F650 - More than Feeder Protection & Control

imagination at work

GE Consumer & Industrial
Multilin

F650
Bay Controller

A Comprehensive Protection and Control solution for Transmission and Distribution Networks

Introduction:

What is the F650?

Protection, Control, Metering, Monitoring, Analysis and Energy Management System

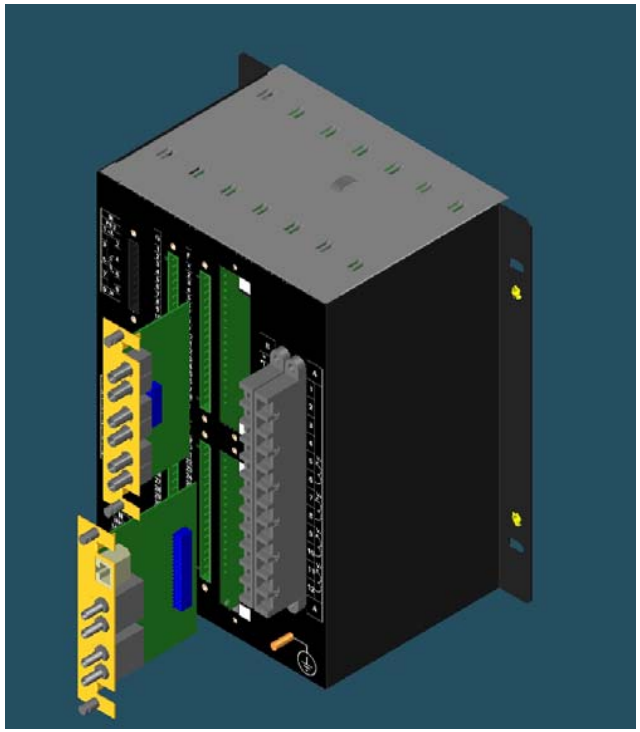
- Supports open communications protocols such as ModBus/DNP for integration with other IEDs
- Applicable for electrical utilities as well as industrial electrical systems
- Best value for price
- Building block for systems
- Large graphical built-in interface
- Meets well established IEC 61131-3 standard for easy logic configuration
- Graphical editor for programming logic
- Pre-assigned interlocking

Applications

The F650 can be used for:

- Comprehensive feeder protection and control functionality at any voltage level
- Backup protection for transformers, busbars, generators and large motors
- Control functions include synchronism-check, recloser and breaker failure
- Monitoring functions:
  - Oscillography
  - Event Recorder
  - Fault Recorder
  - Data Logger

Features & Benefits

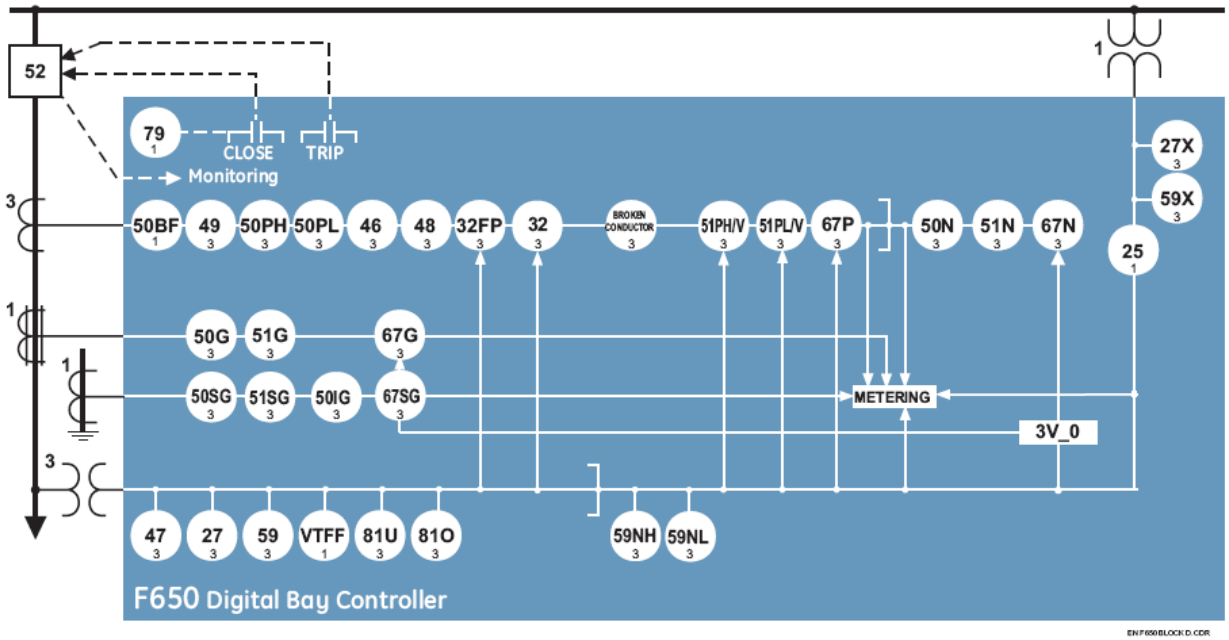


The F650 features advantage such as:

- Modular hardware architecture:
  - Main CPU board with two plug and play comm boards
  - Universal magnetic (CTs & VTs) module
  - Programmable I/O module
  - Single or redundant power supply
  - Front board: HMI (Graphical or alphanumerical display, LEDs, RS232)
- Modern and open communication protocols for easy integration

Block Diagram

F650 Protection and Control characteristics:



DEVICE	COMMON PROTECTION ELEMENTS
25	Synchrocheck
27/27X	Bus/Line Undervoltage
32	Sensitive Directional Power
32FP	Forward Power
46	Negative Sequence Time Overcurrent
49	Thermal Image - overload protection
47	Negative Sequence Voltage
50 BF	Breaker Failure
50PH/PL	Phase Instantaneous Overcurrent (High/Low)
50N	Neutral Instantaneous Overcurrent
50G	Ground Instantaneous Overcurrent
50SG	Sensitive Ground Instantaneous Overcurrent
50IG	Isolated Ground Instantaneous Overcurrent
51N	Neutral Time Overcurrent
51G	Ground Time Overcurrent
51SG	Sensitive Ground Time Overcurrent
51PH/V	Voltage Restraint Phase Time Overcurrent
59/59X	Bus/Line Overvoltage
59NH/NL	Neutral Overvoltage - High/Low
67P	Phase Directional Overcurrent
67N	Neutral Directional Overcurrent
67G	Ground Directional Overcurrent
67SG	Sensitive Ground Directional Overcurrent
81 U/O	Under/Over Frequency
	Broken Conductor Detection
VTFF	VT Fuse Failure Detection

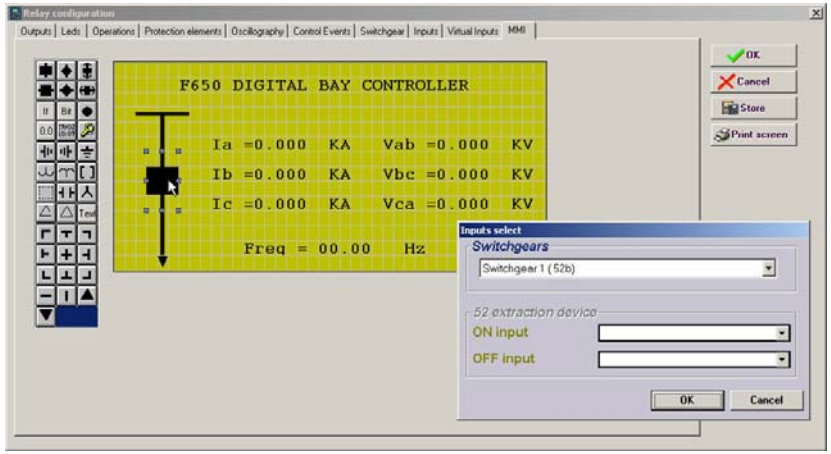
Protection

F650 Protection functions include:

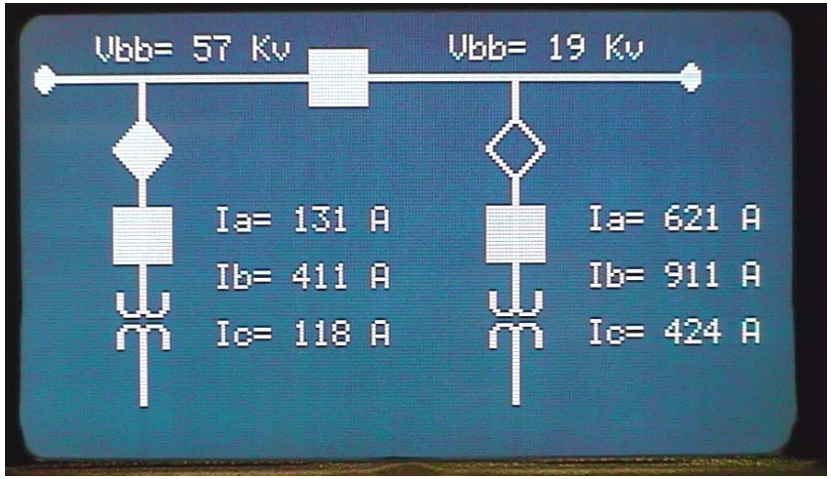
- Phase, neutral and ground TOCs and IOCs
- Standard curves and programmable user curves:
  - IEEE
  - IEC
  - ANSI
  - IAC
  - I2t
  - Definite time
  - Rectifier
  - User curves
- Bidirectional protection
- Sensitive earth fault
- Under and overvoltage elements
- Under and overfrequency elements
- RMS / DFT choice independent from mains frequency (50 / 60 Hz)
- Use of established protection algorithms
- Designed to withstand surges, overcurrents and DC-biased faults
- True universal current range 1/5 A
- DSP to unload main CPU (64 samples/cycle)

Control

PC design mode example



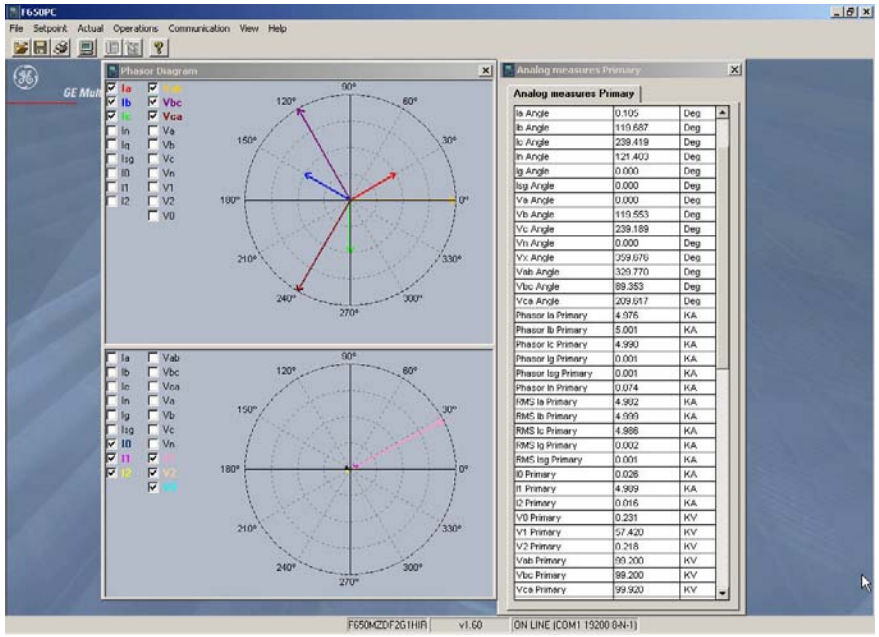
F650 Actual screen example



F650 Control functions include:

- Synchrocheck
- 4 Shot autorecloser is fully programmable
- Breaker failure
- Fuse failure
- One line diagram in graphic LCD display with capability to display switchgear elements
- Full control of switches and breakers
- Built in pre-configured interlockings for secure control.
- Annunciator panel viewing
- Three setting groups available

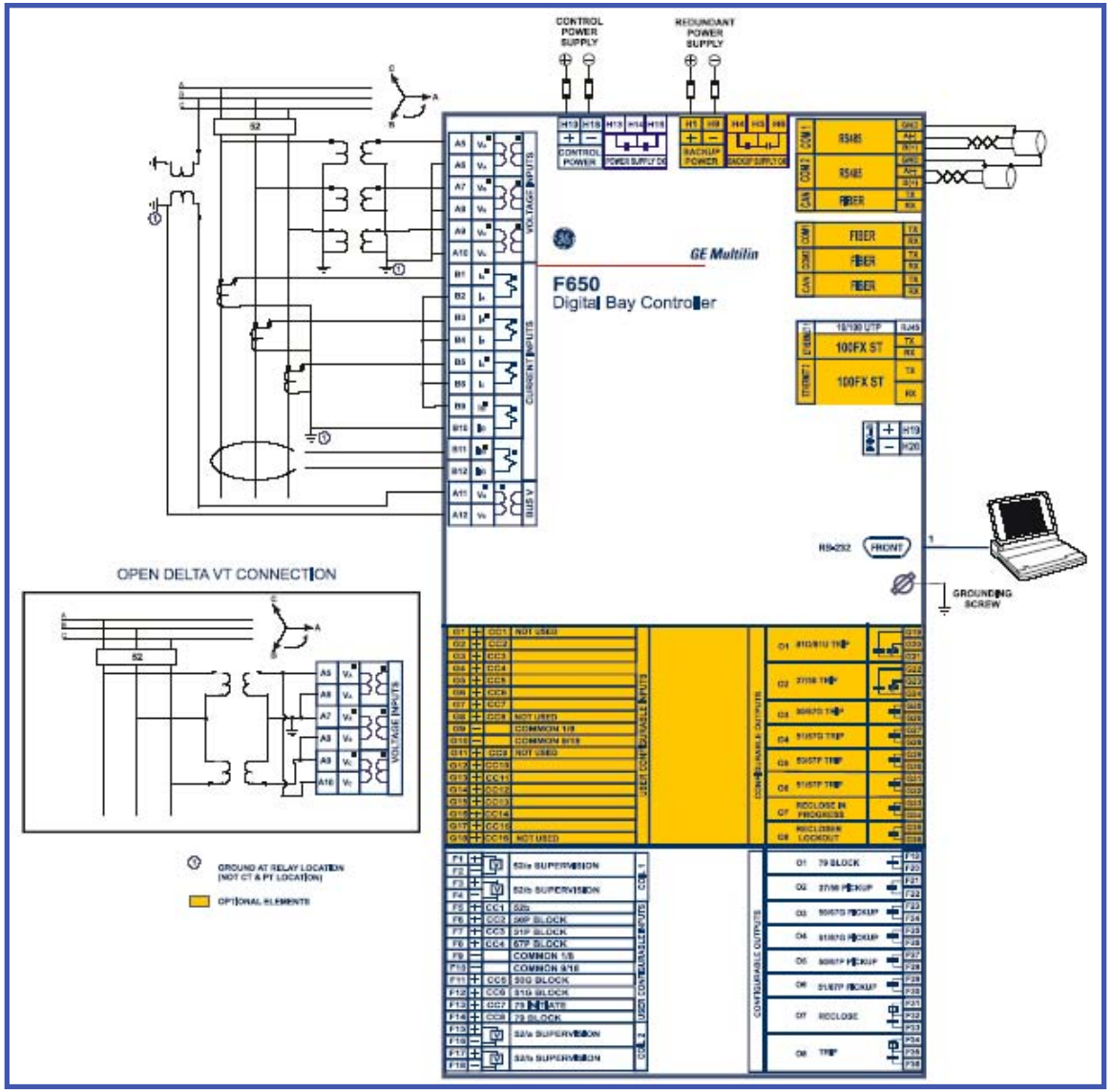
Monitoring & Metering



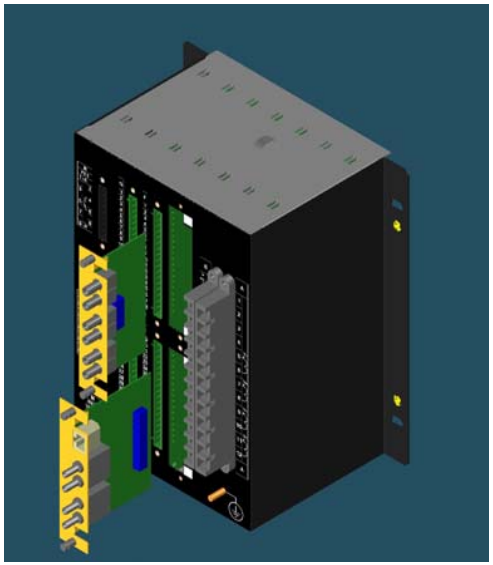
The F650 provides:

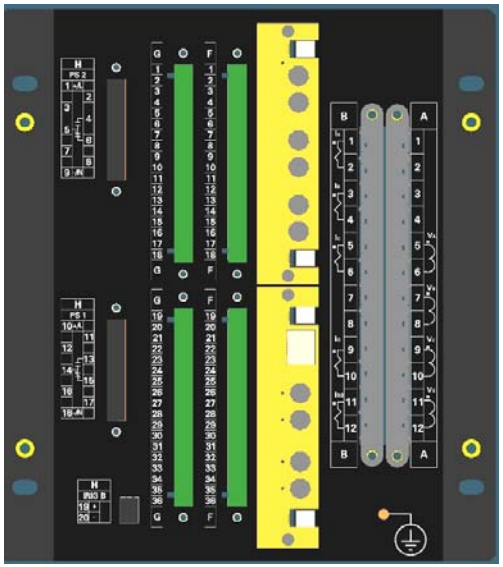
- Data logger (16 Channels)
- Event recording of up to 479 time-tagged events
- Programmable oscillography feature (up to 20 records)
- Monitoring of current, voltage, power, power factor, energy, demand and frequency
- Fault recording and location with 10 fault reports
- IRIG-B DC for accurate 1 ms time tagging
- Breaker monitoring
- Three phase energy metering

Typical Wiring



Mechanical





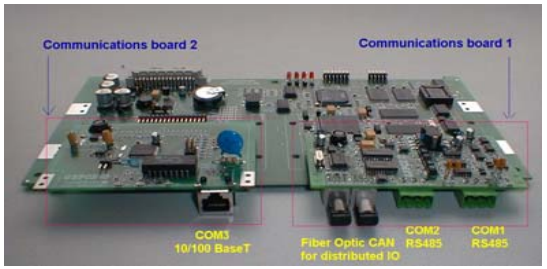
Mechanical advantages of the F650:

- Modular concept
- 6 unit height allows optimising space for terminals
- Built in guide-rails facilitate board insertion/extraction
- Grounding screw built into case
- Printed labels on the rear plate facilitates wiring
- Power supply is clearly marked with positive and negative terminals far from each other to prevent accidents
- TX and RX LEDs for Ethernet port communications visible from rear side helps troubleshooting

Hardware

Redundant Power Supply

CPU+DSP

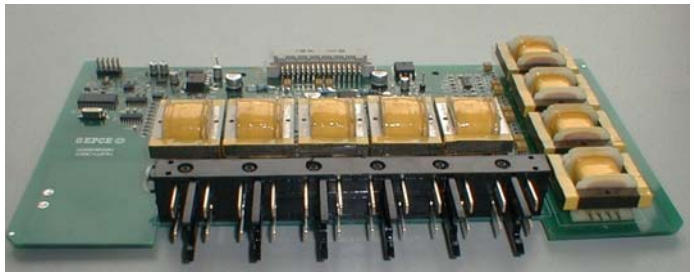


- Wide input range (HI & LO)
  - LO 24 - 48 VDC
  - HI 110 - 250 VDC 120 - 230 VAC
- Switching Mode Power Supply with High Efficiency > 80%
- Redundant model available through the use of 2 modules assembled in the mother board

- High-speed 32-Bit RISC CPU > 50 MIPS with more than 32 Megabytes memory
- DSP for quick processing through maximum speed bus
- Firmware upgrades through the use of flash memory
- CAN bus for distributed I/O
- Modular communications for flexibility and cost effective solutions
- High-speed communications: 10/100Mbps Ethernet LAN, single/redundant Fiber Optic 100Mbps.

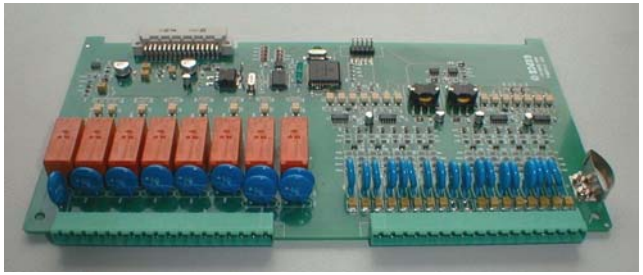
Hardware

Magnetic Module



- 9 analog inputs total:
  - 4 VT
  - 4 universal CT
  - 1 sensitive earth CT
- Modular universal range CT (Valid for 1 or 5 A to only one terminal)
- On-board DSP provides high-speed digital sampling for detailed oscillograms and accurate measurements
  - >16 Bit A/D
  - 64 samples / power cycle

Digital I/O



- CAN bus for increased number of I/Os
- Embedded micro controller provides improved security, speed and low power consumption
- Status inputs
  - 20 - 300 VDC
  - Programmable threshold levels
- Control outputs
  - Heavy duty relays valid for heavy inductive loads
  - Fast activation speeds (< 8ms)
- Supervision
  - 2 voltage monitors and 1 current monitor available per trip circuit supervision unit
  - 2 independent trip circuit supervision units

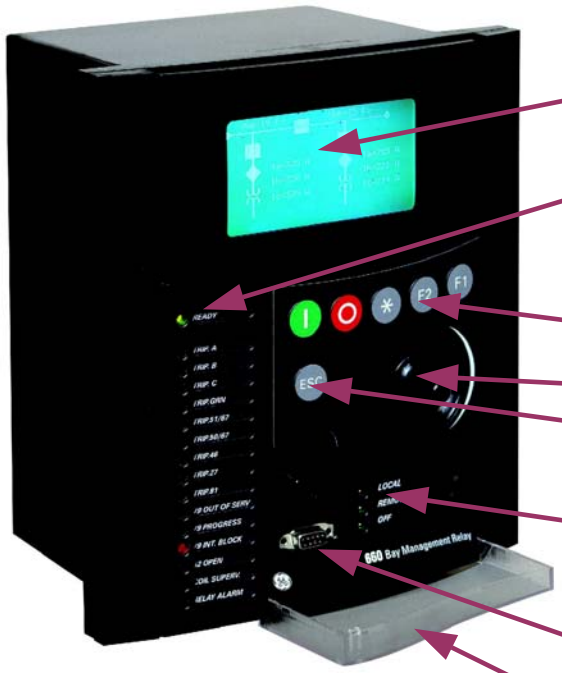
Hardware

DCMA INPUTS

- Current Input (mA DC) - Programmable:
  - 0 to -1
  - 0 to +1
  - -1 to +1
  - 0 to 5
  - 0 to 10
  - 0 to 20
  - 4 to 20
- Input Impedance: 166 ohms +/- 10 %
- Conversion Range: -1 to +20 mA DC
- Accuracy: +/-0.2% of full scale
- Type: Passive

Hardware

User Interface



DISPLAY & LEDS

- Graphic 16x40 or text 4x20 LCD display
- Fluorescent backlight to improve visibility
- Multicolor programmable LEDs with label panel

KEYPAD & SHUTTLE

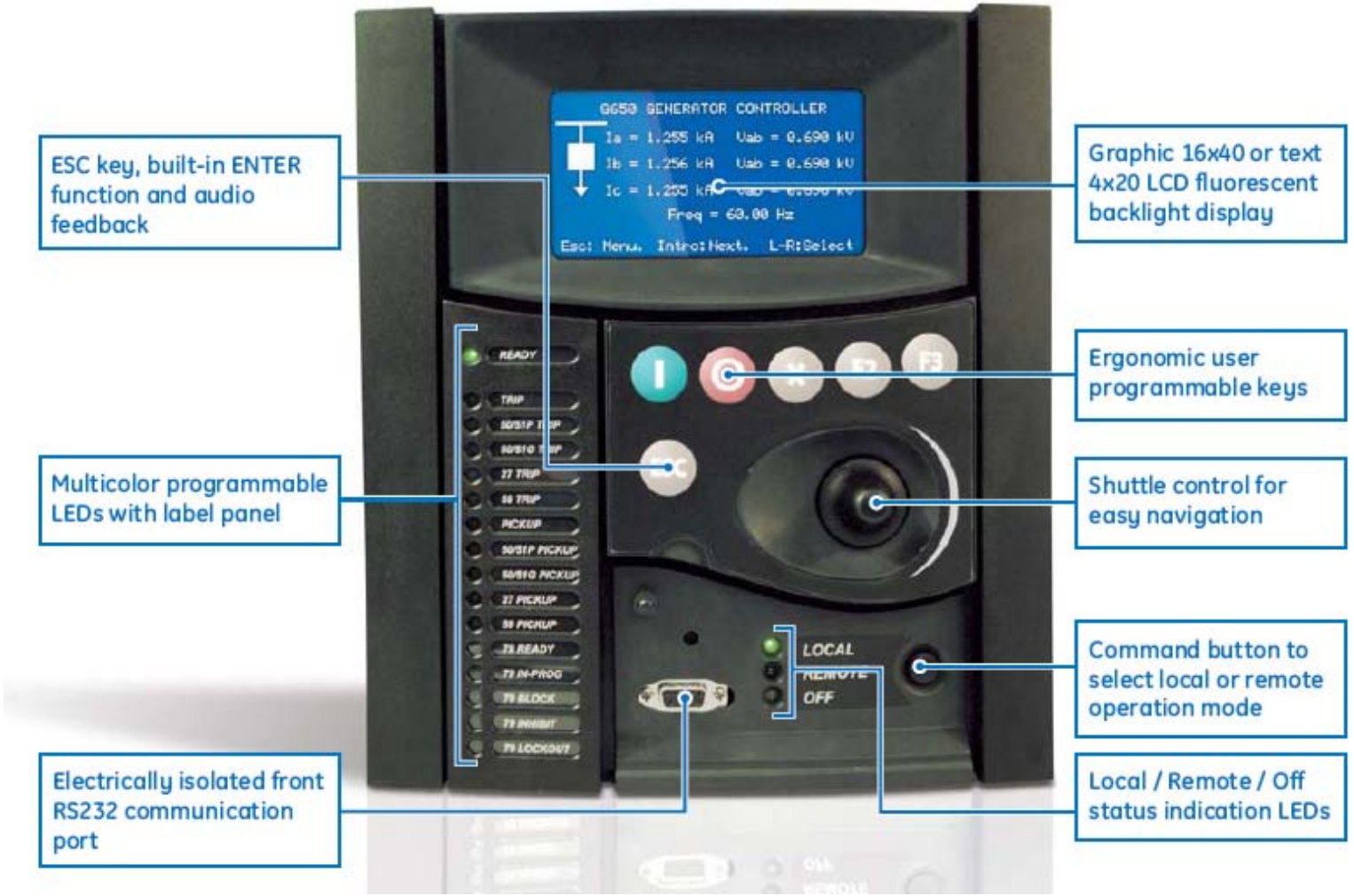
- Ergonomic programmable keys
- Shuttle control for easy navigation
- ESC key, built-in ENTER function and audio feedback
- Local / Remote / Off pushbutton with LEDs

FRONT PORT

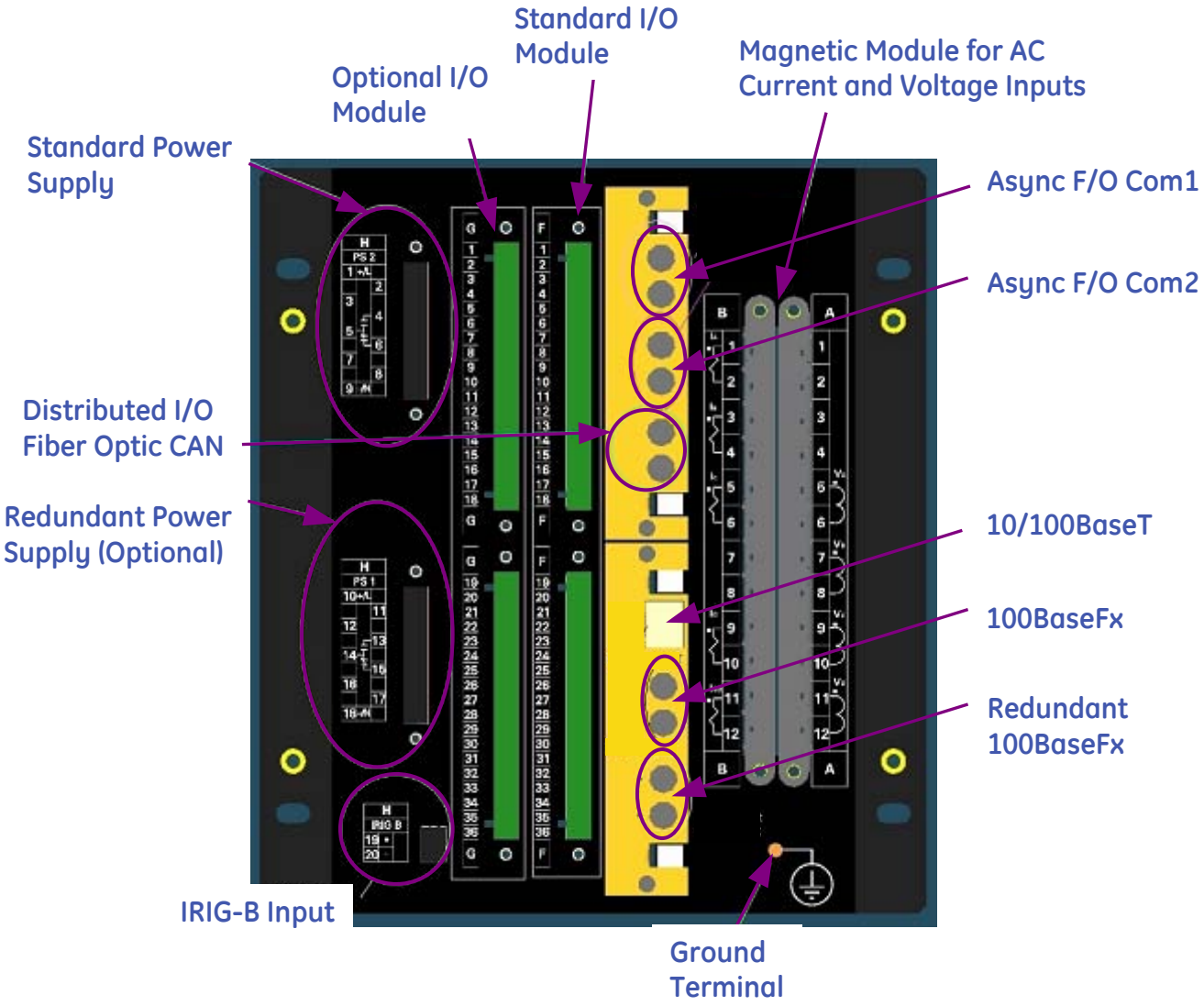
- Electrically isolated front RS232 communication port
- Transparent cover can be sealed for security

Hardware

User Interface



Hardware



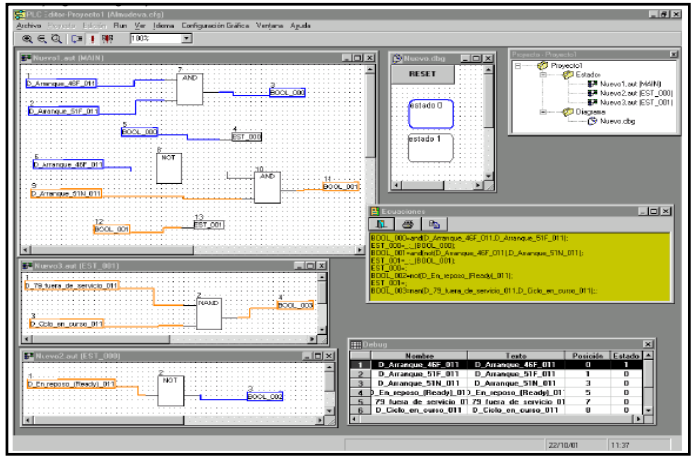
Rear-View diagram displays I/O, Magnetic Module (CTs & VTs), and other connector locations

EnerVista F650 Setup Software

The EnerVista F650 Setup Software provides the following functions:

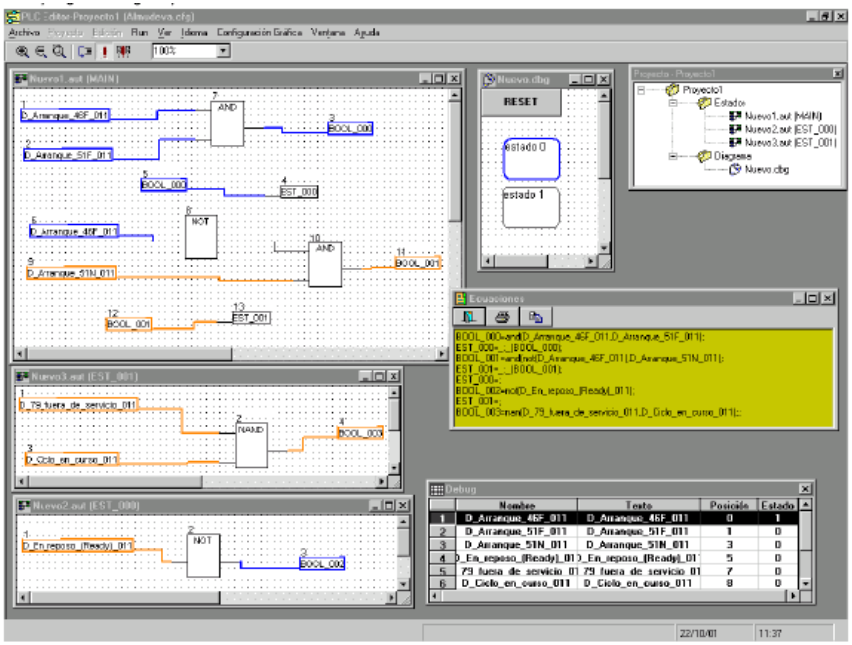
Settings

Metering



Configuration

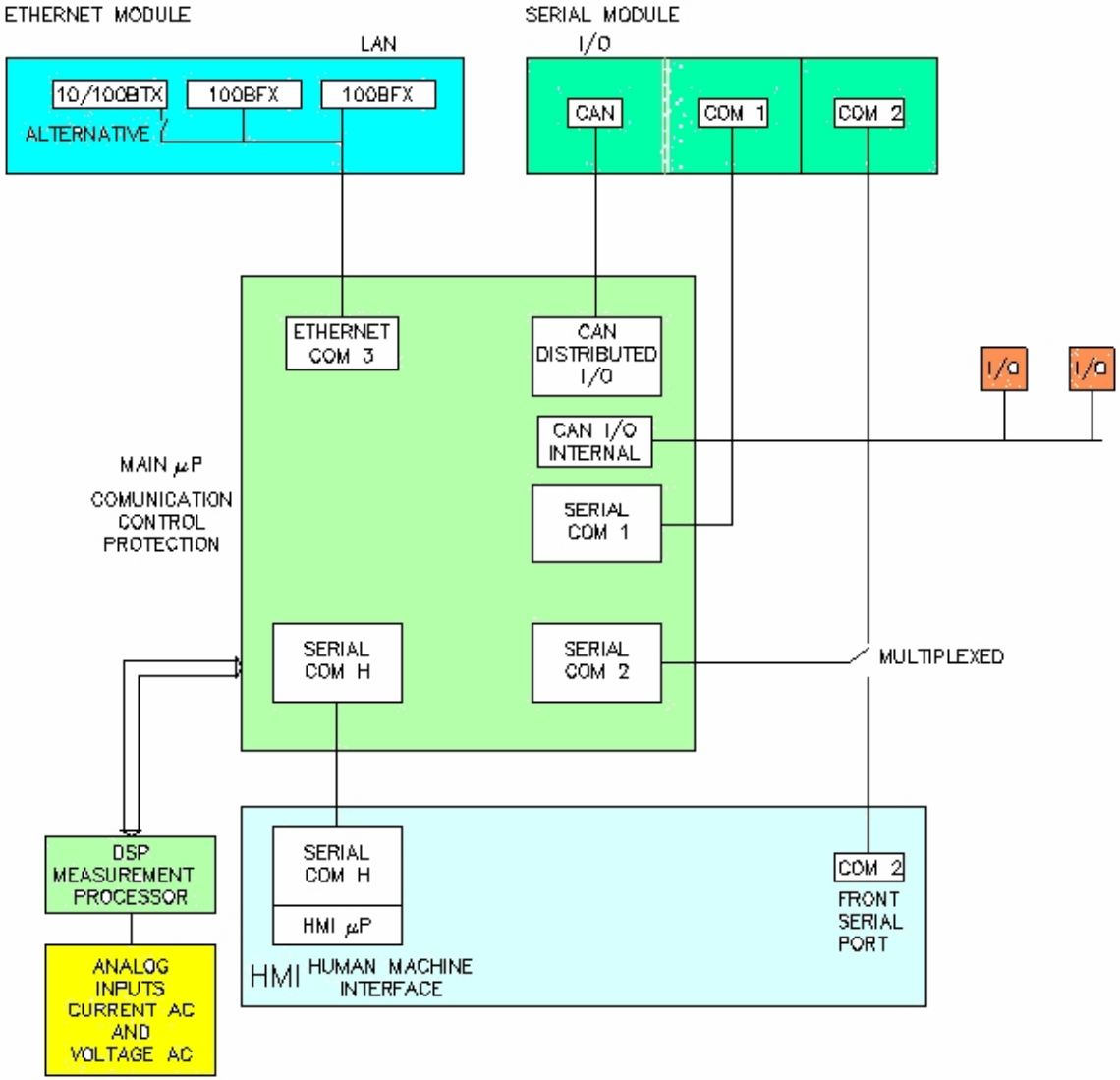
Configuration



The F650 is easy to configure:

- The F650 visual environment (based on IEC 61131-3 standard PLC language) permits easy configurable logic
- Simply make connections on the screen and load them into the flash memory
- Configurable HMI interface

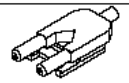
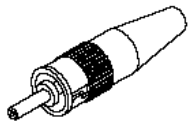
Communications



Block Diagram:

- Internal serial buses to optimize security and immunity to EMC.
- High speed buses to avoid bottlenecks.
- 100 Mbps Ethernet fibre optic for maximum performance.
- CAN bus for distributed IO up to 1 km.

Communications

TYPE OF COMMUNICATION	CONNECTOR	
RS485	Plug-in, 3 poles.	
IRIG B	Plug-in, 2 poles.	
Plastic fiber optic	Versatile Link	
Ethernet 10/100 UTP (10/100BaseTX)	RJ45, Class 5.	
Glass fiber optic (100BaseFX)	ST	
Ethernet 100 FX (100BaseFX)	ST	
CAN Distributed I/O	ST	

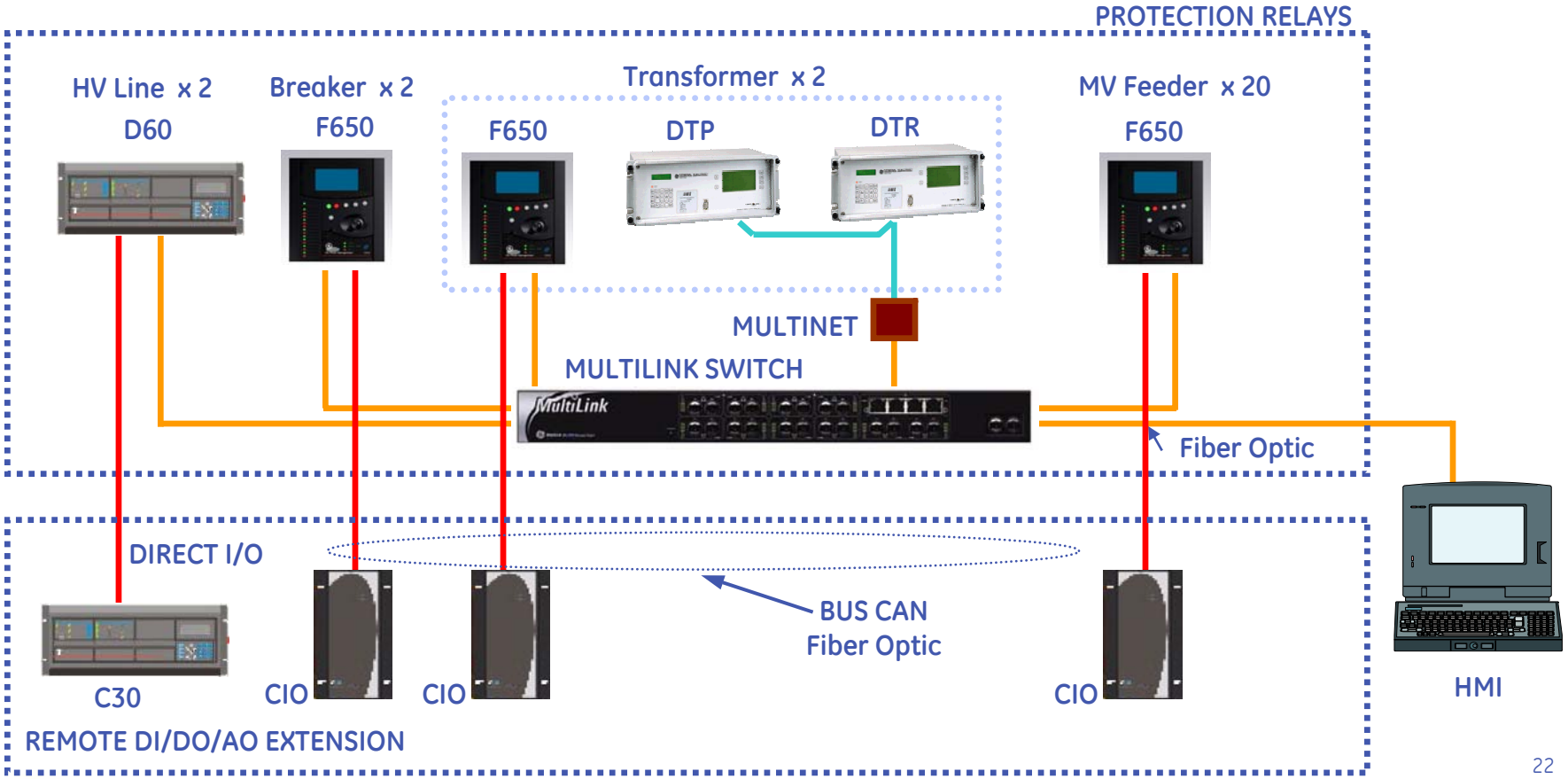
Physical layer:

- RS485 asynchronous port up to 115200 bauds.
- Fibre optics asynchronous port up to 115200 bauds.
- Synchronous Ethernet port up to 100 Mbits/s.
- CAN port for distributed I/O.
- Option for redundant ports (both synchronous and asynchronous).

Communications

Protocols:

- Modbus RTU and Modbus TCP/IP
- DNP 3.0 Level 2 over TCP/IP, UDP/IP and serial
- IEC 60870-5-104



Reliability

Hardware:

- Redundant power supply
- Distributed supply concept
- “Cool” temperature design through low power consumption
- Replacing hardware by firmware reduces parts count

Firmware:

- Double Flash memory concept avoids program crashes during field upgrades. This allows secure remote reprogramming
- CMM model approach for quality
- OOP in high level C language

F650 Ordering Code

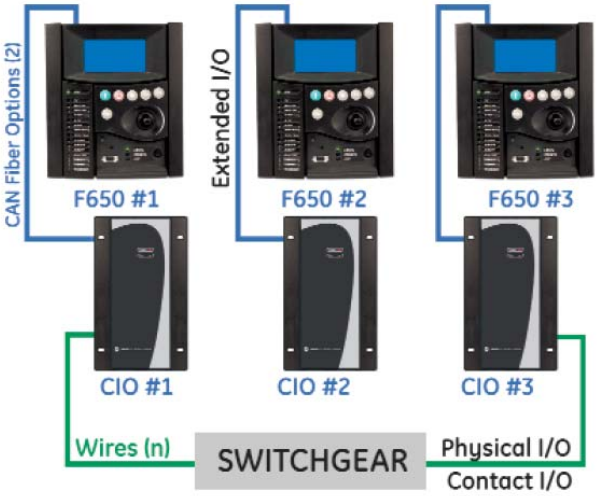
Ordering

F650	*	*	*	F	*	G	*	*	*	Description
F650										**Digital bay management device**
	B									Basic display (4 x 20 characters)
	M									Graphical mimic display (240 x 128 pixels)
										Rear Serial Communications Board 1
		F								None
		A								Redundant RS485
		P								Redundant plastic F.O.
		G								Redundant glass F.O.
		X								Redundant RS485 + remote CAN bus I/O (*)
		Y								Redundant plastic F.O. + remote CAN bus I/O (*)
		Z								Redundant glass F.O. + remote CAN bus I/O (*)
										Rear Ethernet Communications board 2
			B							10/100 BaseT
			C							10/100 BaseT + 10/100 BaseF
			D							10/100 BaseT + redundant 10/100 BaseF
										I/O board 1
				1						16 inputs + 8 outputs
				2						8 Inputs, 4 circuits for circuit supervision, 6 Outputs + 2 outputs with circuits for trip current supervision (latching)
				4						32 digital inputs
				5						16 digital inputs + 8 analog
										I/O board 2
						0				None
						1				16 Inputs + 8 Outputs
						4				32 digital inputs
						5				16 digital inputs + 8 analog
										Auxiliary Voltage
							LO			24-48 Vdc (range 19.2 - 57.6)
							HI			110-250 Vdc (range 88-300)120-230 Vac (range 102-264)
							LOR			Redundant LO
							HIR			Redundant HI
										Language
								-		English/English
								F		French/English
								P		Russian/English

CAN Bus Remote I/O Module

Remote CAN Bus Input/Output Module for the 650 Family

Released March 2005



Example of connection for F650s with CIOs linked by an Ethernet lan

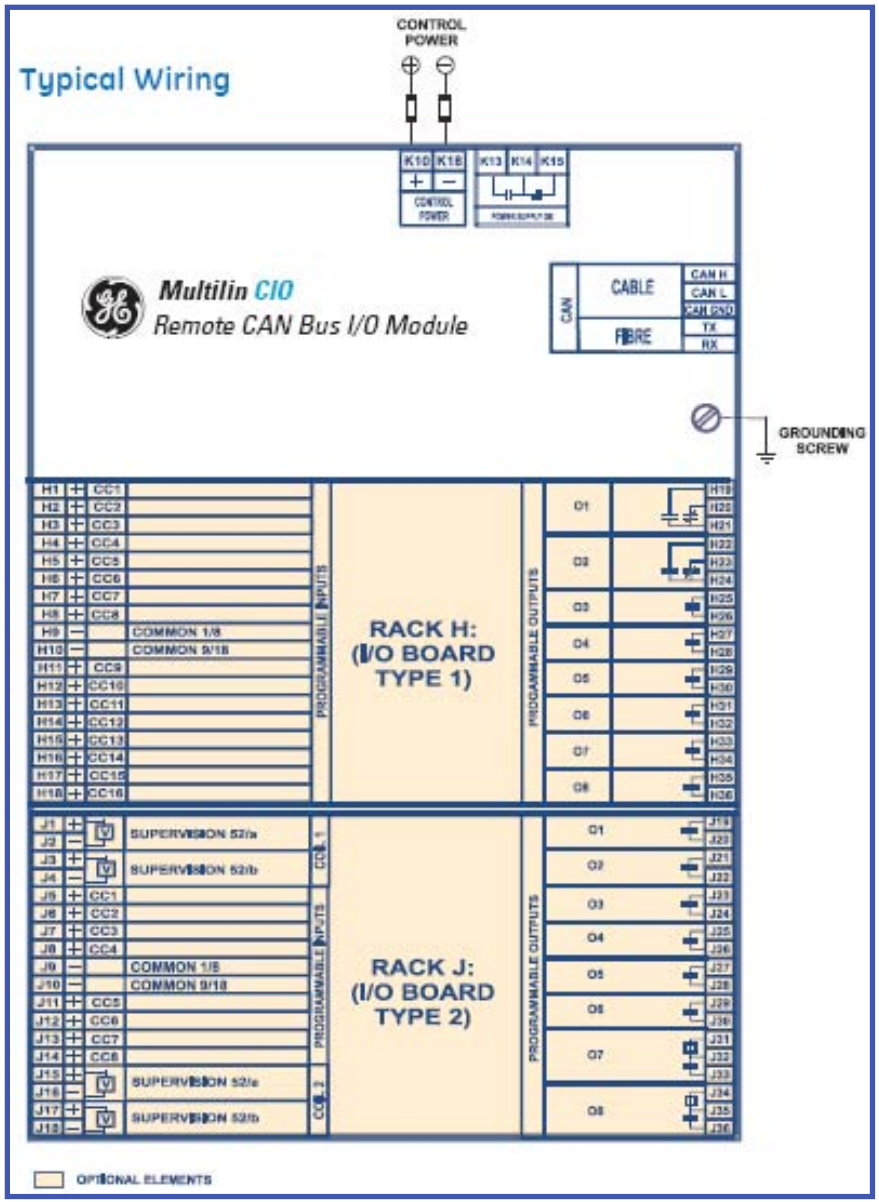
Target Applications/Industries:

- Target any applications involving a F650, W650 or G650 systems to replace RTU units
- Use CIO remote I/O modules for higher reliability, lower cost, and more functions, instead of settling for an RTU.
- Sense up to 32 digital inputs, 8 outputs, 2 with trip coil supervision, 8 dcmA transducers inputs for pressures, temperatures, fluid levels, or other process values. Report these values to SCADA or DCS systems, and use them in local automatic control equations.

Key Values:

- Additional I/O for 650 family of relays
- Remote mounting from relay location (up to 1km)
- Operates connected to one F650, W650, and G650 family of relays
- Each module includes up to 32 inputs and 16 outputs
- One 650 type relay can handle up to 1 CIO (future releases will allow increased number of CIO units per relays)
- Simplified wiring (2 fiber optic cables) for lower cost and increased reliability
- Scaleable solution (1 or 2 boards, different modules to fit the application)
- 1 ms time tagging

CIO Typical Wiring



CIO Ordering Code

Ordering

CIO H *	J *	*	
CIO			
1			16 inputs + 8 outputs
2			8 inputs + 8 outputs, 2 trip coil supervision
4			32 digital inputs
5			16 digital inputs + 8 analog
	0		No module
	1		16 digital inputs + 8 outputs
	2		8 digital inputs + 8 outputs, 2 trip coil supervision
	4		32 digital inputs
	5		16 digital inputs + 8 analog
		HI	Source: 110-250 VDC (range: 88~300)
			Source: 120-230 VAC (range: 88~264)
		LO	Source: 24-48 VDC (range: 19.2~57.6)

Accessories

EnerVista Program Setup and monitoring software included.

F-650
Feeder Manager and Bay Controller

- Integrate protection and control
  - > Remote control
  - > Local control
- Monitor trip/close circuits, rack in/out switches
- Applicable for radial and looped feeders

F-650 Bay Controller

Standardization & Minimization

- **Control Points Eliminate the Need For:**
  - > Trip/Close Switches & Indicators
  - > Miscellaneous Function Switches
    - – Metering Display
    - – Maintenance Lockout
    - – Transfer, Autotransfer, Block Transfer
- **PLC Logic Eliminates the Need For:**
  - > Auxiliary Relays
  - > Timers
- **Dynamic Mimic Eliminates the Need For:**
  - > On-Panel Hard Mimic and Indicators

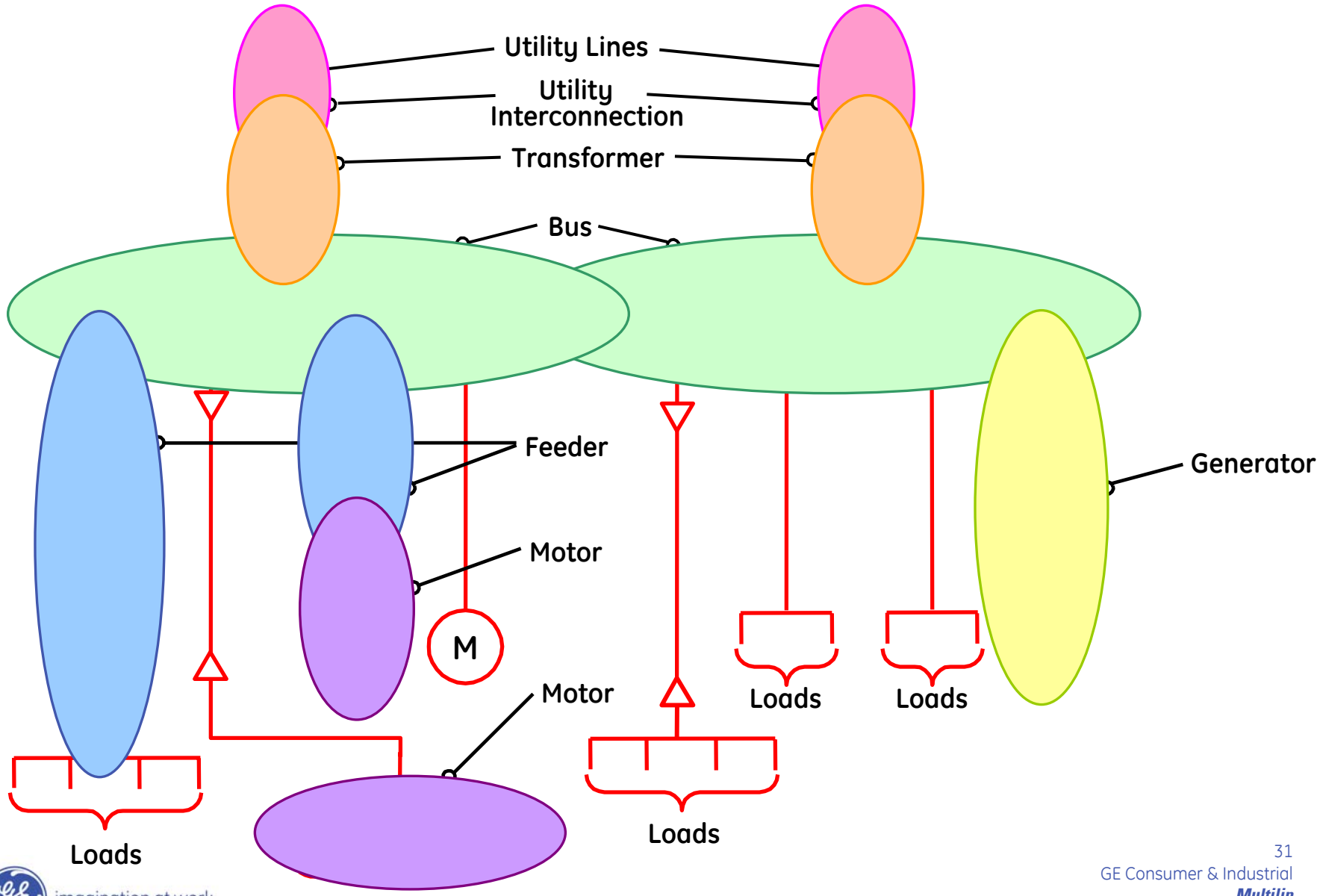
Industrial/Switchgear Protection & Control Solutions

Mains and Feeders

"Smart Switchgear"

imagination at work

Feeder and Backup Protection



imagination at work

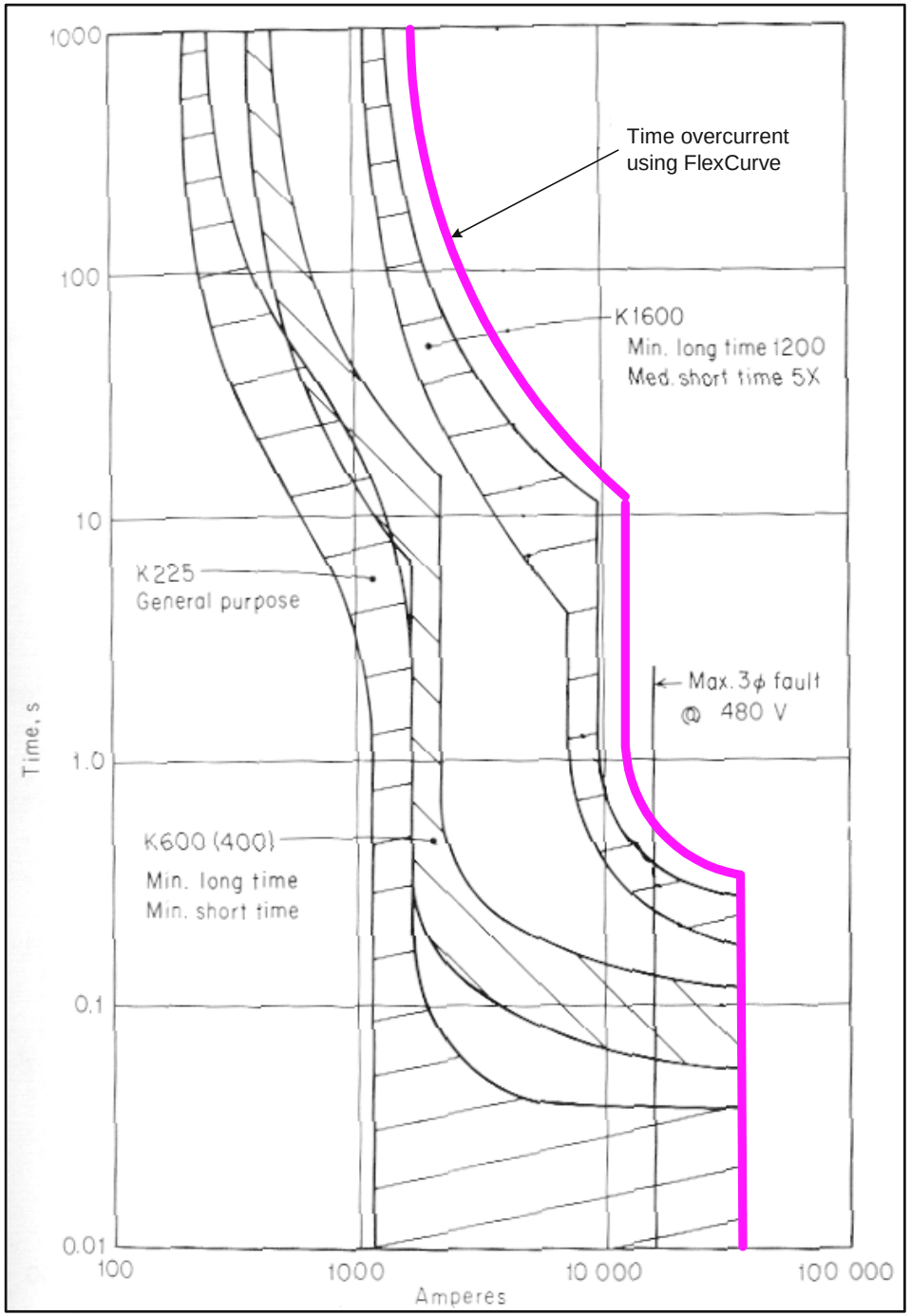
Feeder Management

Desirable Performance

- Short Circuit Protection
- Metering (Energy, Demand, etc.)
- Logging (Events, Trips, Oscillography)
- Transformer, Switchgear and Instrument Transformer Monitoring
- Integrated Control Switches
- Communications
- Advanced Applications

Feeder Management

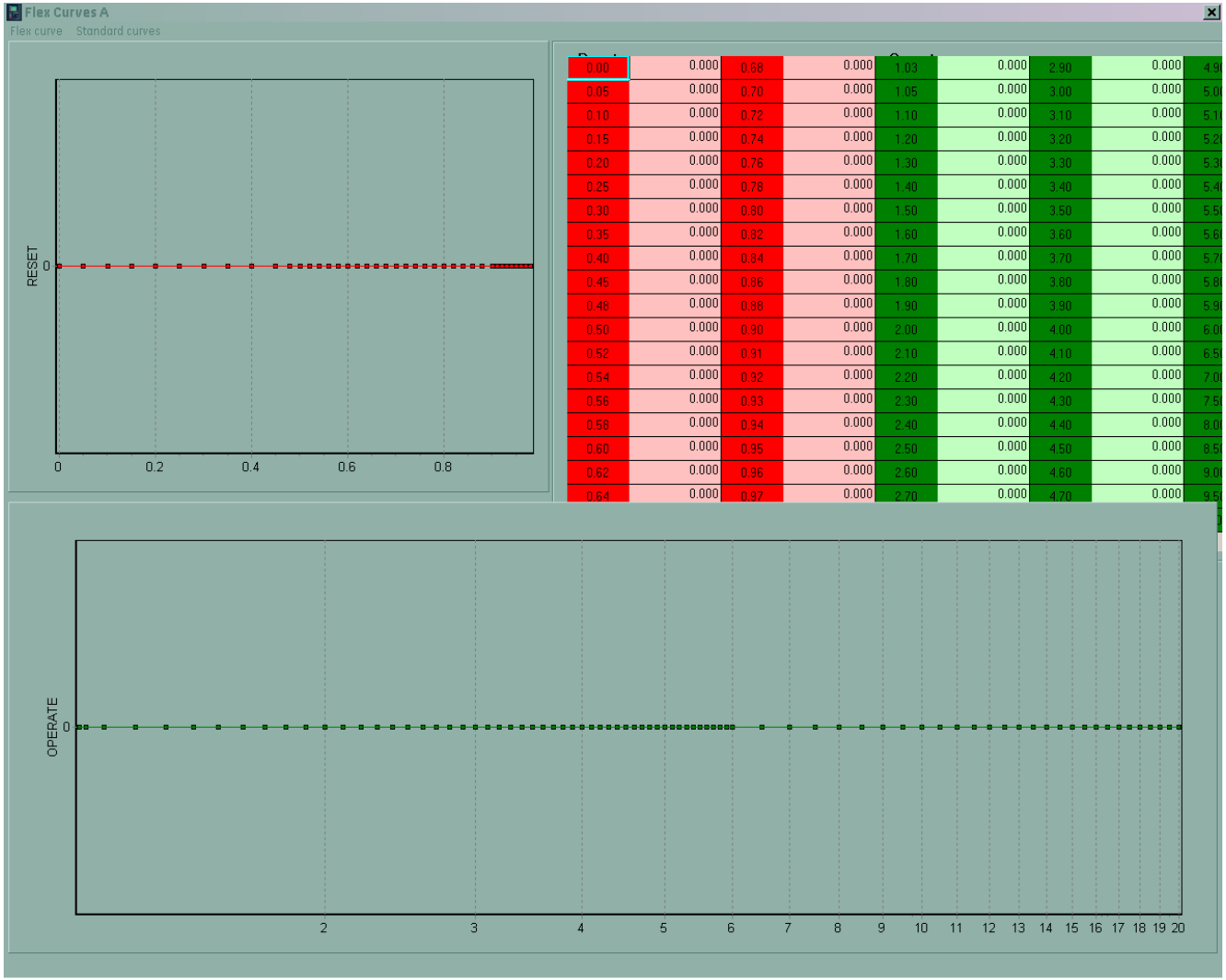
- Applications
  - > Radial or Looped Feeders
  - > Transformer Back Up
  - > Bus Protection
- *Relays* with Protection + Metering + Monitoring + Comms
  - > Programmable I/O for Tripping/Blocking
  - > Simple 3/4 Current Input (w, w/o 79)
- *Bay Controller* with Protection, Metering, Monitoring, Comms, Control Points, PLC Logic, with full dynamic mimic)



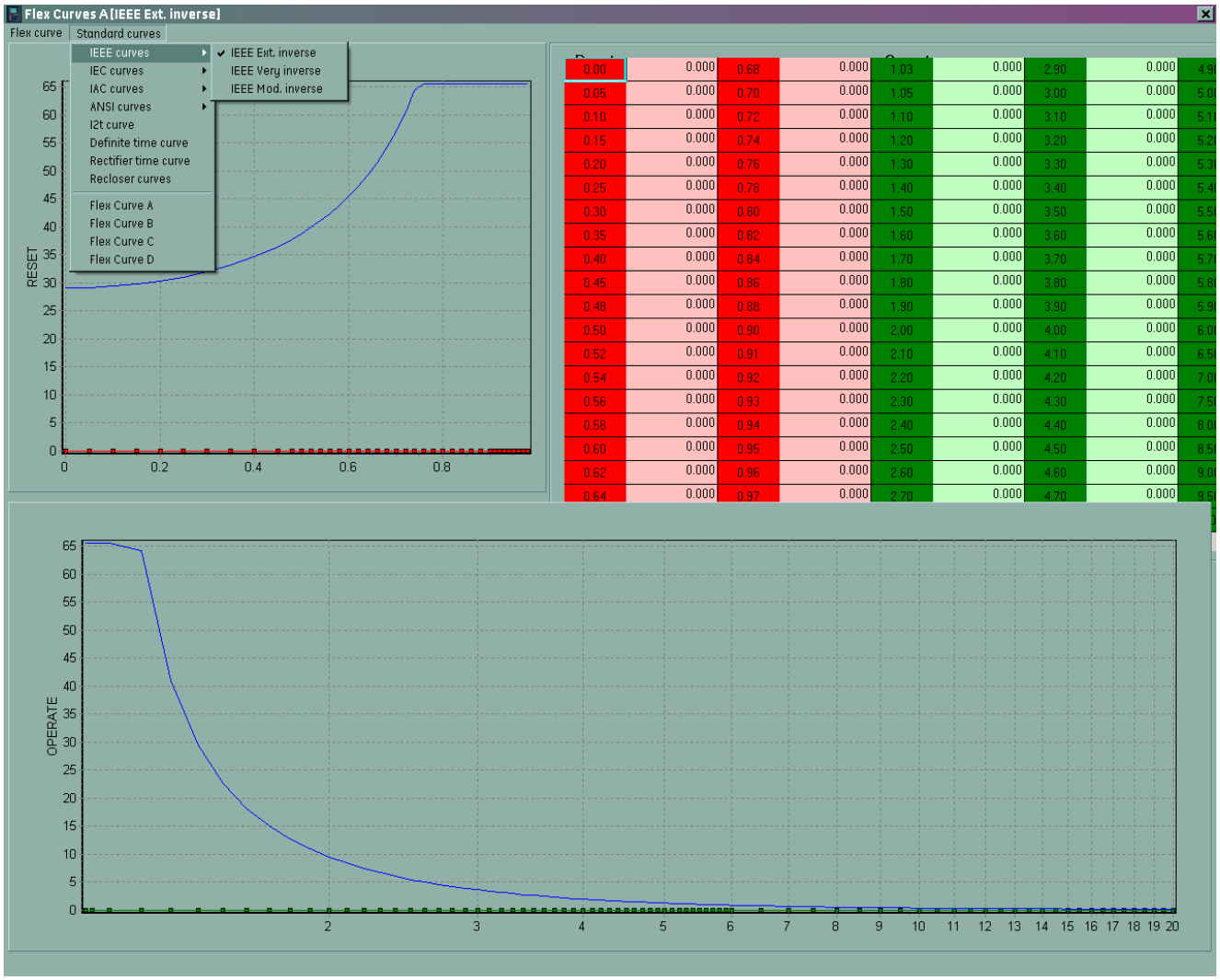
FlexCurve

Useful for coordination of relays with downstream static trip devices, fuses, molded case breakers, transformer damage curves, etc.

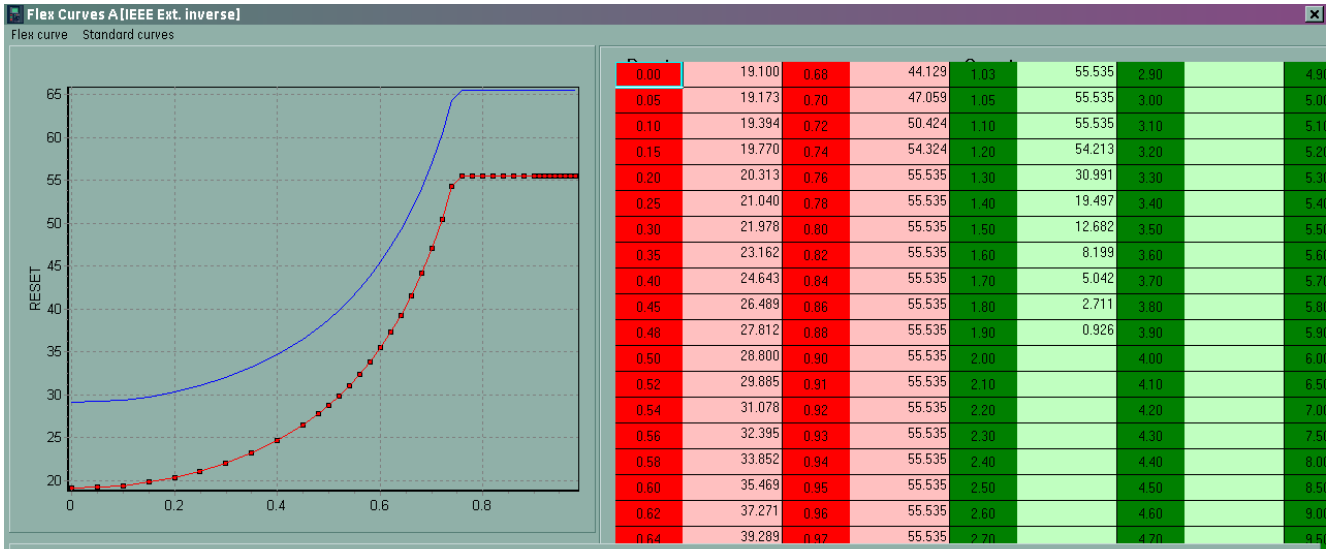
FlexCurve – Blank Working Sheet



FlexCurve – Select Standard Reference Curve

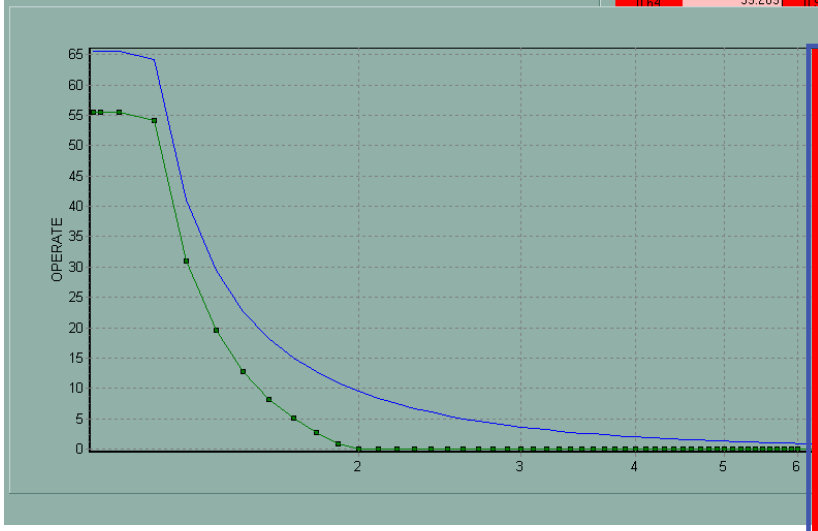


FlexCurve – Use MS Excel to Manipulate Data



0.00	19.100	0.68	44.129	1.03	55.535	2.90		4.9
0.05	19.173	0.70	47.059	1.05	55.535	3.00		5.0
0.10	19.394	0.72	50.424	1.10	55.535	3.10		5.1
0.15	19.770	0.74	54.324	1.20	54.213	3.20		5.2
0.20	20.313	0.76	55.535	1.30	30.991	3.30		5.3
0.25	21.040	0.78	55.535	1.40	19.497	3.40		5.4
0.30	21.978	0.80	55.535	1.50	12.682	3.50		5.5
0.35	23.162	0.82	55.535	1.60	8.199	3.60		5.6
0.40	24.643	0.84	55.535	1.70	5.042	3.70		5.7
0.45	26.489	0.86	55.535	1.80	2.711	3.80		5.8
0.48	27.812	0.88	55.535	1.90	0.926	3.90		5.9
0.50	28.800	0.90	55.535	2.00		4.00		6.0
0.52	29.885	0.91	55.535	2.10		4.10		6.5
0.54	31.078	0.92	55.535	2.20		4.20		7.0
0.56	32.395	0.93	55.535	2.30		4.30		7.5
0.58	33.852	0.94	55.535	2.40		4.40		8.0
0.60	35.469	0.95	55.535	2.50		4.50		8.5
0.62	37.271	0.96	55.535	2.60		4.60		9.0
0.64	39.289	0.97	55.535	2.70		4.70		9.5

Cut & Paste data from MS Excel Spread Sheet



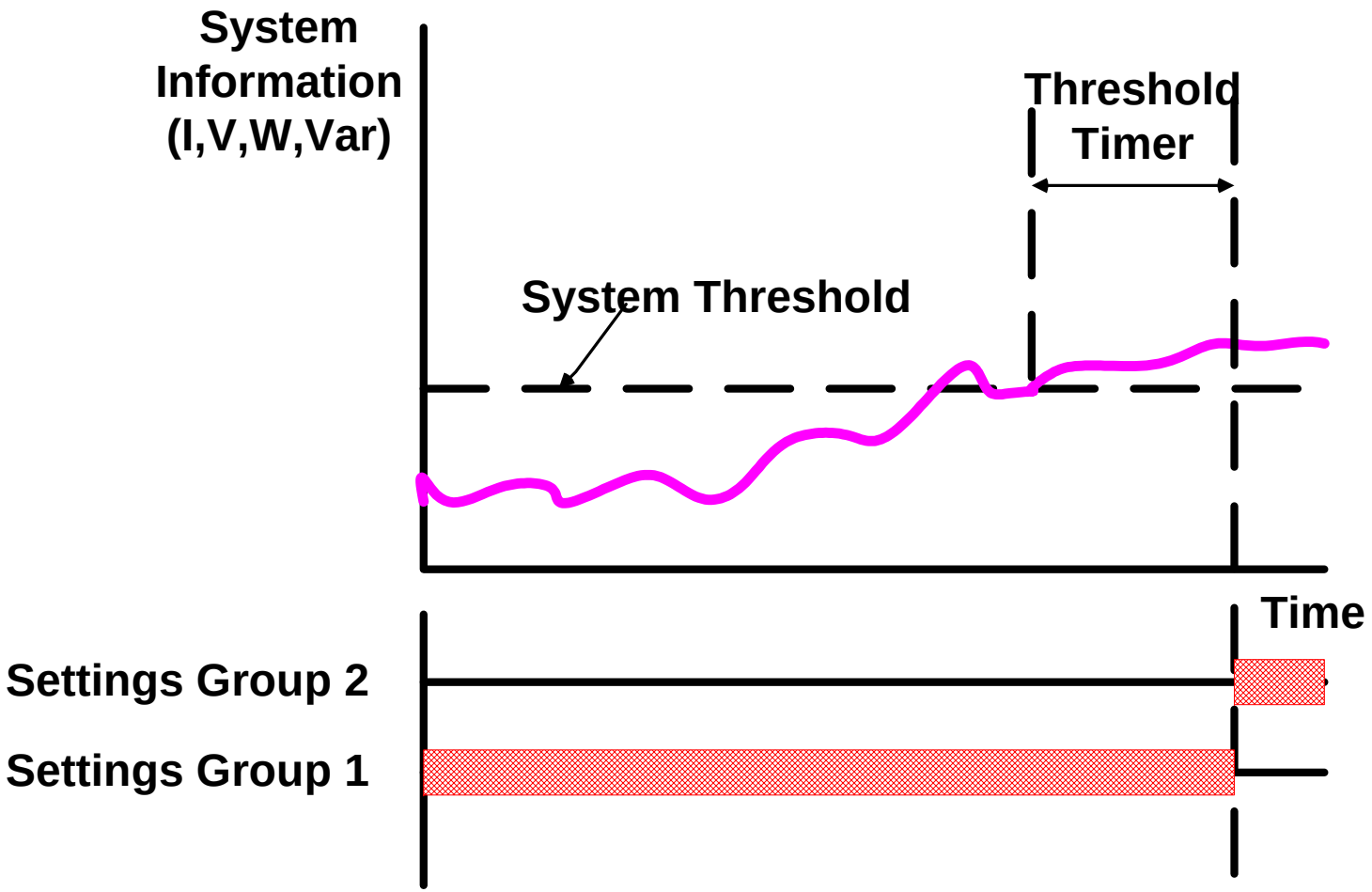
0	19.1	0.68	44.129	1.03	55.535	2.9	-6.073	4.9
0.05	19.173	0.7	47.059	1.05	55.535	3	-6.353	5
0.1	19.394	0.72	50.424	1.1	55.535	3.1	-6.603	5.1
0.15	19.77	0.74	54.324	1.2	54.213	3.2	-6.826	5.2
0.2	20.313	0.76	55.535	1.3	30.991	3.3	-7.027	5.3
0.25	21.04	0.78	55.535	1.4	19.497	3.4	-7.208	5.4
0.3	21.978	0.8	55.535	1.5	12.682	3.5	-7.372	5.5
0.35	23.162	0.82	55.535	1.6	8.199	3.6	-7.52	5.6
0.4	24.643	0.84	55.535	1.7	5.042	3.7	-7.656	5.7
0.45	26.489	0.86	55.535	1.8	2.711	3.8	-7.78	5.8
0.48	27.812	0.88	55.535	1.9	0.926	3.9	-7.894	5.9
0.5	28.8	0.9	55.535	2	-0.478	4	-7.998	6
0.52	29.885	0.91	55.535	2.1	-1.609	4.1	-8.095	6.5
0.54	31.078	0.92	55.535	2.2	-2.535	4.2	-8.184	7
0.56	32.395	0.93	55.535	2.3	-3.305	4.3	-8.266	7.5
0.58	33.852	0.94	55.535	2.4	-3.954	4.4	-8.342	8
0.6	35.469	0.95	55.535	2.5	-4.507	4.5	-8.413	8.5
0.62	37.271	0.96	55.535	2.6	-4.982	4.6	-8.479	9
0.64	39.289	0.97	55.535	2.7	-5.395	4.7	-8.541	9.5
0.66	41.559	0.98	55.535	2.8	-5.755	4.8	-8.599	10

Dynamic Settings

Use Plant Status to Modify Protection to Maximize Dependability

- Power System Measurements
- Paralleling of Transformers
- Placing of Gensets on Bus, Loss of Utility
- Creation of Loops
- Compromised CT/VT Source
- Failed Relay

Dynamic Settings



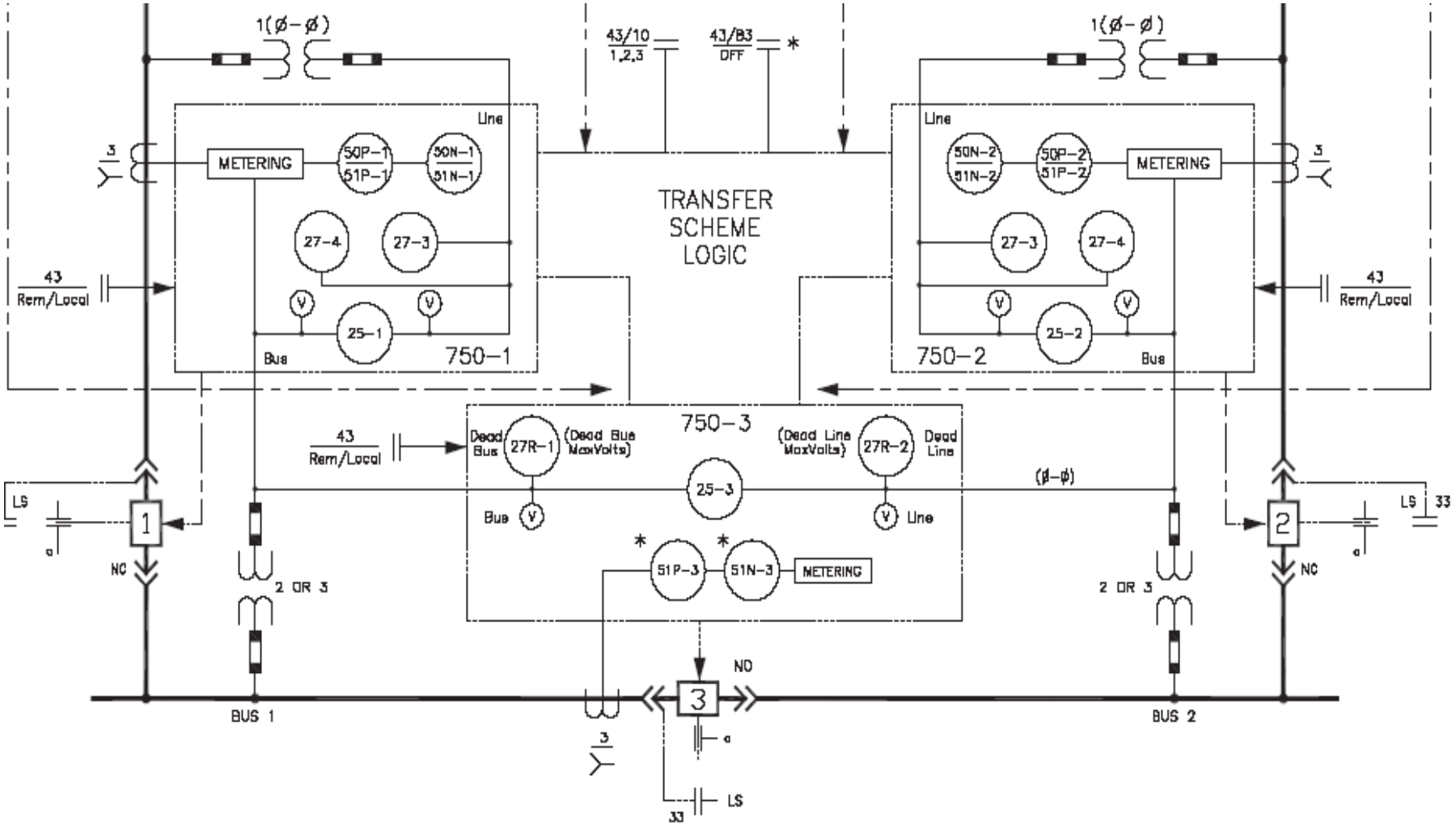
Transfer Scheme

- Uses 3 F650s to perform bus transfer in a M-T-M scheme
- Employs voltage monitoring and current monitoring
- Known as Open Transfer – Incomers are tripped before the tie breaker is closed
- Voltage monitoring assures dead source
- Current Monitoring assures no transfer made on faulted source
- Logic can be built using programmable logic; easy to implement

Source Transfers

- Used to promote power/process continuity
- Can be manual or automated
  - > Manual
    - Hot parallel transfers typically applied
  - > Automatic
    - Sequential transfers used
    - Residual and time delay used for non-rotating machinery loads, or for loads with small motors
    - Fast and In-Phase may be used (in addition to above) with large rotating machinery loads

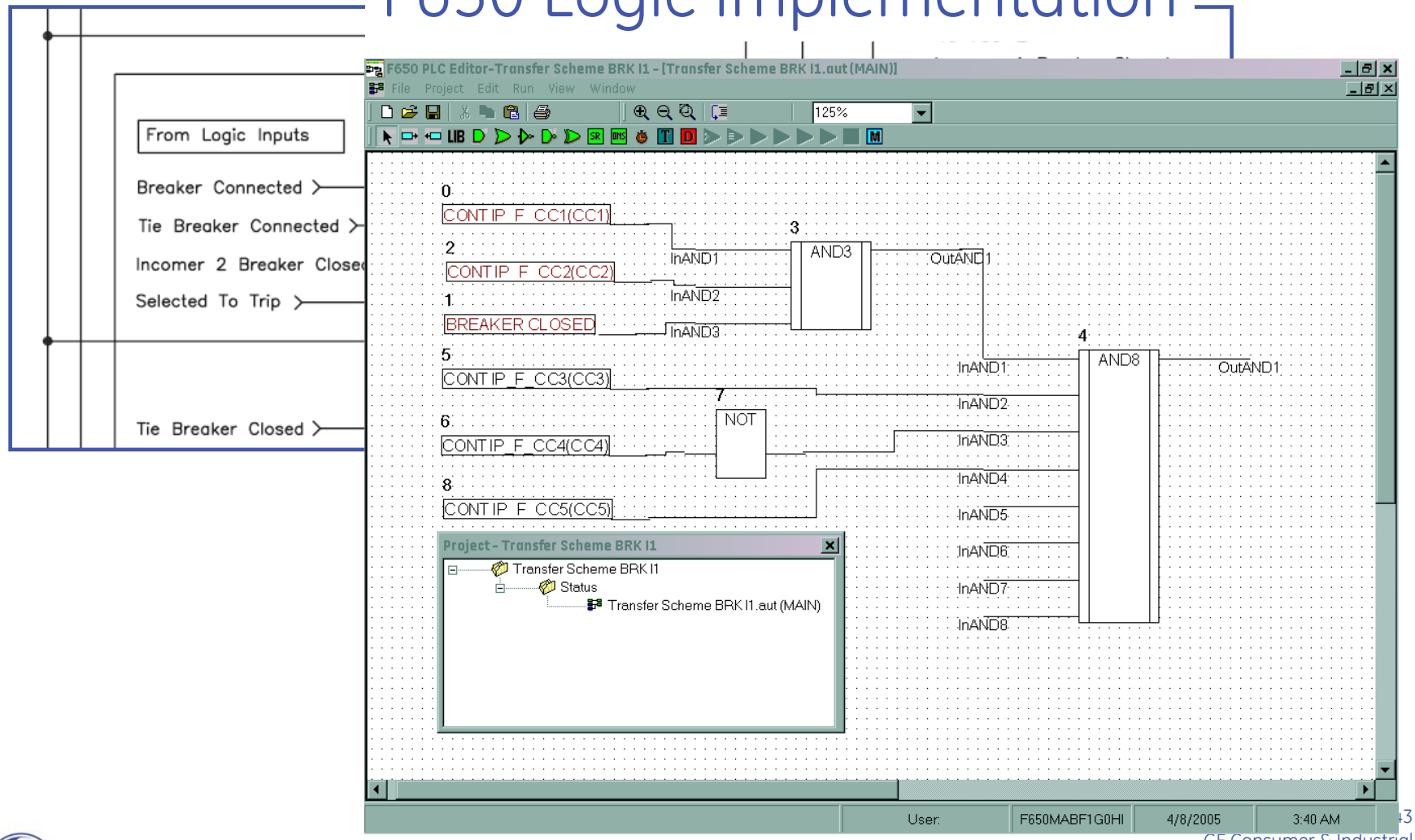
SR750 Transfer Scheme Logic



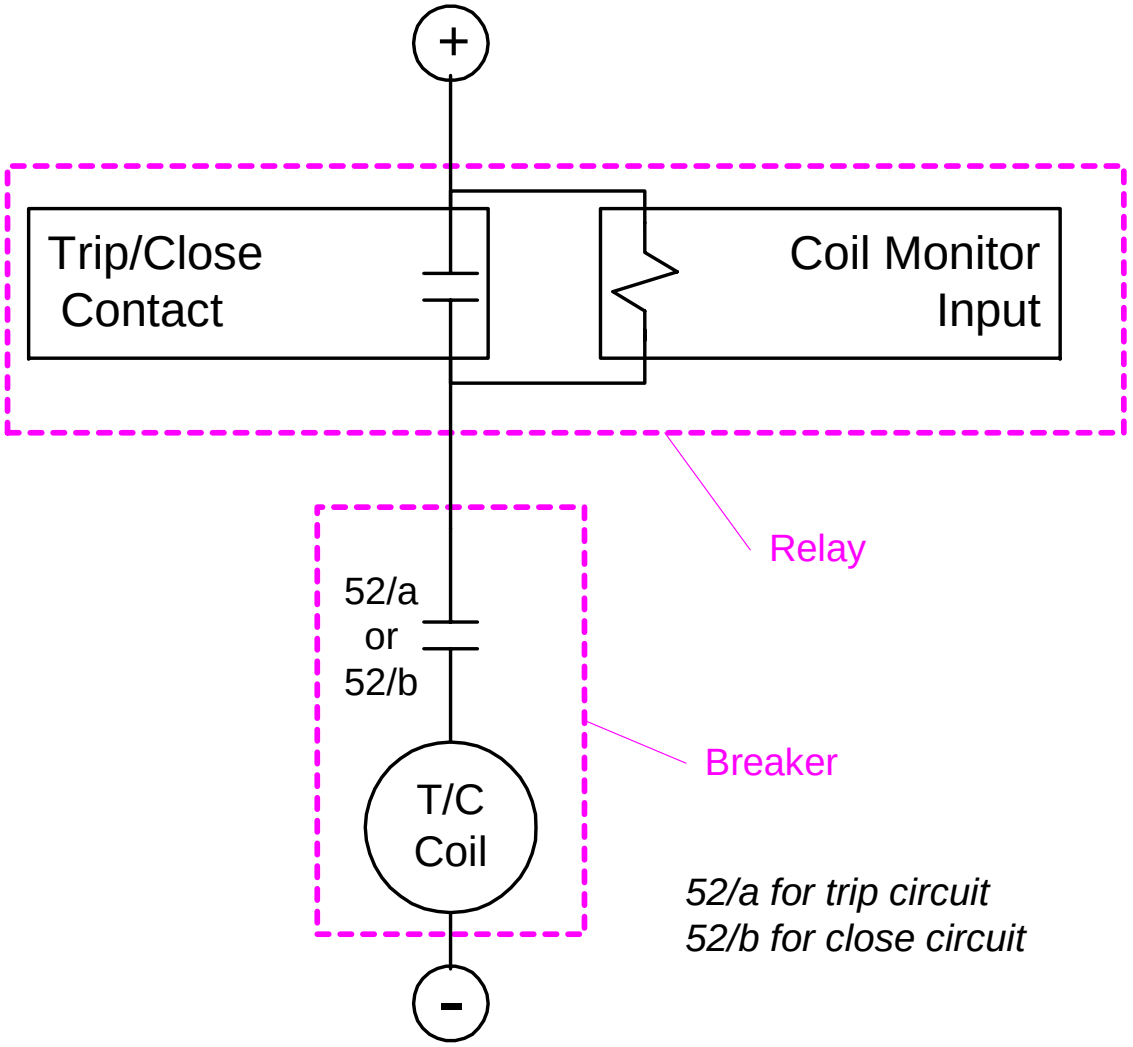
F650 Transfer Scheme Logic

SR750/760 Logic Diagram

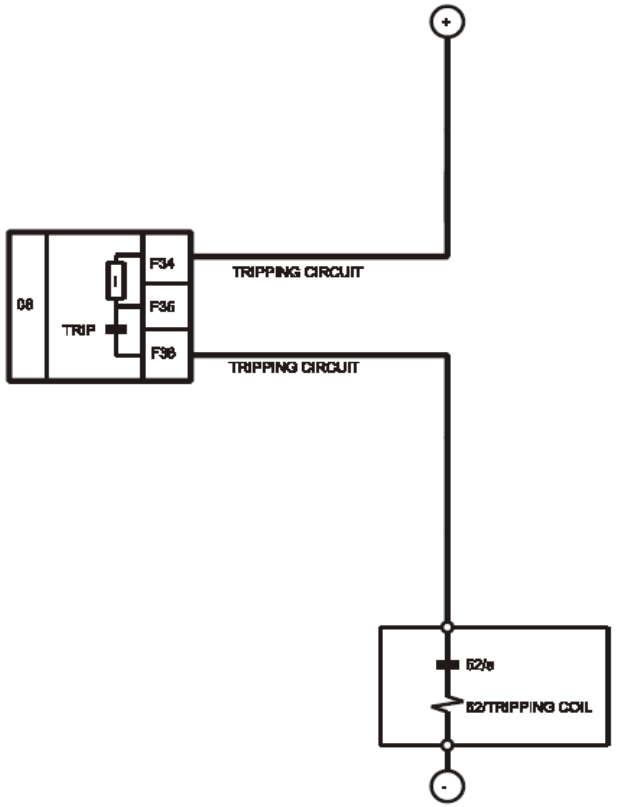
F650 Logic Implementation



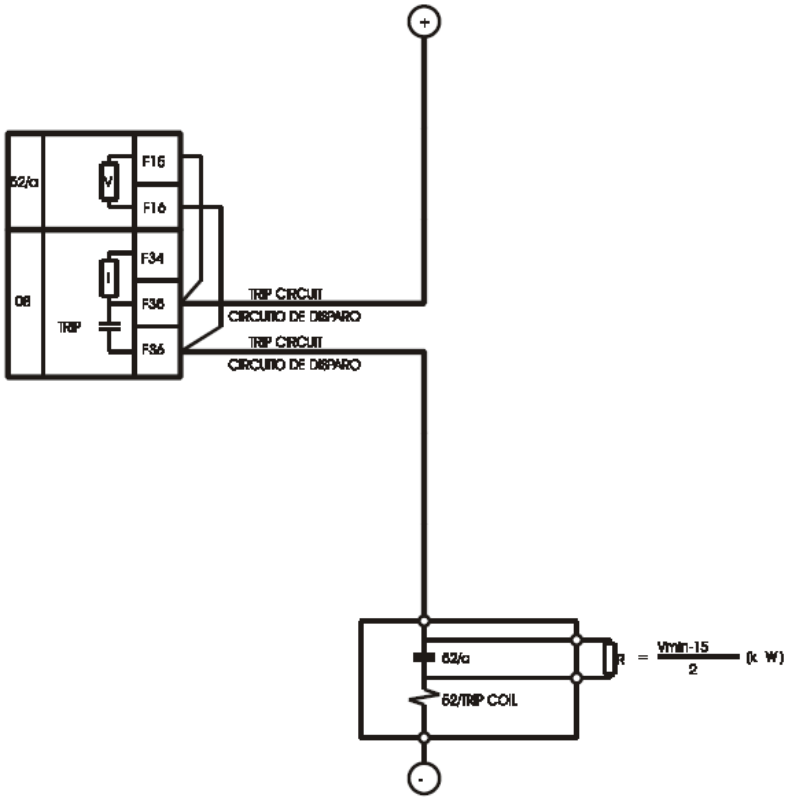
CB Coil Circuit Monitoring: T with CB Closed; C with CB Opened



CB Coil Circuit Monitoring: Both T&C Regardless of CB state



DRAWING A: CONNECTION WHERE ACCESS TO BREAKER COIL IS AVAILABLE ('BREAKER STATE BYPASS' SETPOINT SHOULD BE ENABLED FOR THIS TYPE OF CONNECTION.)*



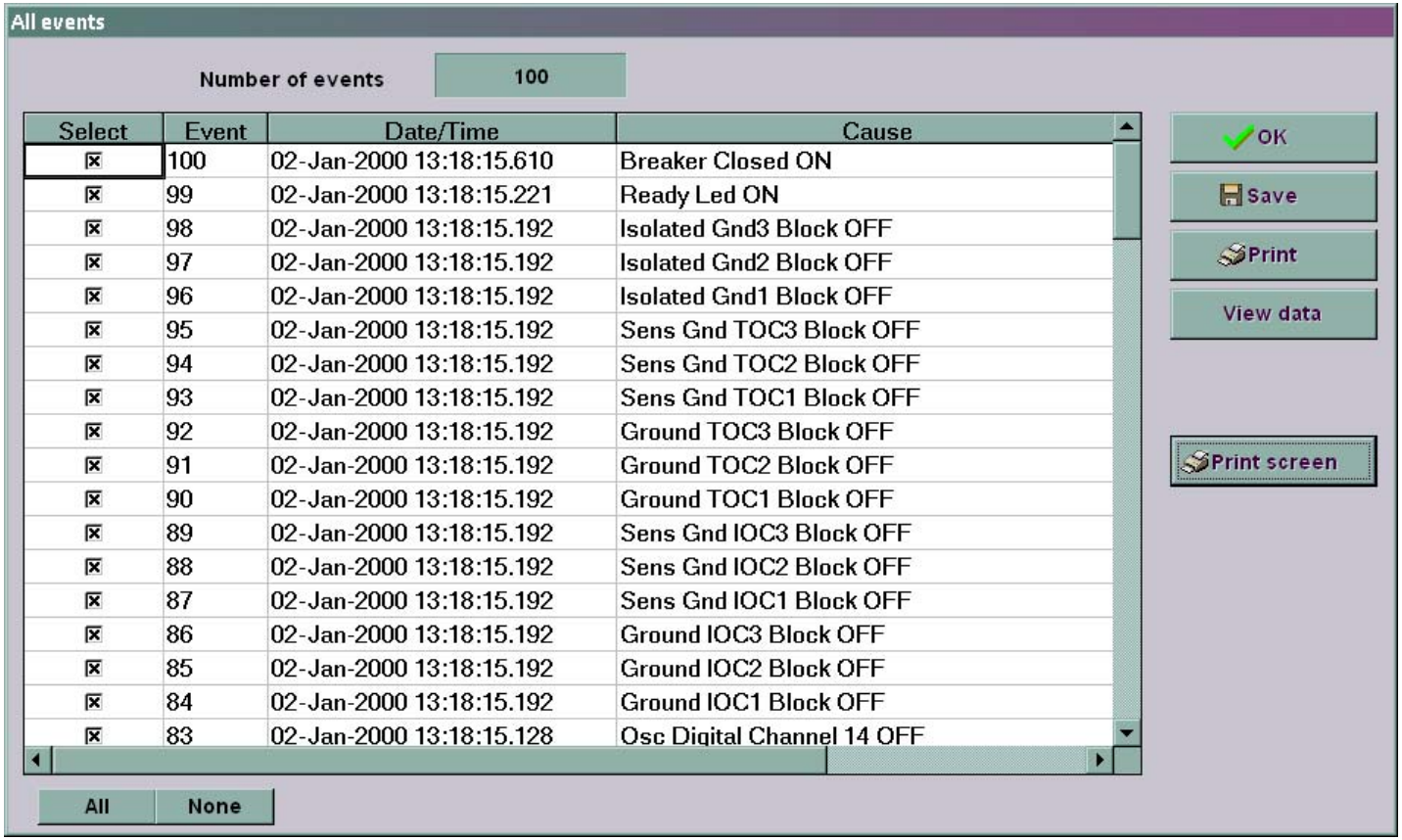
DRAWING B: ALTERNATE PATH WITH ONE BREAKER AUXILIARY CONTACT.

Event Analysis Tools

These are used to diagnose and provide root cause of relay and trip scheme operations or non-operations. They are also very useful for test & commissioning

- Event Log: Triggered by Events
  - Element trip, pick up, drop out
  - Control/Status Input change, Output Contact Closure
- Waveform Capture: Triggered by Trip or Manually

Event Log



- Select the Event you wish to examine in more detail
- Many power system parameters are recorded in each individual event log

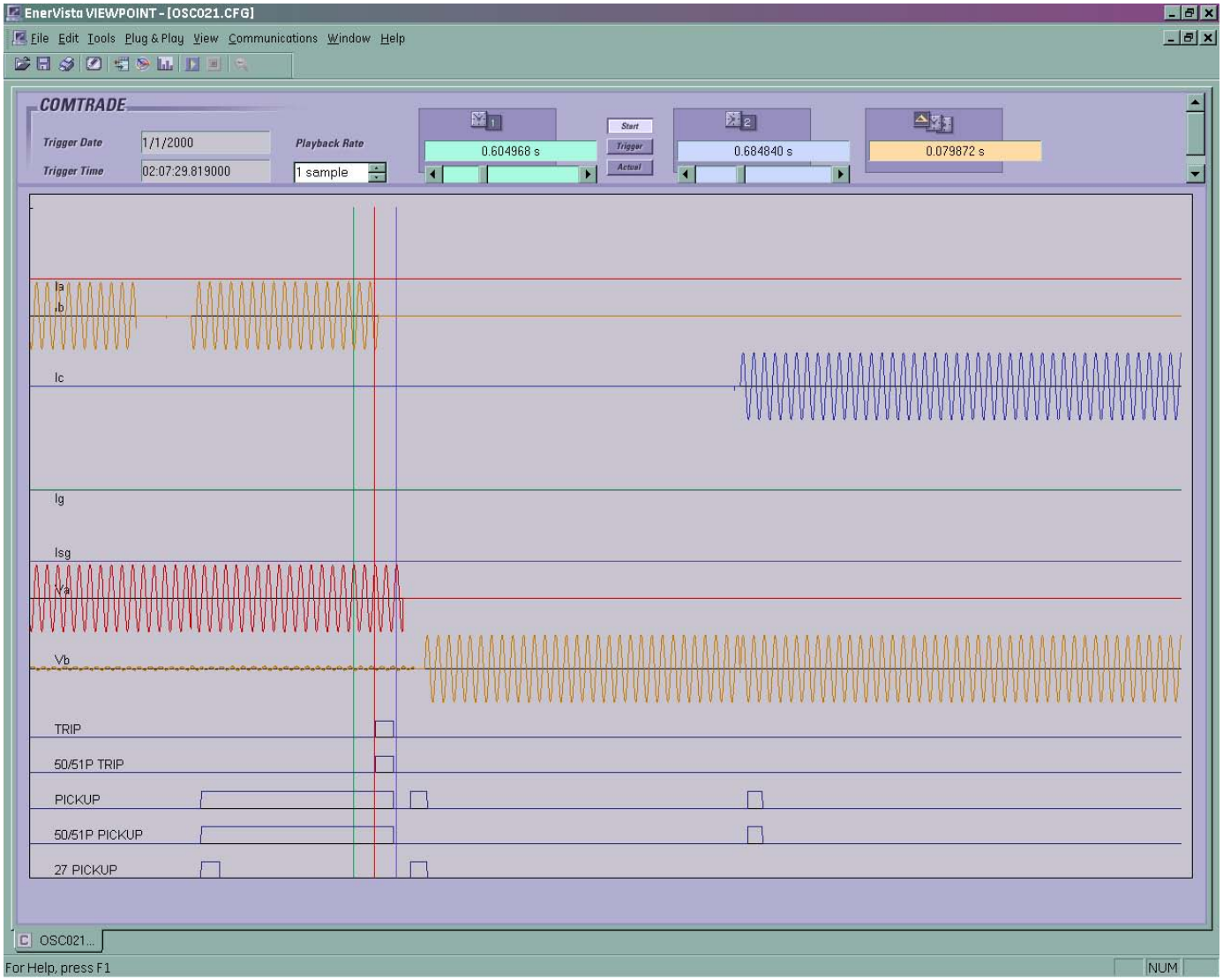
Web Server Event Log

Monitoring

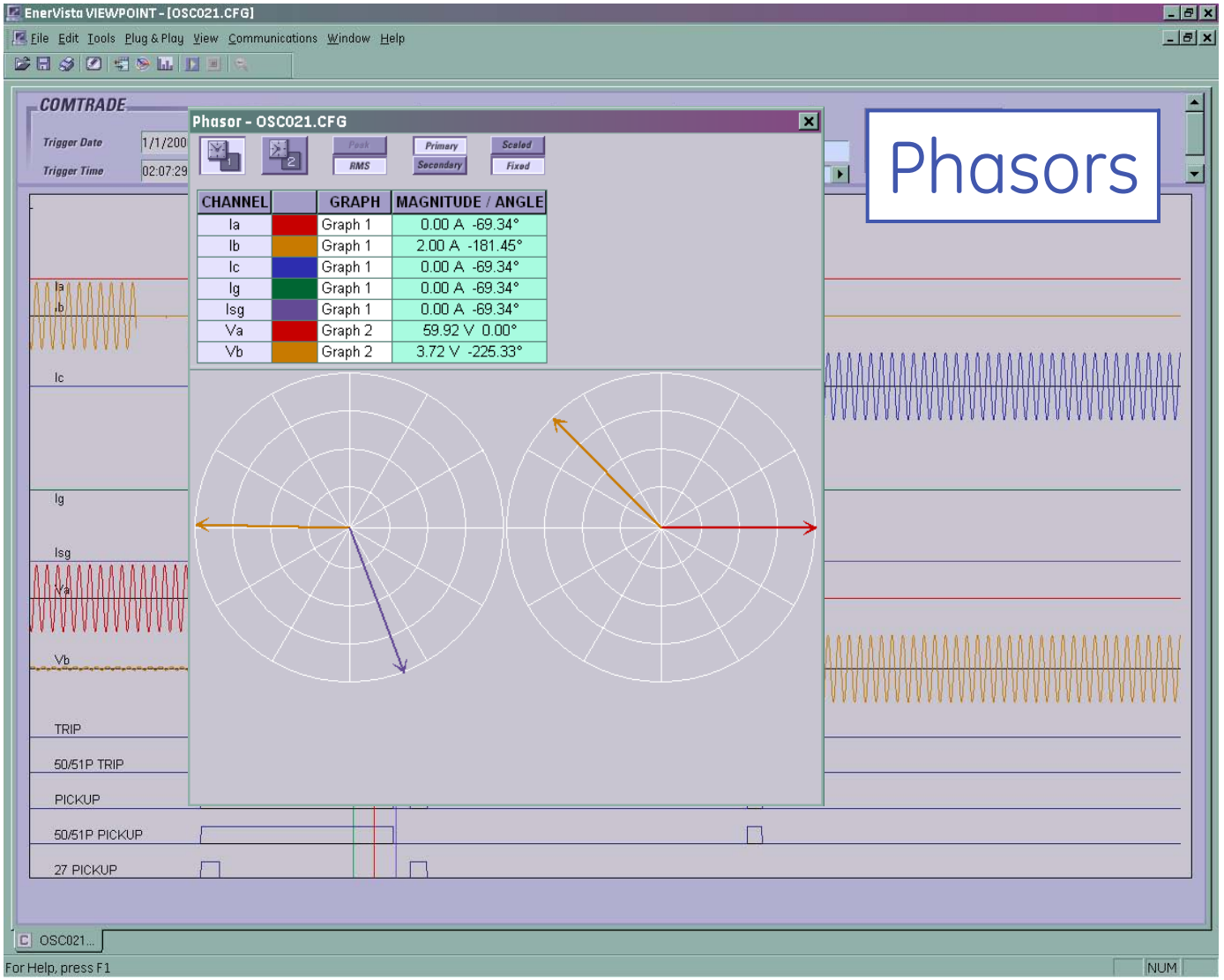
Waveform Capture (108 cycles @ 64 samples/cycle)

- Useful for forensic engineering as well as commissioning
- Easy identification of fault types, evolving faults, restrikes, arcing, etc.
- May be triggered by events or manually
- Time tagging, vector diagrams
- Automated fault playback is an advanced diagnostic tools

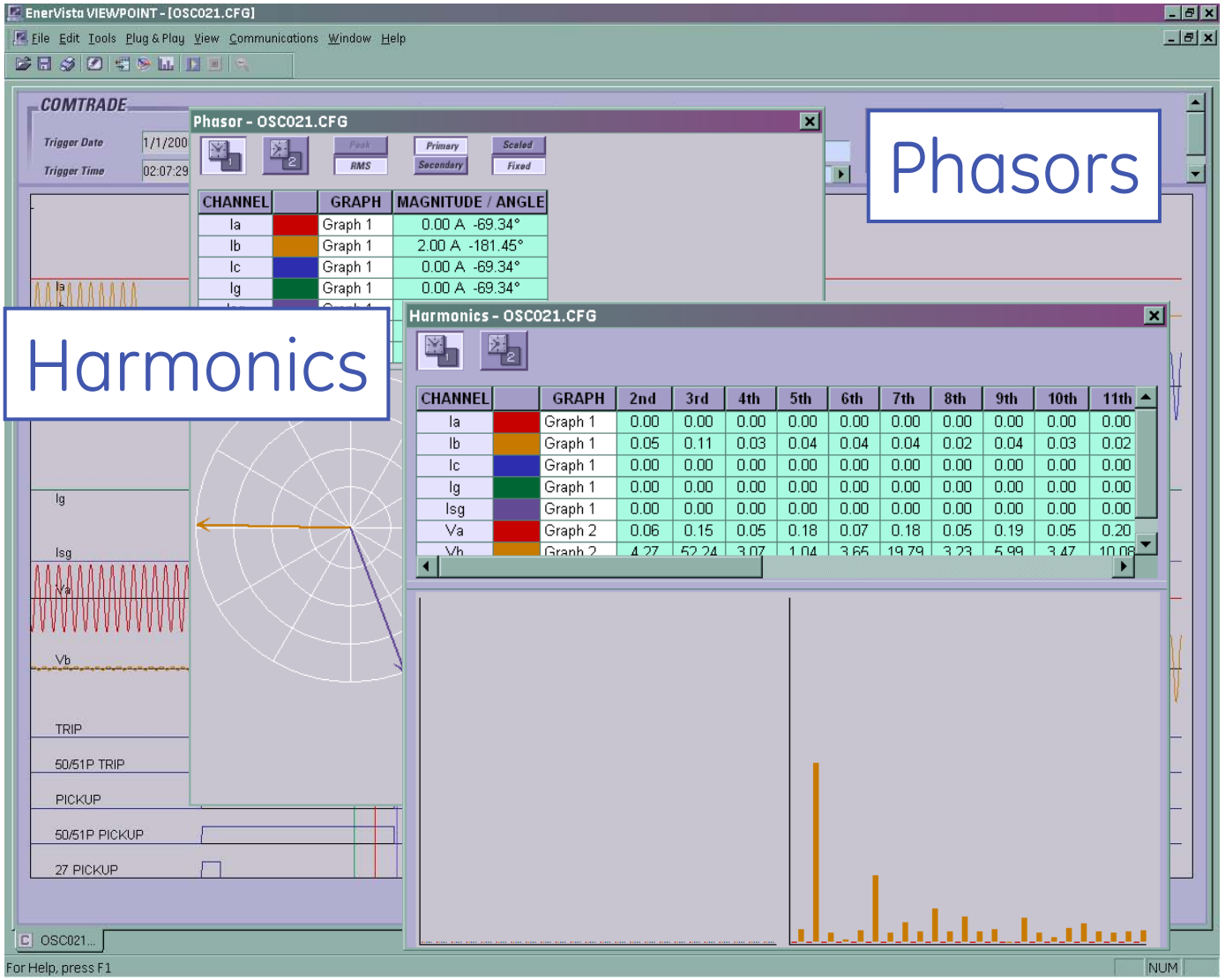
Waveform Capture – EnerVista View Point



Waveform Capture – EnerVista View Point



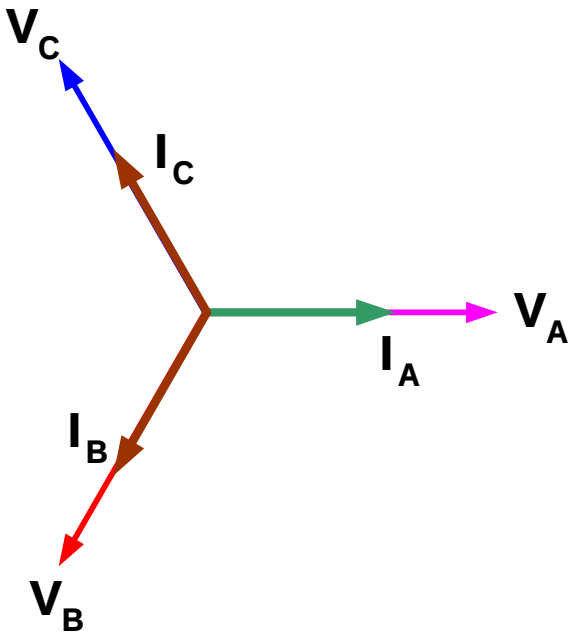
Waveform Capture – EnerVista View Point

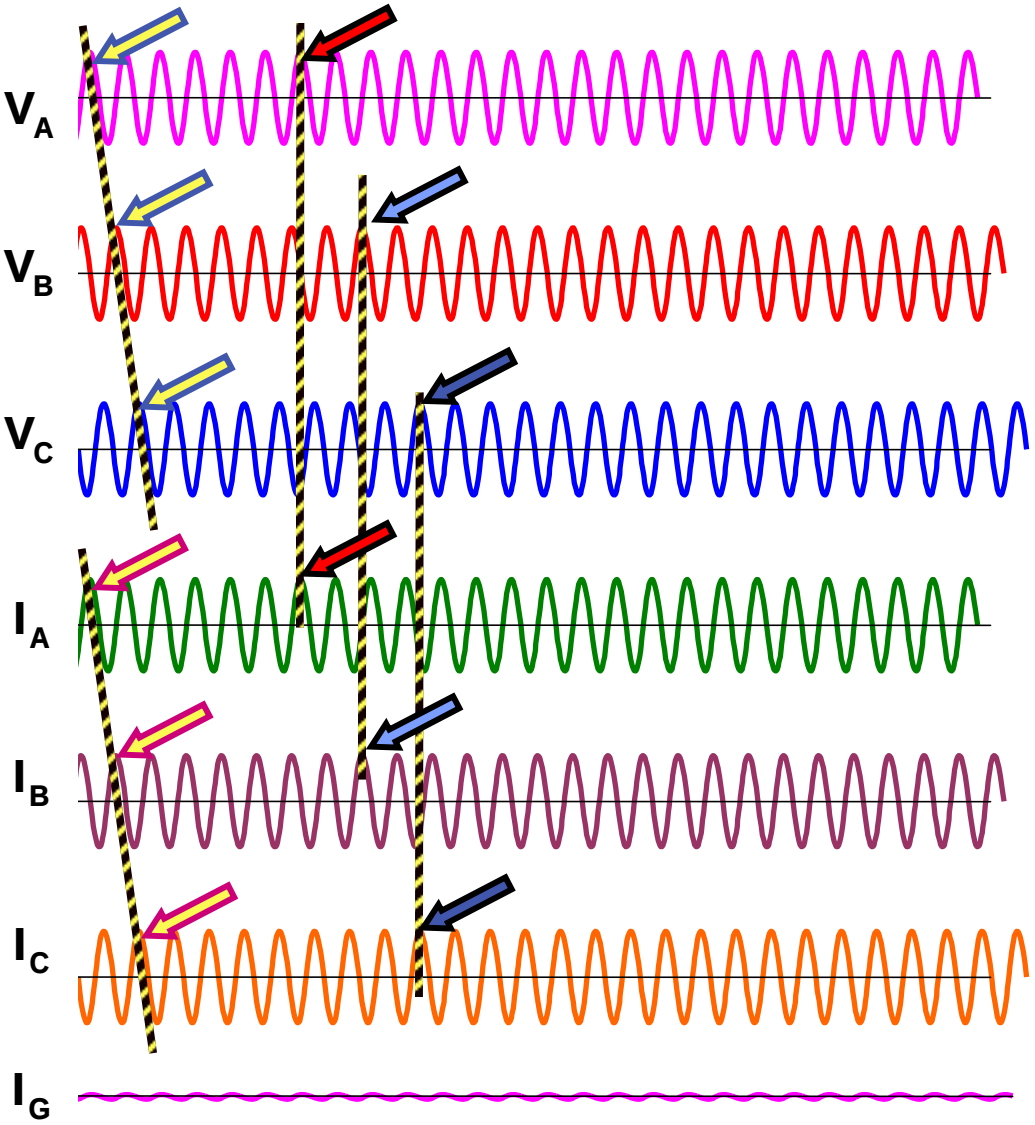


Normal Loadflow

V_A at Zero Degrees (reference)

Unity PF assumed



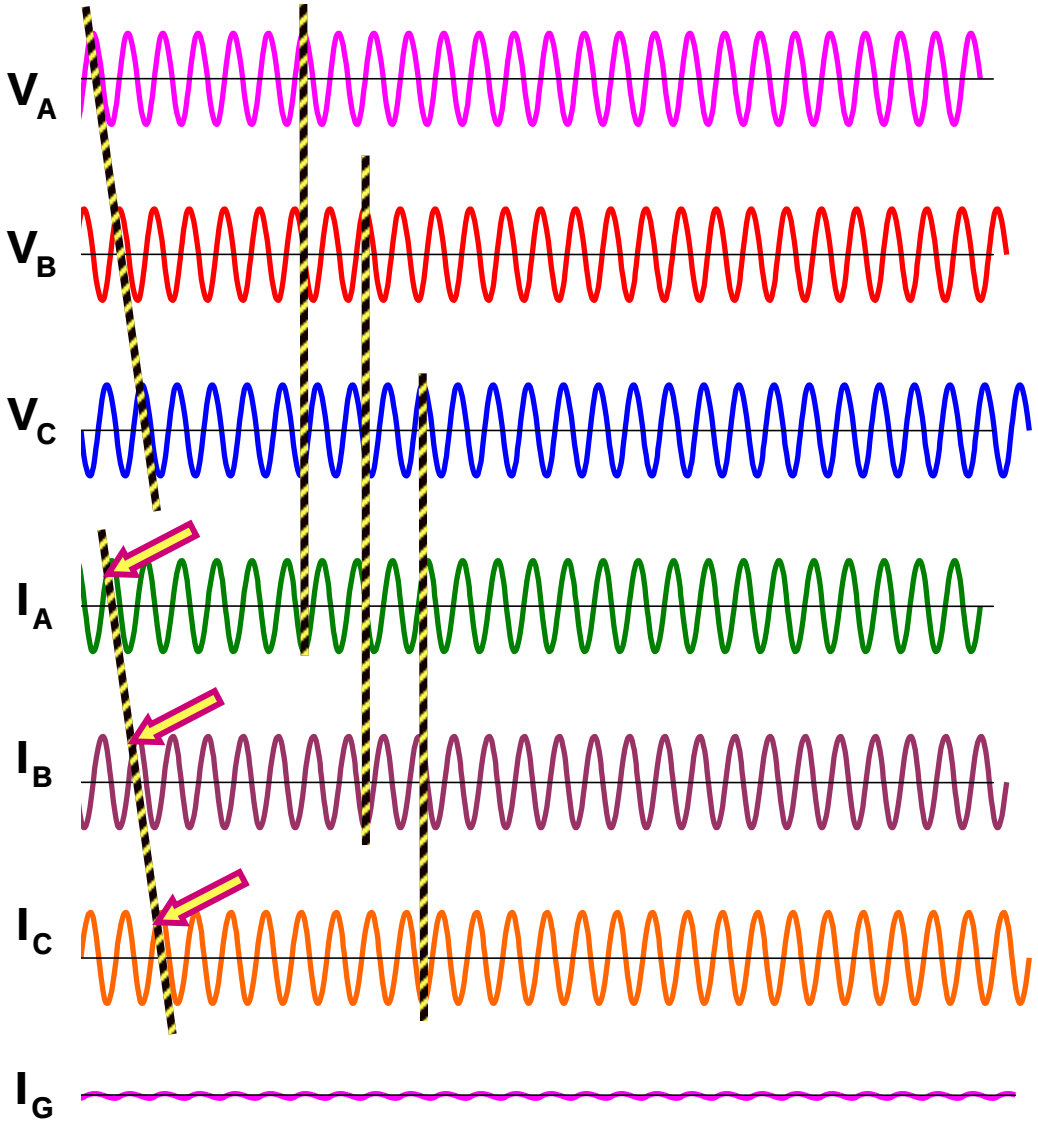


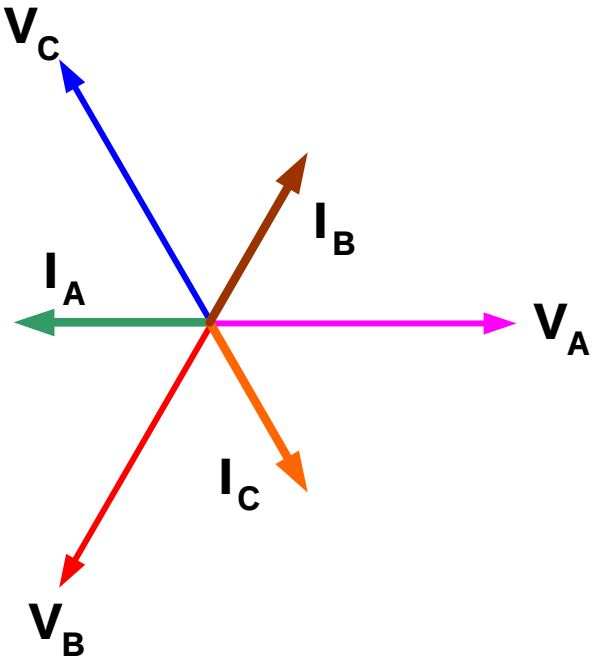
Trip

Reverse Loadflow

V_A at Zero Degrees (reference)

Unity PF assumed

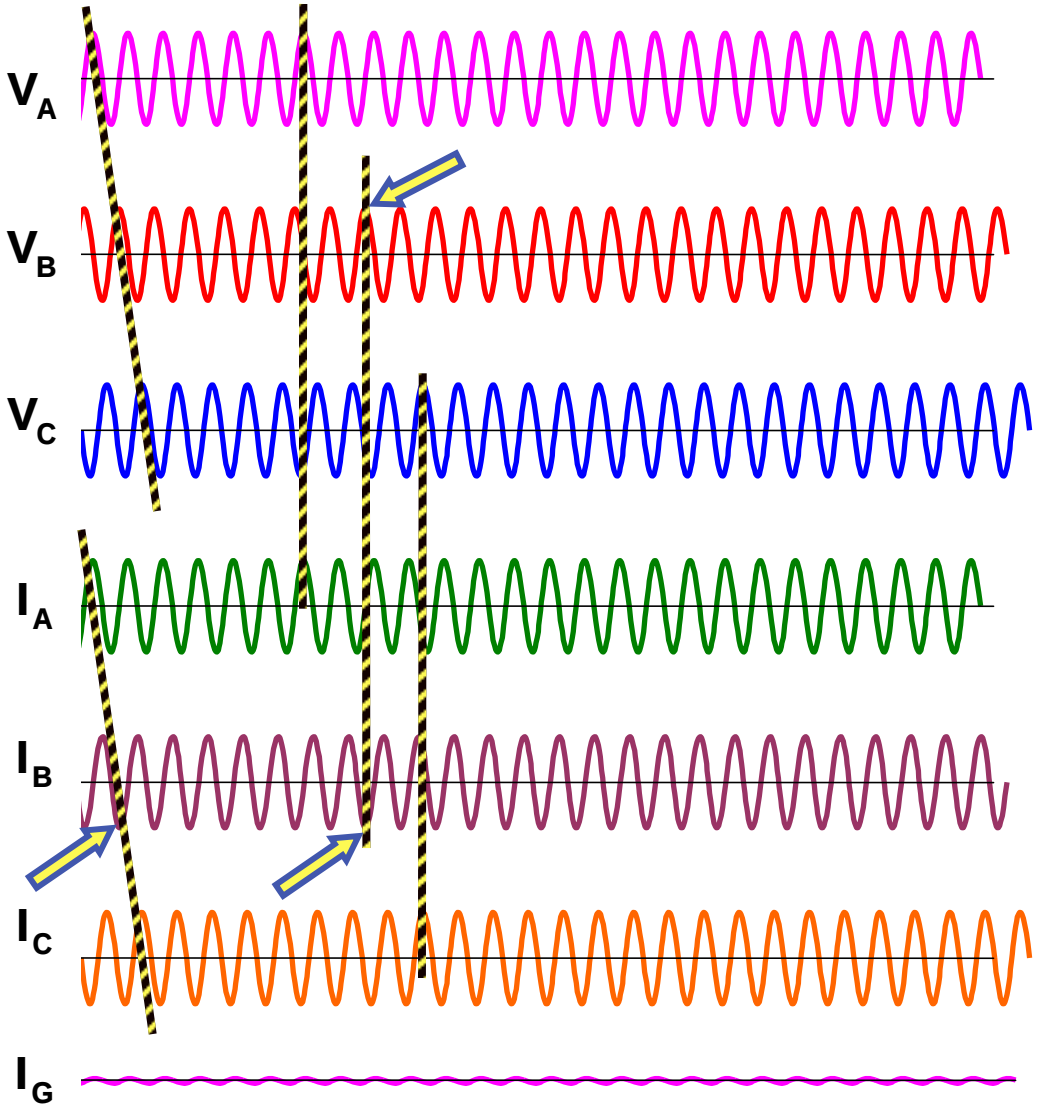


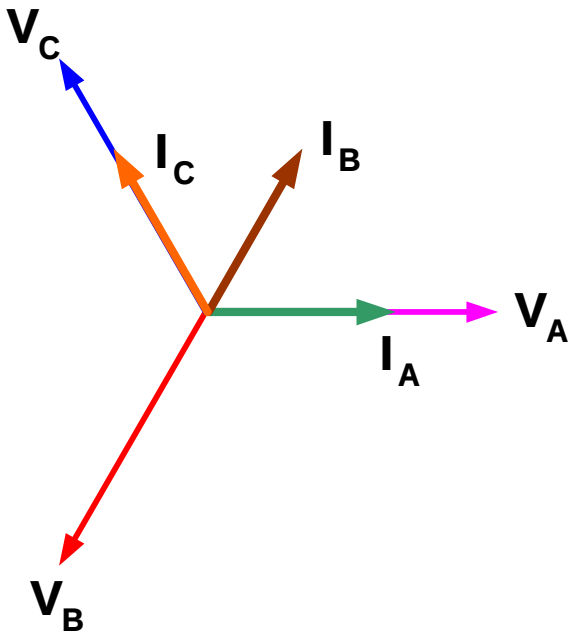


Normal Loadflow IB Rolled

V_A at Zero Degrees (reference)

Unity PF assumed

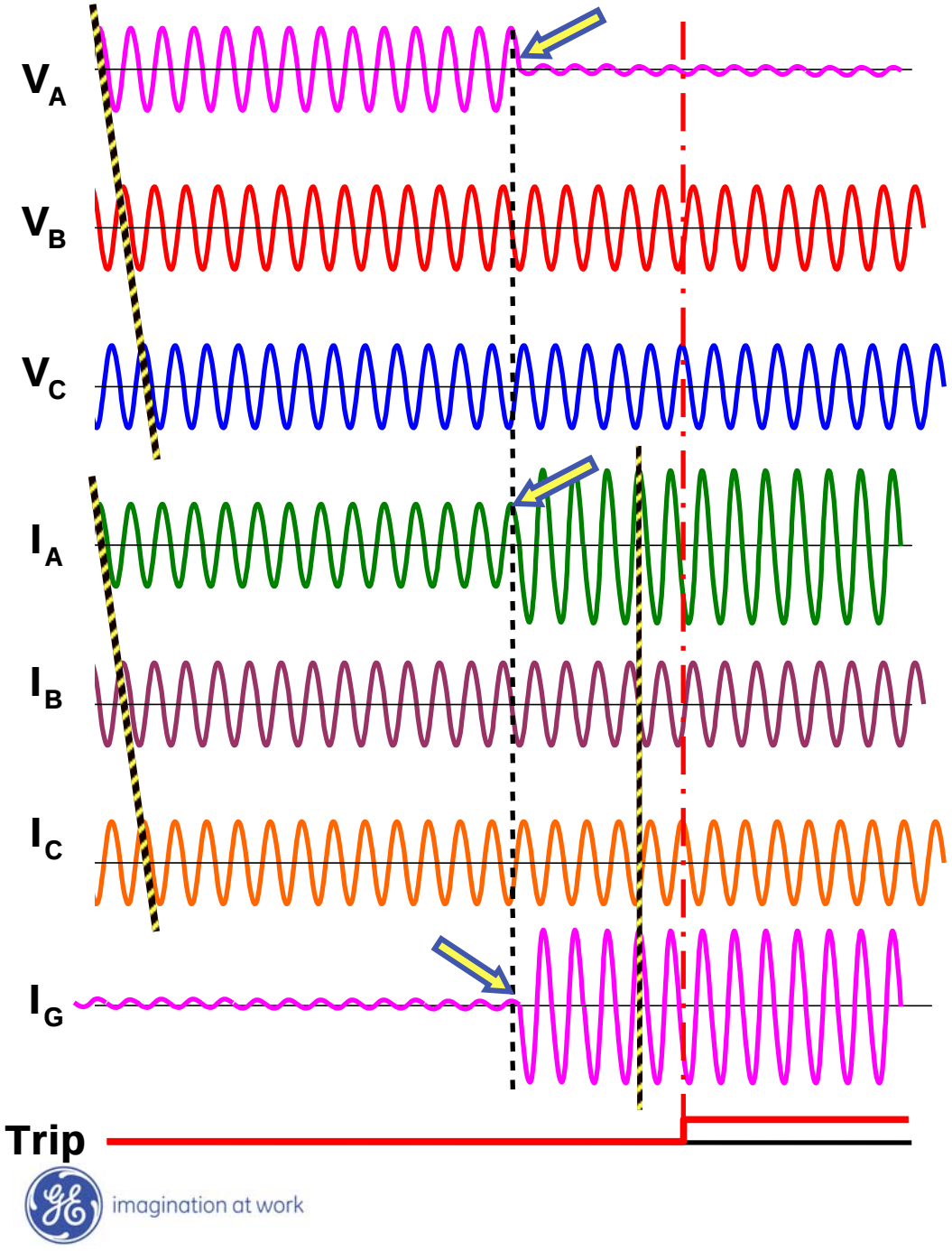


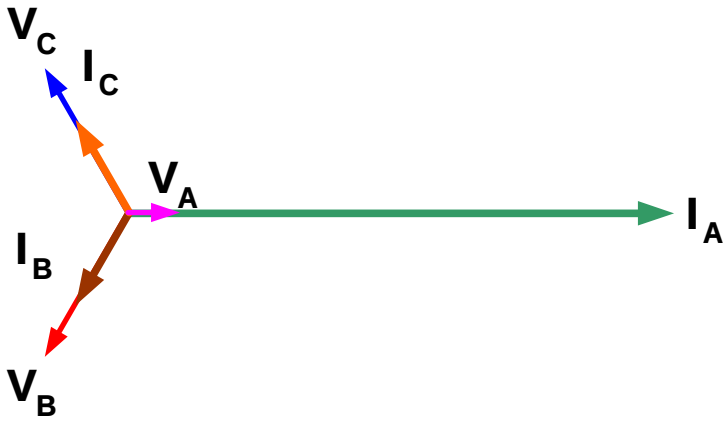


Ground Fault: IA

V_A at Zero Degrees (reference)

Unity PF assumed



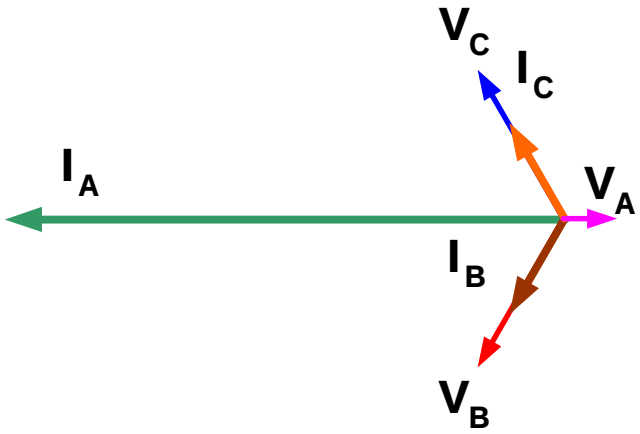


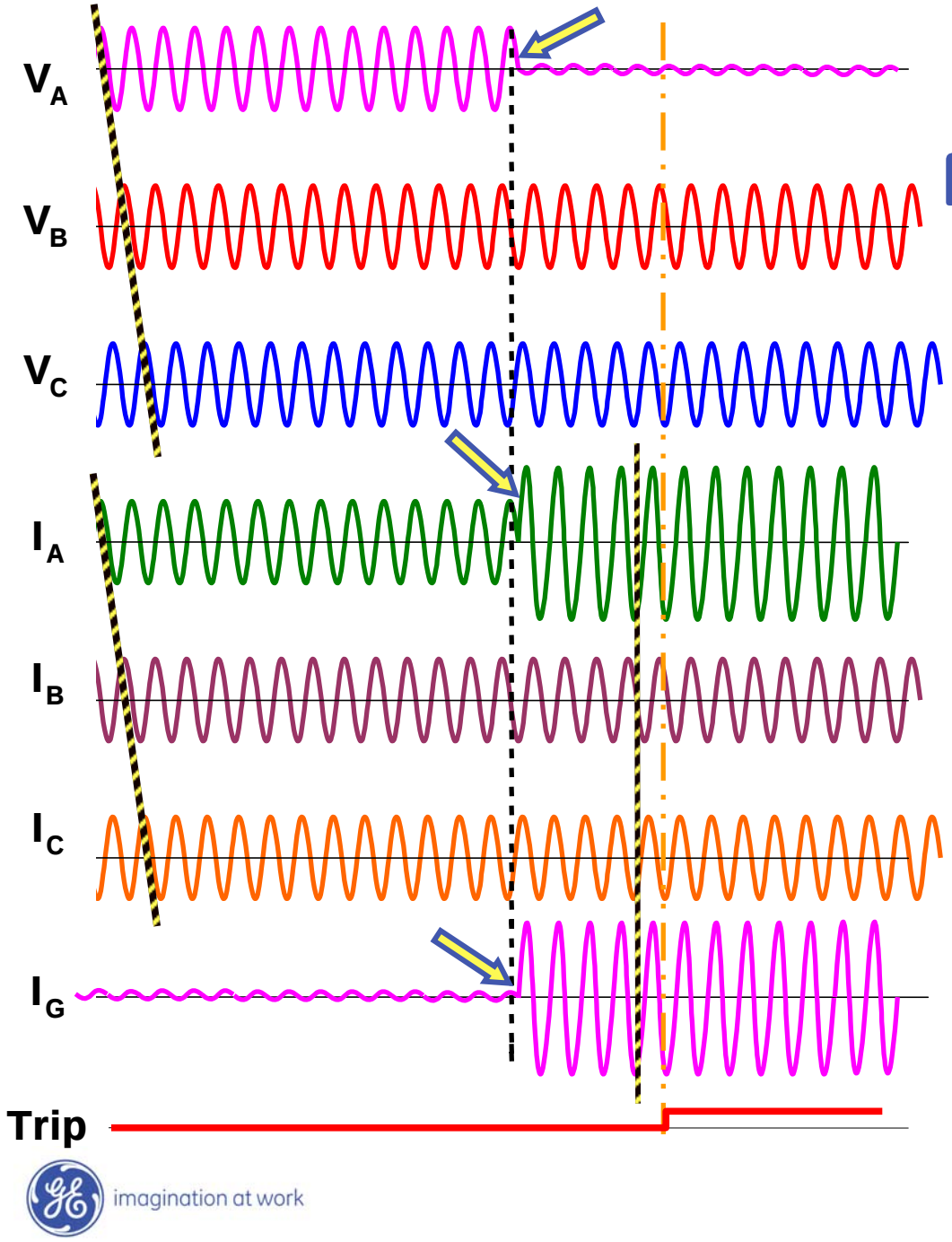
imagination at work

Ground Fault: IA
Reverse to Loadflow

V_A at Zero Degrees (reference)

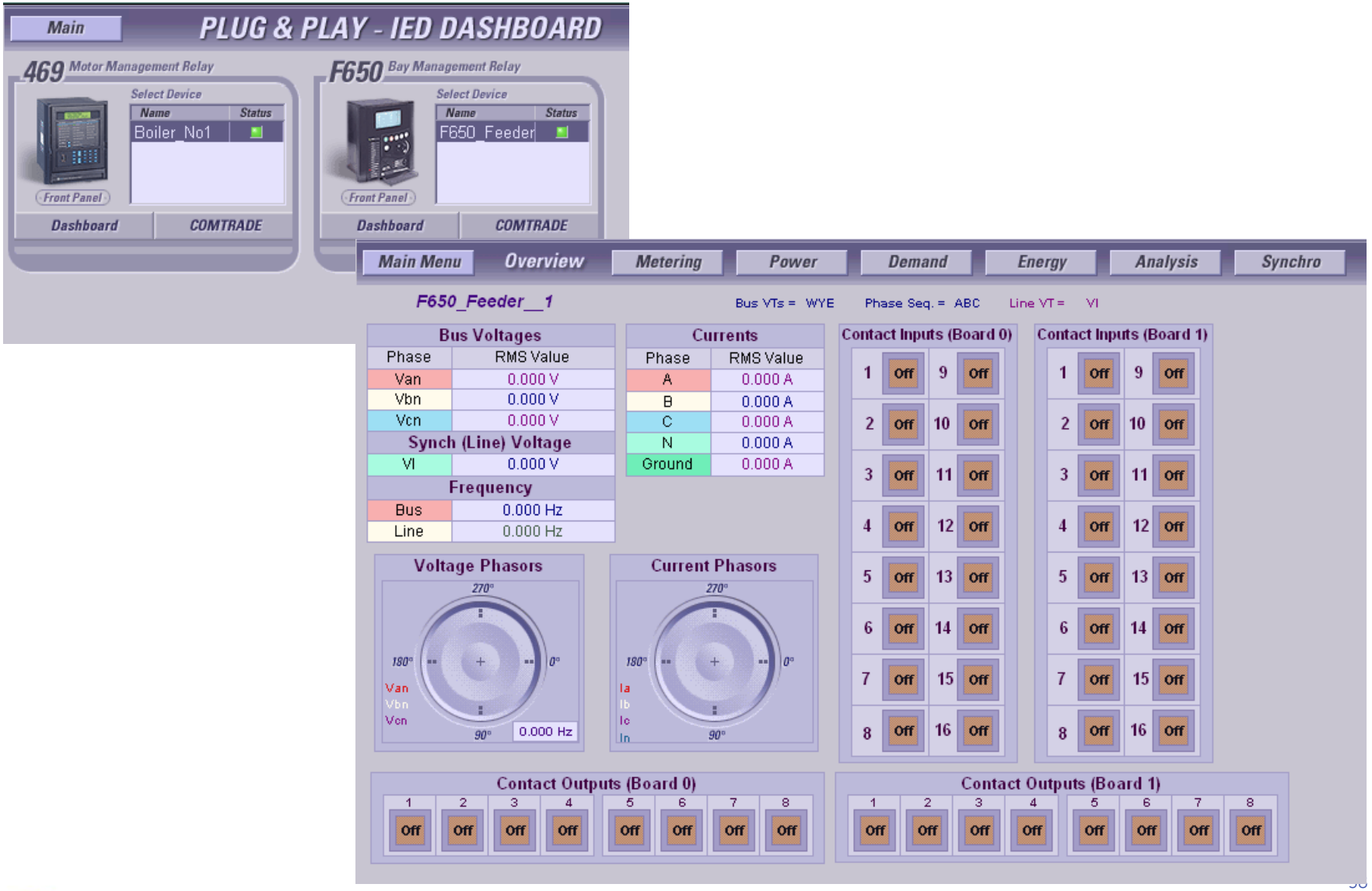
Unity PF assumed



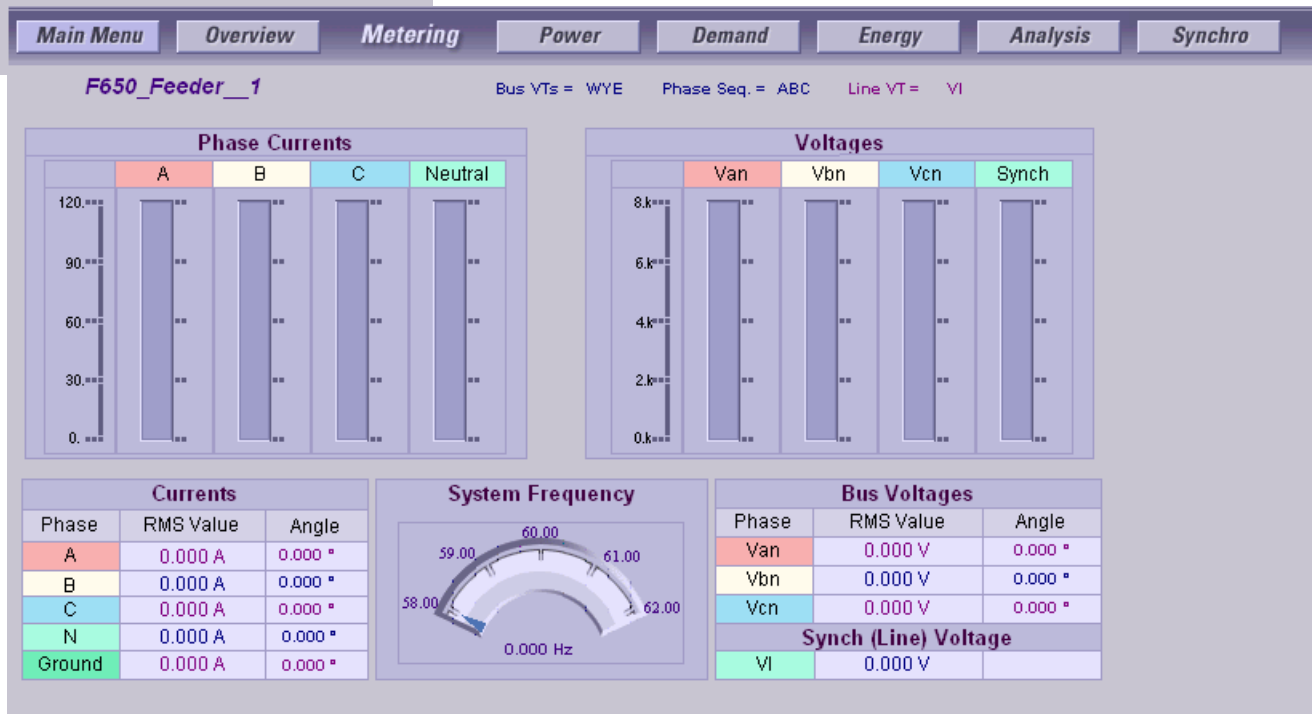


imagination at work

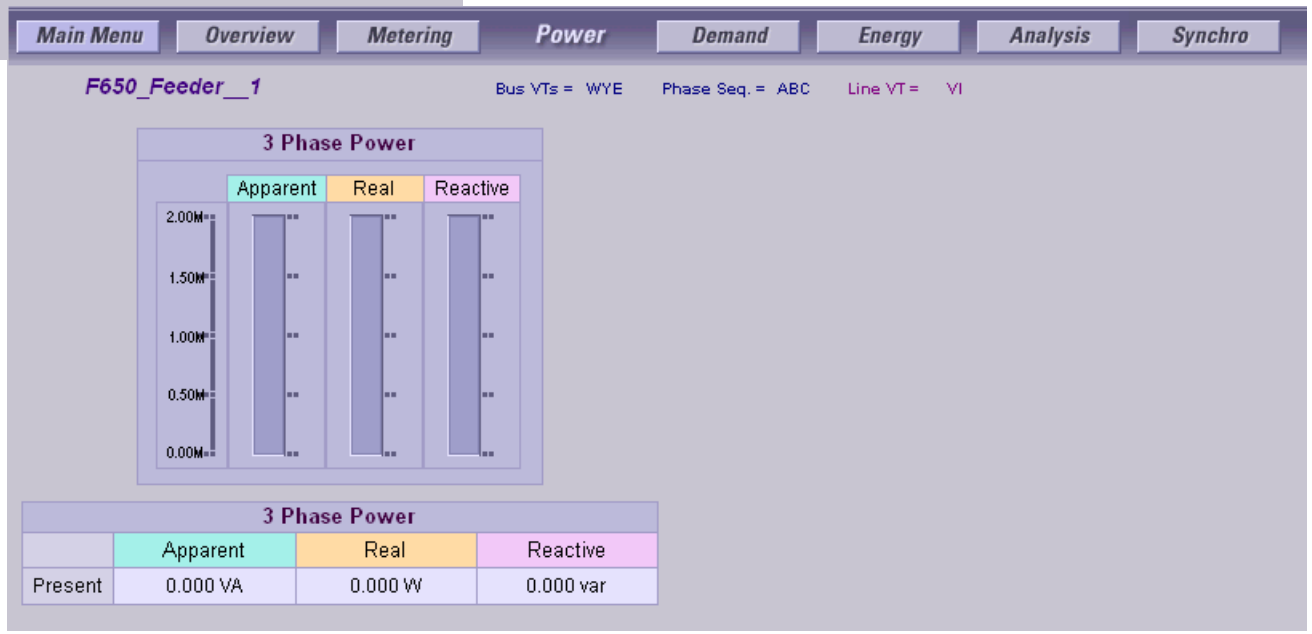
EnerVista Viewpoint – Plug & Play



EnerVista Viewpoint – Plug & Play



EnerVista Viewpoint – Plug & Play



EnerVista Viewpoint – Plug & Play

F650 Summary

- Comprehensive protection and control for Transmission and Distribution bays of any voltage
- User-friendly visual software for setting, monitoring, metering and single line diagrams
- Graphical display and shuttle controller for local operation
- Component based architecture for easy switching of internal boards
- Communications via RS232, RS485 and Ethernet ports for fiber optics
- Distributed I/O Capabilities with the CAN Bus Remote I/O Module

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Email: Multilin.Tech@ge.com