uses three sets of control and I/O (channels M1, M2, and C) and votes the results.

Underexcitation limit (UEL)
UEL software functions to prevent generator over-heating caused by underexcitation.

Unit Data Highway (UDH)
Connects the EX2100, Mark VIe turbine controllers, LS2100, PLCs, and other GE provided equipment to the HMI servers; runs at 10/100 Mbaud and supports peer-to-peer communications.

V/Hz V/Hz is the ratio of generator voltage to the frequency; this is limited to prevent overfluxing the generator.

Warm backup Two bridges are connected to the field but only one is actively producing power. The other bridge does not receive gating pulses until it is required to take over from the active bridge.

Windows NT Advanced 32-bit computer operating system from Microsoft.

Notes