Consultant specification and design resources

Generator paralleling switchgear

Contents

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General Description

Generator Paralleling Switchgear

Eaton Generator Paralleling Switchgear (GPS) couples Eaton's industry leading Low-Voltage Switchgear and Medium-Voltage Switchgear offerings with a modular control design that is centered on power system reliability. The complete automation solution is provided within Eaton switchgear and is serviceable by Eaton's expansive Electrical Engineering Services and Systems (EESS) team located in strategic locations across the United States. Eaton's design gives the customer the flexibility to use any engine-generator supplier while maintaining the power envelope and automation solution to be supplied and commissioned entirely by Eaton. Eaton encourages system designers to use this design guide in conjunction with Eaton's low-voltage switchgear and medium-voltage switchgear design guides which provide additional details and options available in all of Eaton's switchgear offerings. This document focuses exclusively on the controls/automation build out within the switchgear and aims to simplify the design process and ensure that all application needs are addressed. Guide form specifications are available on the website www.eaton.com/guidespecs that detail the features covered in this design guide.

Eaton Generator Paralleling Switchgear is built with Eaton's industry-leading Magnum PXR and Magnum DS low-voltage switchgear with Magnum breakers and VacClad medium-voltage switchgear with VCPW vacuum breakers. This allows common components to be used on both the normal and generator power systems. Common and interchangeable breakers, relays, switchgear assembly parts, breaker maintenance procedures, and so on can be used to help reduce the overall operating cost and increase the maintainability of the entire facility.

Paralleling switchgear contains the monitoring, protection, control, and instrumentation required for connecting either multiple engine-generators or an engine-generator and at least one other power source to a centralized distribution bus. In general, the engine is either diesel, natural gas, or methane driven and the generator, or alternator, is designed to output three phase electrical power at the required system voltage. Each engine-generator is self-contained and accepts control signals from the switchgear's automation controller to change the power output from the alternator.

The monitoring capabilities built into the switchgear provide critical feedback to the system operator on the current state of the power system sources, breakers, engine-generators, and auxiliaries. The protectives built into the switchgear ensure that the system operates within parameters that protect the operator, the switchgear, the generators, and downstream loads. The controls built into the switchgear provide automatic and manual switching capabilities between desired power system configurations.

Power Applications

- Emergency and legally required standby systems
- Optional standby backup systems
- Distributed Generation / Grid Support
- Peak shaving
- Prime power

Application Description

- Data center
- Healthcare
- Critical industrial/chemical processes
- Distributed generation/cogeneration
- Water/wastewater treatment
- Government/military
- Banking/credit card processing
- Landfill gas power
- Universities

Features and Benefits

- Controller Redundancy
- Control Power Redundancy
- Touchscreen interface
- Simple, intuitive operation
- Non-proprietary Control Hardware
- Ease of Serviceability
- Universal Interface to All Engine-Generators
- Modular / Distributed Control Methodology
- Built-in Diagnostics of critical automation hardware
- Generator control and protection
- Detailed engine and electrical reports

Product Standards Compliance

Low-Voltage Switchgear conforms to the following applicable standards:

- CSA C22.2 No. 31-10
- IEEE C37.20.1
- ANSI C37.51
- UL® 1558
- NFPA 110, 99

The switchgear uses Magnum Breakers that are designed to IEEE Standards C37.13, C37.16, C37.17 and UL 1066. Optional switchboard construction is available that is built to UL 891. These switchboards use PowerDefense SB and Magnum SB Breakers for generator mains, utility mains and electrically operated feeders, and molded-case breakers for non-switched feeders.

Medium-Voltage Switchgear conforms to the following applicable standards:

- ANSI/IEEE C37.20.2
- CSA-C22.2 No. 31
- NFPA 70, 99, 110

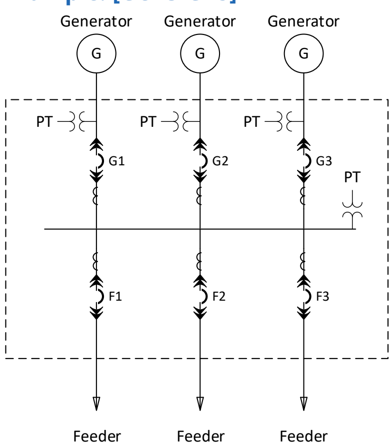
The switchgear uses VCP-W vacuum circuit breakers that are designed to meet or exceed all applicable IEEE/ANSI standards including C37.04, C37.06, and C37.09.

Applications & Functional Sequences

Eaton has developed standardized programming templates for the most common generator applications. The programming templates provide a consistent solution that is proven to provide reliable operation. These standard templates can also be leveraged for custom schemes to meet the unique needs of each project. An abbreviated overview of common schemes is provided in this section. These functional sequences are intended as directional starting points. More detailed O&M documentation is provided with each project for customer review during the design submittal stage.

[GCBx-GPS] Generator Common Bus Generator Paralleling Switchgear

(x represents the number of generators in the system)

Description This application is used to parallel multiple gensets to a common bus where interconnect with the utility is not necessary. These systems are typically used in conjunction with downstream Transfer Switches that automatically switch between utility and generator sources.	Parallel Multiple Generators	Parallel with Utility	Emergency Standby	Transfer Switches	Soft Load / Unload	Peak Shave	Load Shed / Add	Export / Import Power
Example: [GCB3-GPS] 	●		●	●			●	

Sequence of Operations

1. Normal – The normal system state operates with the Primary Mode Switch in AUTO, all Generator Automation Controllers in AUTO, and each Automatic Transfer Switch (ATS) in AUTO. The generator switchgear is normally de-energized, utility power is normally available, and all ATSs are in the Normal position connected to the utility source.

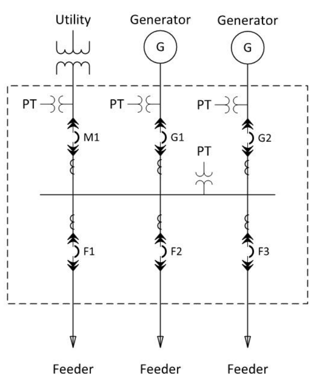
2. Utility Failure – Utility power fails and all ATSs send generator run requests to the generator paralleling switchgear. The system calls all generators to start and sends 'inhibit transfer to emergency signals' to ATSs according to the load shed/add settings. The first generator to reach rated voltage and frequency closes to the bus. Subsequent generators synchronize and close to the bus until the system connects all generators. As generators connect to the bus, the load shed/add scheme sequences each ATS to transfer to the emergency source by removing the "inhibit transfer to emergency" signals according to the load shed/add settings. Once the system connects all generators and loads and the generators run for a predetermined period, the generator load demand start/stop settings take effect, cycling generators on and off to optimize running generator capacity to meet load demand.

3. Utility Return – Once utility power returns, all ATSs wait a predetermined period and then switch back to the Normal position removing the generator run request. The system disconnects the generators from the generator bus and initiates a cooldown period before shutting down each generator.

4. For descriptions of additional features, such as Generator Test and Load Shed/Add, consult the Primary GUI section of this design guide.

[MGx-GPS] Main-Gen(s) Generator Paralleling Switchgear

(x represents the number of generators in the system)

	Parallel Multiple Generators	Parallel with Utility	Emergency Standby	Transfer Switches	Soft Load / Unload	Peak Shave	Load Shed / Add	Export / Import Power
Description This application is used when generators are paralleled with a single utility source. This scheme allows for closed transition transfer to/from the utility as well as continuous paralleling with the utility for peak shaving or exporting.								
Example: [MG2-GPS] 	●	●	●		●	●	●	●

Sequence of Operations

1. Normal – The normal system state operates with the Primary Mode Switch in AUTO and all Generator Automation Controllers in AUTO. The utility main and feeder breakers are closed, and all generator breakers are open.

2. Utility Failure – Utility power fails, and all generators start in the generator paralleling switchgear. The main breaker opens, and the system sheds all non-essential loads according to the load shed settings. As generators are synchronized and connected to the bus, the system adds back additional loads according to the load shed/add settings. Once the system connects all generators and loads and the generators run for a predetermined period, the generator load demand start/stop settings take effect, cycling generators on and off to optimize running generator capacity to meet load demand.

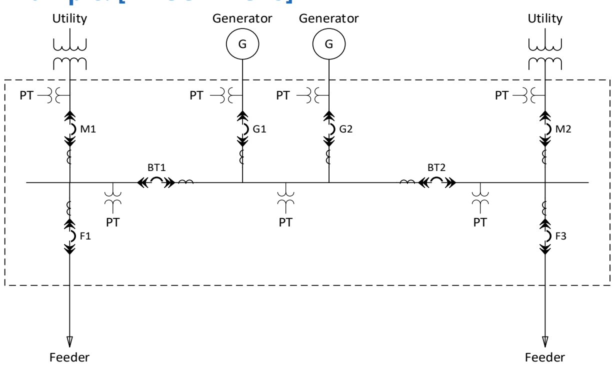
3. Utility Return [OPEN TRANSITION] – Once utility power returns, the system opens the generator breakers after a retransfer time delay. The system closes the utility main breaker after a neutral time delay. The generators cool down before shutting down.

4. Utility Return [CLOSED TRANSITION] – Once utility power returns, following a retransfer time delay, the generators synchronize to the utility source. After the system detects synchronization, it closes the utility main breaker and the generators soft ramp down until the system detects less than 100kW of load across each generator breaker, triggering the generator breakers to open. The generators cool down before shutting down.

5. Prefer Generator Source (Storm Avoidance / Island Mode) – With the system in the Normal state described above, an operator can select “Prefer Generator Source” from the Graphical User Interface. All available generators start and parallel to the bus, the generators ramp until there is less than 100kW of load detected across the utility breaker, then the utility breaker opens. Once the generators run for a predetermined period, the generator load demand start/stop settings take effect. The system will run on generator until an operator returns to the Graphical User Interface and selects “Prefer Utility Source”.

6. For descriptions of additional features, such as Generator Test and Load Shed/Add, consult the Primary GUI section of this design guide.

[xxxx-GPS] Custom Configuration Generator Paralleling Switchgear

Description Custom products are available to meet the most demanding or unique system requirements. (ex., multiple utility sources, multiple tie breakers, special load control, custom sequence of operations)	**Parallel Multiple Generators**	**Parallel with Utility**	**Emergency Standby**	**Transfer Switches**	**Soft Load / Unload**	**Peak Shave**	**Load Shed / Add**	**Export / Import Power**
Example: [MTGGTM-GPS] 	●	●	●	●	●	●	●	●

Sequence of Operations

1. Normal –The normal system state operates with the Primary Mode Switch in AUTO, all Generator Automation Controllers in AUTO. The generator bus is normally de-energized and utility power is normally available. The utility main and feeder breakers are closed and all tie and generator breakers are open.

2. Single Utility Failure – Utility source 1 fails, the utility main breaker 1 opens, bus tie 2 breaker closes, and bus tie 1 breaker closes. Utility source 2 now powers Bus 1 and Bus 2 loads.

3. Single Utility Return [OPEN TRANSITION] – Once utility source 1 power returns, following a retransfer time delay, the system opens the tie breakers. After a neutral time delay, the system closes the utility main 1 breaker. Utility source 1 now powers Bus 1 loads and utility source 2 powers Bus 2 loads.

4. Single Utility Return [CLOSED TRANSITION] – Once utility source 1 power returns, following a retransfer time delay and verification that both utility sources are in sync, the system closes the utility main 1 breaker and opens the tie breakers (<100ms). Bus 1 loads are now powered by utility source 1 and Bus 2 loads are powered by utility source 2.

5. Dual Utility Failure – Both utility power sources fail, causing all generators in the generator paralleling switchgear to start. The system opens both main breakers, sheds all non-essential loads according to the load shed settings, and closes the tie breakers. The first generator to reach rated voltage and frequency closes to the bus. Subsequent generators synchronize and close to the bus until the system connects all generators. As the system synchronizes and connects generators to the generator bus, it adds back additional loads according to the load shed/add settings. Once the system connects all generators and loads and the generators run for a predetermined period, the generator load demand start/stop settings take effect, cycling generators on and off to optimize running generator capacity to meet load demand.

6. Dual Utility Return [OPEN TRANSITION] – Once utility power returns, following a retransfer time delay, the system opens the tie breakers. After a neutral time delay, the system closes the utility main breakers. The system disconnects the generators from the generator bus and initiates a cooldown period before shutting down the generators.

7. Dual Utility Return [CLOSED TRANSITION] – Once utility power returns, following a retransfer time delay, the system synchronizes the generators to utility source 1. After detecting synchronization, the system closes the utility main 1 breaker and the generators soft ramp down until the system detects less than 100kW of load across bus tie 1, triggering the bus tie 1 breaker to open. Next, the system synchronizes the generators to utility source 2. After detecting synchronization, the system closes the utility main 2 breaker and the generators soft ramp down until the system detects less than 100kW of load across bus tie 2, triggering the bus tie 2 breaker to open. The generators disconnect from the generator bus and enter a cooldown period before the generators shut down.

8. For descriptions of additional features, such as Generator Test and Load Shed/Add, consult the Primary GUI section of this design guide.

Switchgear Layout

Eaton Generator Paralleling Switchgear (Magnum PXR and 5/15kV VCPW) has the flexibility to handle unique configurations and project requirements. If the standard MGx-GPS (Main-Generator), and GCBx-GPS (Generator Common Bus) configurations do not fit the needs of a specific project, Eaton offers fully customized solutions. In many cases, custom configurable systems are based on standard MGx-GPS or GCBx-GPS configurations with additional requirements such as:

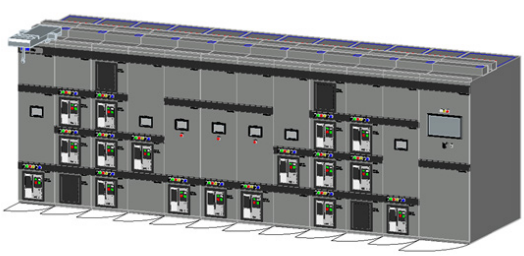
- Multiple utility connections
- Multiple tie breakers
- Unique sequence of operations
- Special switchgear layout requirements, and so forth

Regardless of what the project requires, Eaton has a solution.

An Eaton generator paralleling switchgear lineup is designed using typical structure layouts or “Modular Building Blocks”. Use these Modular Building Blocks when planning a custom paralleling switchgear configuration. For detailed information on the system features offered by a generator paralleling switchgear assembled with Modular Building Blocks, refer to the next section titled ‘Features’. This section includes topics on redundancy, communication networks, control power, instrumentation, and field wiring.

Low-voltage Switchgear

The following designs are based on using Eaton’s Magnum PXR Low-voltage Switchgear. If having 3D BIM models of the switchgear will help with project planning, reach out to an Eaton representative.



Modular Building Blocks

The following Modular Building Blocks are presented first by a simplified single-line component and then by the corresponding switchgear structure, highlighting the correlation between the two. It is typical for a Modular Building Block to consist of power circuit breakers, Control Power Transformers (CPTs), Potential Transformers (PTs), automation hardware, and instrumentation organized into a vertical structure for optimal construction, safety, and repeatability.

For examples of common switchgear layouts using Modular Building Blocks refer to Appendix A.

Utility Building Block

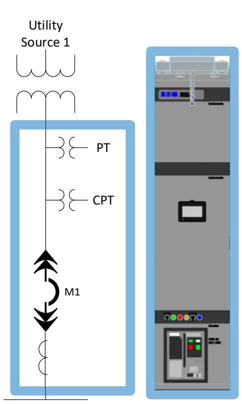


Figure 1 – Typical LV Utility Main Breaker Structure

The utility main breaker structure is used any time synchronizing and momentary or extended paralleling of the generator plant occurs across the utility breaker. The uppermost compartment contains a CPT for the breaker spring charge motor and a PT to convert the three-phase bus voltage to a safer instrumentation voltage. The middle compartment contains the utility breaker automation controller and supporting automation hardware. The bottom compartment contains the power circuit breaker and associated indication lights and control switches.

Generator Building Block

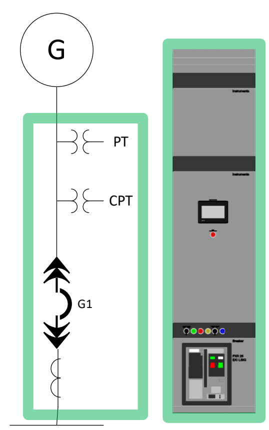


Figure 2 –Typical LV Generator Main Breaker Structure

The generator main breaker structure is used any time synchronizing and momentary or extended paralleling of the connected generator to a generator plant or other source is required. The uppermost compartment contains a CPT for the breaker spring charge motor and a PT to convert the three-phase bus voltage to a safer instrumentation voltage. The middle compartment contains the generator breaker automation controller and supporting automation hardware. The bottom compartment contains the power circuit breaker and associated indication lights and control switches.

Tie Building Block

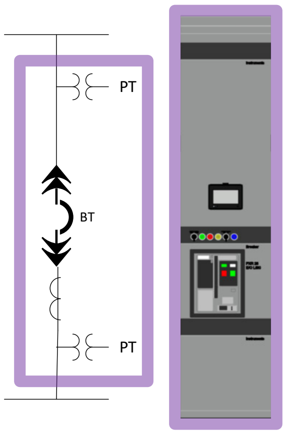


Figure 3 – Typical LV Bus Tie Breaker Structure

The tie breaker structure is used any time synchronizing and momentary or extended paralleling of utility and generator sources is required across a tie breaker. The upper compartment contains the tie breaker automation controller and supporting automation hardware. The middle compartment contains the power circuit breaker and associated indication lights and control switches. The lower compartment contains two PTs to convert each of the three-phase bus voltages to a safer instrumentation voltage.

Feeder Building Block

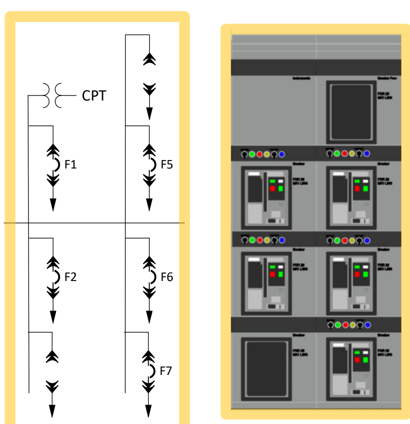


Figure 4 – Typical LV Feeder Breaker Structure

The feeder breaker structures are mainly comprised of electrically operated feeder breakers. Electrically operated feeder breakers are used any time automatic load shed/add is required. The upper most compartment contains automation hardware for monitoring and control of each feeder breaker and a bus connected CPT that provides control power for all feeder and tie breaker spring charge motors.

Primary Control Building Block

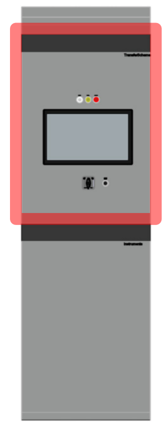


Figure 5 – Typical LV Dedicated Primary Control Structure

The primary control structure contains the Primary GUI and the Primary Controller. It occupies a half high compartment and can be located anywhere in the switchgear lineup and sometimes is removed entirely from the switchgear and instead located in a free-standing or wall-mount enclosure. The Primary GUI serves as the focal point for interaction with the system, making it best to locate the primary controls in the most convenient and safe location for access.

Primary Control with Feeders Building Block

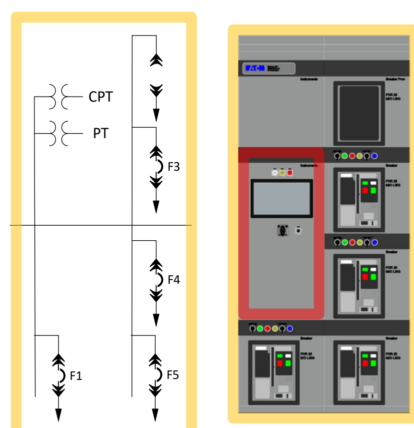


Figure 6 – Typical LV Primary Control Cabinet with Feeders Structure

Combining the last two building blocks produces a primary control with feeders building block. The upper most compartment contains automation hardware for monitoring and control of each feeder breaker and a bus connected CPT that provides control power for all feeder and tie breaker spring charge motors. The half-high primary control cell (in red) contains the Primary GUI interface and the Primary Controller.

Switchgear Current Ratings / Dimensions / Weight / Conduit

The following section provides guidance for determining the overall dimensions of the switchgear Additional tables are provided for estimating the weight of each structure based on the system configuration. Refer to Eaton Rear-Access Low-Voltage Switchgear Design Guide for additional detail.

Generator and Breaker Sizing

Table 1 – Breaker sizing based on Generator kW Size
(Note: typical sizing is provided, but sizing can vary based on the presumed power factor.)

Generator kW (480V)		
Min.	Max.	Generator Breaker Size
0	532	800
533	1064	1600
1065	1330	2000
1331	2000	3000

Switchgear Sizing

Table 2 – Switchgear Sizing Guide

Maximum Breaker Size	Main Bus Rating ①	Dimensions		
		Height	Width	Depth Min.
800	1600+	99.00 (2514.6)	22.00 (558.8) per structure	72.00 (1828.8)③
1200				
1600				
2000	2000+			
3200	3200+			
4000 ②	4000+		30.00 (762)	
4000	4000+		44.00 (1117.6)	
5000	5000+			
6000	6000+			

① Actual required bus rating is dependent on the size and distribution of source and feeder breakers across the switchgear lineup.

② Utilizes 4000A MDN or MPN narrow frame breaker

③ The depth of a 22.00 inch wide structure must increase to account for additional conduit space when the sum of the breakers in a single structure exceeds 4000A

Contact an Eaton Application Engineer for more details.

Conduit Space

Table 3 – Conduit Space for 22.00-Inch (558.8 mm) Wide Structures – Top or Bottom Entry

Structure Depth	Rear Conduit Opening		Recommended Number of 3.50 or 4.00-inch Conduits
	Width	Depth	
66.00 (1676.4)	16.00 (406.4)	19.30 (490.2)	9
72.00 (1828.8)	16.00 (406.4)	25.30 (642.6)	12
78.00 (1981.2)	16.00 (406.4)	31.30 (795.0)	15
84.00 (2133.6)	16.00 (406.4)	37.30 (947.4)	18

Switchgear Structure Weight (less breakers)

Table 4 – Magnum PXR Indoor Rear Switchgear Structure Approximate Weights (Standard Construction Less Breakers)

Width in Inches (mm)	Depth in Inches (mm)	Approximate Weight in lb (kg)
22.00 (558.8)	72.00 (1828.8) 78.00 (1981.2) 84.00 (2133.6) 90.00 (2286.0)	1350 (614) 1400 (639) 1450 (659) 1500 (682)
30.00 (762.0)	72.00 (1828.8) 78.00 (1981.2) 84.00 (2133.6) 90.00 (2286.0)	2100 (955) 2200 (1000) 2300 (1045) 2400 (1091)

Breaker Weight (Standard Frame)

Table 5 – Magnum Circuit Breakers with PowerXpert Release Trip Unit Weights (Note: Impact weight equals 1.5 times breaker static weight. Three-pole frame weight given; four-pole frame weight equals 1.33 times more.)

Breaker	Drawout in lb (kg)
MPS-408 MPS-608 MPS-808	130 (59) 130 (59) 145 (66)
MPS-C08 MPS-616 MPS-816	145 (66) 130 (59) 145 (66)
MPS-C16 MPS-620 MPS-820	145 (66) 145 (66) 145 (66)
MPS-C20 MPS-632 MPS-832 MPS-C32	145 (66) 175 (79) 175 (79) 175 (79)

For more detail on general switchgear construction please reference Design Guide DG019008EN sections 20.7-20 through 20.7-32 (Low-voltage switchgear (eaton.com)).

Medium-voltage Switchgear

The following building blocks are based on using Eaton's 5/15kV Metal-Clad VCPW Switchgear. If having 3D BIM models of the switchgear will help with project planning, reach out to an Eaton representative.

Modular Building Blocks

The following Modular Building Blocks are presented first by a simplified single-line component and then by the corresponding switchgear structure, highlighting the correlation between the two. It is typical for a Modular Building Block to consist of power circuit breakers, Control Power Transformers (CPTs), Voltage Transformers (VTs), automation hardware, and instrumentation organized into a vertical structure for optimal construction, safety, and repeatability.

For examples of common switchgear layouts using Modular Building Blocks refer to Appendix B.

Utility Building Block

The utility main breaker structure is used any time synchronizing and momentary or extended paralleling of the generator plant occurs across the utility breaker. The upper half of the top compartment contains a VT to convert the three-phase bus voltage to a safer instrumentation voltage. The lower half of the upper compartment contains the utility breaker automation controller and supporting automation hardware. The bottom compartment contains the power circuit breaker and associated indication lights, protective relay, and control switches.

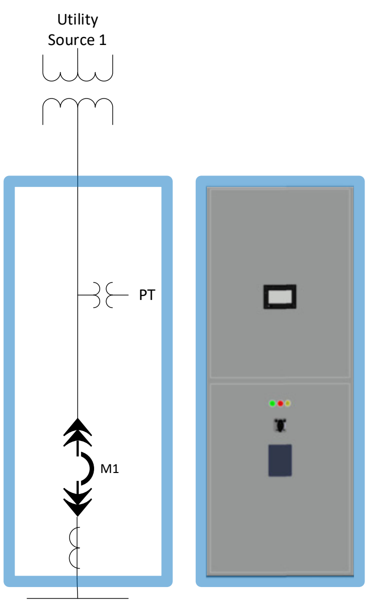


Figure 7 – Typical MV Utility Breaker Structure

Generator Building Block

The generator main breaker structure is used any time synchronizing and momentary or extended paralleling of the connected generator to a generator plant or other source is required. The upper half of the top compartment contains a VT to convert the three-phase bus voltage to a safer instrumentation voltage. The lower half of the upper compartment contains the generator breaker automation controller and supporting automation hardware. The bottom compartment contains the power circuit breaker and associated indication lights, protective relay, and control switches.

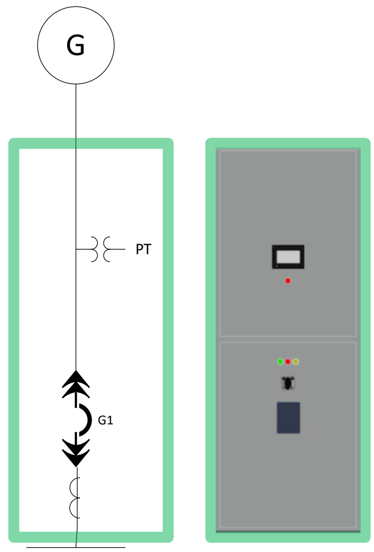


Figure 8 – Typical MV Generator Breaker Structure

Tie Building Block

The tie breaker structure is used any time synchronizing and momentary or extended paralleling of utility and generator sources is required across a tie breaker. The upper half of the top compartment contains a VT to convert the three-phase bus voltage to a safer instrumentation voltage. The bottom half of the upper compartment contains the tie breaker automation controller and supporting automation hardware. The lower compartment contains the power circuit breaker and associated indication lights, protective relay, and control switches. The upper half of the top compartment in the next structure over contains a second VT to convert the three-phase bus voltage on the other side of the tie breaker to a safer instrumentation voltage.

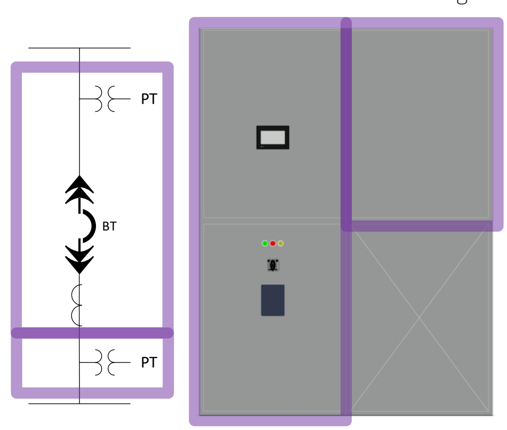


Figure 9 – Typical MV Tie Breaker Structure

Feeder Building Block

The feeder breaker structures are comprised of electrically operated feeder breakers and may participate in an automatically controlled load shed/add scheme. The automation hardware is installed on the panel space between the upper and lower breakers to allow for monitoring and control of each feeder breaker.

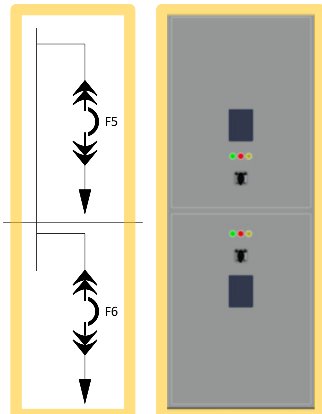


Figure 10 – Typical MV Feeder Breaker Structure

Primary Control Building Block

The primary control structure contains the Primary GUI and the Primary Controller. It consumes a half high compartment and can be located anywhere in the switchgear lineup and sometimes is removed entirely from the switchgear and instead located in a free-standing or wall-mount enclosure. The Primary GUI is the focal point for an operator, where it will interact with the system the most, so it is best to locate the primary controls in the most convenient / safe location for an operator to access.

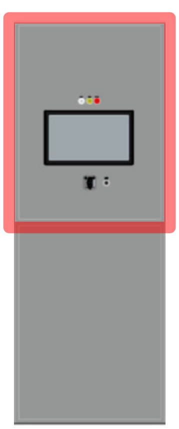


Figure 11 – Typical MV Primary Control Structure

Switchgear Current Ratings / Dimensions / Weight / Conduit

VCPW switchgear structures are standardized to the following dimensions, 95” tall x 36” wide x 96” deep as shown in the pictures below further tables are provided for estimating the weight of each structure based on the specific system configuration.

Switchgear and Breaker Layouts

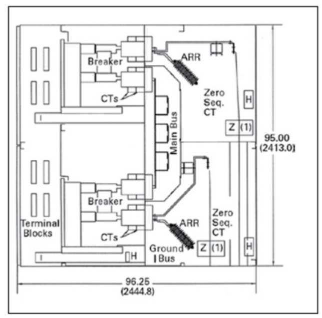


Figure 12 – Dual Breaker Structure Side-View 36.00-Inch (914.4 mm) Wide

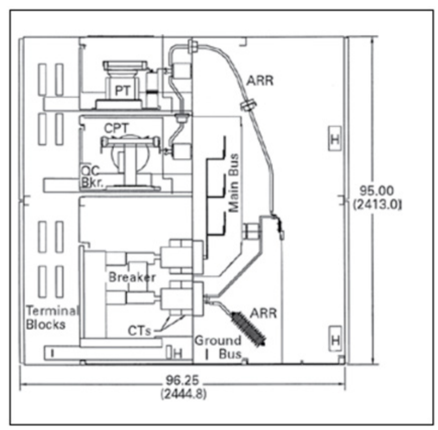


Figure 13 – VT, CPT, and Breaker Structure Side-View 36.00-Inch (914.4 mm) Wide

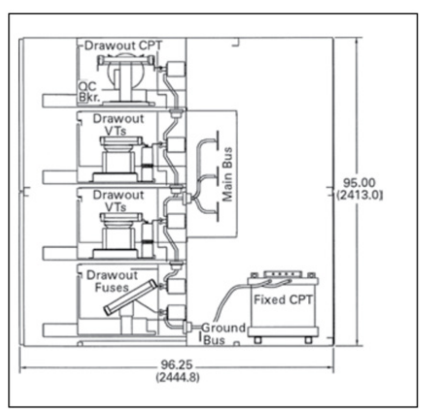


Figure 14 – CPT, Dual VT, and Fuses Structure Side-View 36.00-Inch (914.4 mm) Wide (Note: Drawout Fuses with a Fixed CPT are standard for CPT sizes greater than 15kVA.)

Conduit Space

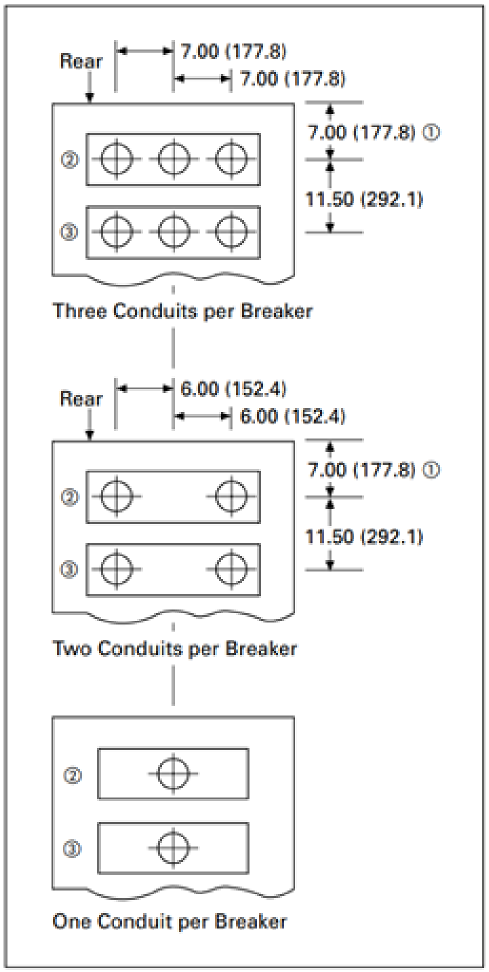


Figure 15 - Primary Conduit Locations for 2-High Breakers

1. Changes to 8.25 (209.6 mm) if optional hinged rear doors are required.

2. Cables enter from the top and connect to the breaker located in the bottom compartment. Cables enter from bottom and the breaker in the upper compartment.

3. Cables enter from the top and connect to the breaker located in the upper compartment. Cables enter from bottom and connect to the breaker in the bottom compartment.

4. Contact Eaton for applications requiring more than three conduits per breaker.

5. It is the end user and/or the end user's designated third-party responsibility to supply and install necessary sealing materials to ensure penetrations made after shipment are properly sealed and weatherproofed to maintain the integrity of the switchgear.

Structure Weight (less breakers)

Vertical Section Type	Main Bus Rating Amperes	Approximate Weight in lb (kg)
Breaker / Breaker	1200 2000 3000 4000 [1]	3550 (1610) 3650 (1656) 3750 (1701) 3275 (1486)
Breaker / Auxiliary Or Auxiliary / Breaker	1200 2000 3000 4000 [1]	3450 (1565) 3550 (1610) 3650 (1656) 3175 (1440)
Auxiliary / Auxiliary	1200 2000 3000 4000	2700 (1225) 2800 (1270) 2900 (1315) 3000 (1361)

Table 6 – VacClad-W 5-15kV, 36" Wide Indoor Switchgear Structure Approximate Weights (Standard Construction Less Breakers)

1. 4000 A offering only available with a single breaker per structure (no auxiliary allowed).

Breaker Weight

Breaker Type	Current Rating, Amperes		
	1200	**2000**	**3000**
	Approximate Weight, Lb (kg), Static		
5 VCP-W 25, 40, 50 15 VCP-W 25, 40, 50	374 (170) 374 (170)	374 (170) 374 (170)	426 (193) 426 (193)
50 VCP-W 250, 25, 40 50 VCP-W 350, 40C, 50C, 50, 63C 50 VCP-W 500, 63	350 (159) 460 (209) 575 (261)	410 (186) 490 (222) 575 (261)	525 (238) 525 (238) 575 (261)
75 VCP-W 500, 50C, 50 150 VCP-W 500, 25C, 25 150 VCP-W 750, 40	375 (170) 350 (159) 350 (159)	410 (186) 490 (222) 410 (186)	525 (238) 525 (238) 525 (238)
150 VCP-W 1000, 40C, 50C, 50, 63C 150 VCP-W 1500, 63	460 (209) 575 (261)	490 (222) 575 (261)	525 (238) 575 (261)

Table 7 – VCP-W Breaker Unit Weights
(Note: Impact weight equals 1.5 times breaker static weight)

For more detail on general switchgear construction please reference Design Guide DG022001EN Section 5.1-44 (Medium-voltage switchgear (eaton.com)).

Features

Overview

An abbreviated overview of both Standard and Optional features is supplied in the table below.

Redundancy and Fault Tolerance	
Dedicated Sync/Load Share Controller for Each Generator, Operates Independent of a Primary Controller Failure	Standard
Primary Controller	Standard
Redundant Primary Controller	Option
Redundant Controller I/O	Option
Engine 24 VDC to Best Source Control Power	Standard
Switchgear 24VDC UPS to Best Source Control Power	Standard
Redundant Switchgear 24VDC UPS to Best Source Control Power	Option
Station Batteries / External 24 VDC to Best Source Control Power	Option
Paralleling Breaker Close Circuit Interlocking	Standard
Communication Network for Automation and Control	
Managed Ethernet Switches (VLAN/Isolate Automation Traffic)	Standard
Ethernet Ring Network	Standard
Redundant Synchronizing and Load Share Networks	Standard
Diagnostic Monitoring of Automation and Control hardware on the Ethernet Network	Standard
Human Machine Interface (HMI) / Graphical Touchscreen	
21” Primary HMI Touchscreen	Standard
10”, 15”, 24” HMI Touchscreen	Option
HMI Touchscreen Display for each Synchronizing and Load Share Controller	Standard
Redundant Primary HMI Touchscreen	Option
Intuitive Menu / Navigation	Standard
Animated Single-line of Power System	Standard
Control, Metering, and Settings Screens	Standard
Multiple levels of User Authentication / Password Protection	Standard
Alarm and Event Report w/Export to USB	Standard
Settings Report w/Export to USB	Standard
Joint Commission JCAHO Report w/Export to USB	Option
Custom Report w/Export to USB	Option
Real Time Trending	Standard
Historical Trending	Option

Instrumentation	
Breaker Control Switch and Open/Closed/ Tripped/Maintenance Mode Pilot Lights	Standard
E-stop next to each gen controller	Standard
Primary Mode Switch, Auto Light, Alarm Horn, Alarm Light, Alarm Reset Pushbutton	Standard
Lighted Annunciator Panels	Option
Manual Sync Control Panel	Option
Voltage Sensing	
Generator Automation Controller Synchronizer	Standard
Backup Sync Check Device	Standard
Utility Grade Multi-Function Relay	Option
Remote Monitoring Capability	
Communication Gateways to BMS/SCADA	Option
Direct Modbus TCP Monitoring (no gateway)	Standard
Remote Control	Option
Firewall	Option
Applications	
Emergency Standby	Standard
Utility Paralleling	Option
Prime Power	Option
MicroGrid	Option
Primary and Paralleling Controllers Mounting Location	
Integrated into Switchgear	Standard
Stand-Alone Control Enclosures	Option

Redundancy & Fault Tolerance

Single points of failure are eliminated through added redundancy and distributed processing:

1. **Distributed Processing –** Dedicated automation controllers are installed/programmed to monitor and control each power source to ensure the larger control system continues to operate in the case of a single controller failure.
2. **Redundant Load Share Networks –** Facilitate all synchronizing and load sharing communications between the generator and load share controllers. The network is configured such that if there is a loss of a single Ethernet switch, the synchronizing and load share controls will be seamlessly transferred to the redundant load share network and continue to operate the generator plant isochronously.
3. **Hot Standby Primary Controller –** Primary functionality maintained through synchronized primary and secondary controllers, providing seamless transfer in the event of a primary controller failure.
4. **Distributed Manual Control –** In the unlikely case of a complete loss of system automation, distributed manual control is available.
5. **Remote Operator Stations –** Additional operator stations function independent of the local operator interface touchscreen. If the local operator interface touchscreen fails, it will not affect the operation of the remote station connected to the system.
6. **Hardwired Emergency Start Backup –** Each system is designed with a hardwired emergency start backup system installed in the event of a catastrophic network communications failure. The hardwired emergency start backup system will initiate a generator start signal to all generator controllers based on any ATS start signal or a Utility Failure signal.
7. **24VDC Best Battery Scheme (Redundant DC Control Power) –** Control power is protected against single points of failure by a 24Vdc Best Source DC system. Each engine battery and an optional station battery are connected to a common DC bus. The entire system is protected so that individual battery/charger faults will not affect the rest of the system. Additionally, shutting down an individual engine's charger or disconnecting the battery for maintenance does not impact the system since control power is supplied from the other sources. Refer to the 'Control Power' section for more information on the use of control power in low-voltage and medium-voltage switchgear.
8. **Paralleling Breaker Close Circuit Interlocking –** All source and tie breakers that are designated as locations where two sources can be paralleled will have electrical interlocking in the breaker close circuit. When a breaker close command is sent, either from an automation controller or manually from a breaker control switch, the signal must first pass through a supervising sync check relay. The supervising sync check relay ensures that the voltage magnitude, phase angle, and slip frequency difference between the line and load side of the breaker are within parameters before the breaker is allowed to close. The supervising sync check relay also detects the condition when the line side of the breaker is energized, and the load side of the breaker is de-energized and permits the breaker to close. In the case of tie breakers, dual supervising sync check relays are used to detect a de-energized bus on either side of the breaker to allow the breaker to close. Note that open transition interlocking, either through use of breaker auxiliary contacts (electrical) or keyed (mechanical) interlocking, is only applied to breakers that are not designated points of paralleling.

Communication Networks

The distributed Eaton control system is made possible by communication networks. Because communication is the backbone of the control system, Eaton has eliminated single points of failure and built in real-time diagnostic monitoring (see the "Network Diagnostics Screen" section) to ensure that failure of any component in the control system is known and can be addressed immediately.

The major control components for a typical Main-Generator-Tie-Generator-Main paralleling switchgear are shown in the network diagram and a description for each communication link is provided below. The level of detail shown in this section is provided for transparency and clarity of the high-level design methodology. To better understand physical space requirements, see the "Layouts and Dimensions" section of this design guide which provides information on how to assemble multiple vertical structures into a generator paralleling switchgear.

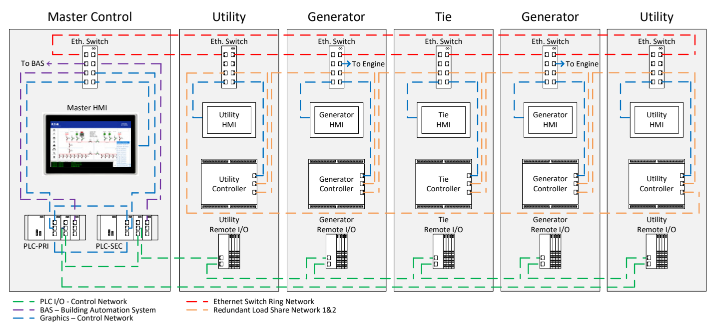


Figure 16 – Standard Control System Communication Network (hardware shown for a MGTGM-GPS)

There are multiple VLAN isolated ethernet networks operating on a managed fault-tolerant ethernet ring. The networks are the graphics control network, redundant load share network 1, redundant load share network 2, the building automation system (BAS) network, and the Programmable Logic Controller (PLC) I/O control network.

1. The graphics control network provides connection from the Primary PLC and the Generator Automation Controllers to the HMI user interfaces.
2. Under normal conditions, load share network 1 facilitates all synchronizing and load sharing communications between all generator and load share controllers.
3. The redundant load share network 2 facilitates all synchronizing and load sharing communications between all generator and load share controllers in the case of load share network 1 failure.
4. The BAS network provides connection between the Primary Controller (PLC) and the building or power monitoring network to provide active mode and status of the power automation system with third party networks.
5. The PLC I/O control network is a fifth isolated network that isolates time sensitive feedback and control between digital I/O drops and the Primary Controller.

Control Power

A critical switchgear design consideration is ensuring a robust source of control power for all automation hardware. This section provides recommendations for how to plan for control power in low-voltage and medium-voltage switchgears.

Most automation control components and circuits are powered from 24VDC battery backed sources. 24VDC is chosen as the standard voltage since most engine batteries and many industrial automation components operate at 24VDC. Operating at 24VDC increases system reliability by limiting the need for voltage converting power supplies. Control power can be supplied solely from the engine batteries. To improve reliability and add redundancy, a station power source can also be provided as an option. Station power is typically provided from a UPS or station batteries. For low-voltage switchgear, a 24VDC UPS is usually provided inside the switchgear. It is important to have the switchgear mounted UPS fed from an external 120VAC emergency panel source (the same panel that supplies 120VAC control power to the engine-generator battery chargers). For medium-voltage switchgear or system requiring a higher battery capacity to meet load or discharge requirements, an external UPS is selected and provides 120VAC control power. The UPS can be dedicated to providing control power for the switchgear only or provided by the customer with a dedicated circuit from a 'house' UPS that is powering critical facility loads. Alternately, station batteries may be supplied to provide 125VDC control power to the switchgear. A power supply converter is used to convert the 120VAC/125VDC to 24VDC for use in the automation control power system.

Batteries are always used for control power to ensure automation control components remain powered when the utility power source fails but the generators have not started providing power. It is critical to ensure all battery chargers or UPS are powered from an emergency panel that receive both normal and emergency power to prevent discharge of the batteries when the system is operating from emergency power. If an emergency panel is not available, control power transformers (CPTs) will need to be installed in the switchgear.

Station power sources need to be sized to accommodate all the automation control system components. The highest power consuming component in the switchgear is the breaker spring charge motor found in all electrically operated power circuit breakers. Spring charge motors are an intermittent high current load, and it is best to run these motors at a higher control power voltage than the automation hardware. Note that the spring charge motors are not required to be powered from a battery-backed circuit, but can be when larger station battery systems are installed. When running, the motor stretches a spring that stores the energy needed to operate the breaker. The motor operates every time a breaker is closed. Once charged, the spring stores enough energy to trip-close-trip the breaker even if control power to the charging motor is not available.

Low-voltage Switchgear

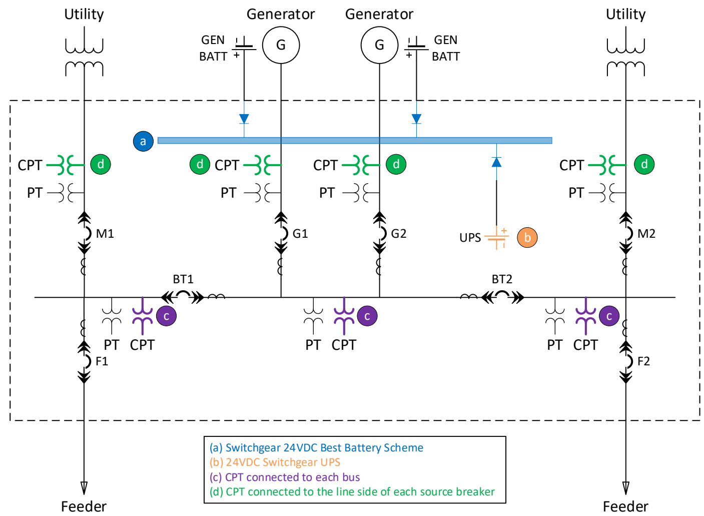


Figure17 – Requirements for a control power scheme typically found in low-voltage switchgear applications.

Note that in low-voltage switchgear applications it is not common to find external station batteries or UPS backed control power supplying the switchgear. Because of this, additional CPTs are typically required inside the switchgear. The devices inside the switchgear are powered as follows:

- 120VAC powered hardware: All breaker spring charge motors.
- 24VDC powered hardware: All other breaker hardware (shunt trip, spring release, trip unit), protective relays, power meters, HMI's, pilot lights, automation controllers, ethernet switches.

Note, that the switchgear UPS should be fed from an emergency panel (similar to the generator battery chargers), but if an emergency panel circuit is not available it may be required to utilize an AC control power throwover or multiple 24VDC power supplies in the switchgear to make sure there is redundancy in the power that charges the UPS.

Typical Generator Breaker Schematic

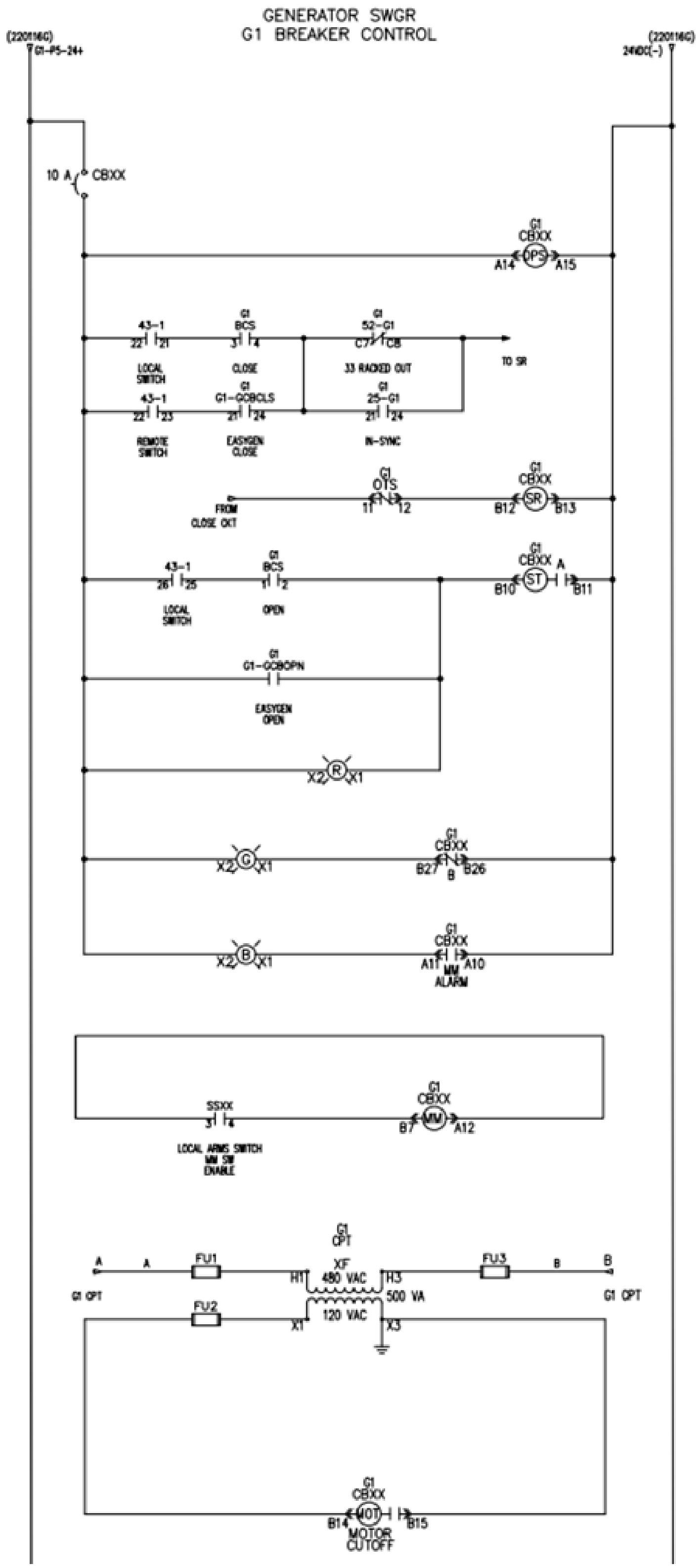


Figure 18 – Typical Generator Breaker Schematic

The generator breaker schematic shown here is typical for low-voltage switchgear. The 24VDC control power is shown feeding the trip unit, close circuit, trip circuit, and breaker status lights. The breaker close commands (auto & manual) are interlocked by the local/remote switch, backup sync check relay, and protective trip status. The dedicated, line connected CPT provides 120VAC control power to the spring charge motor.

Medium-voltage Switchgear

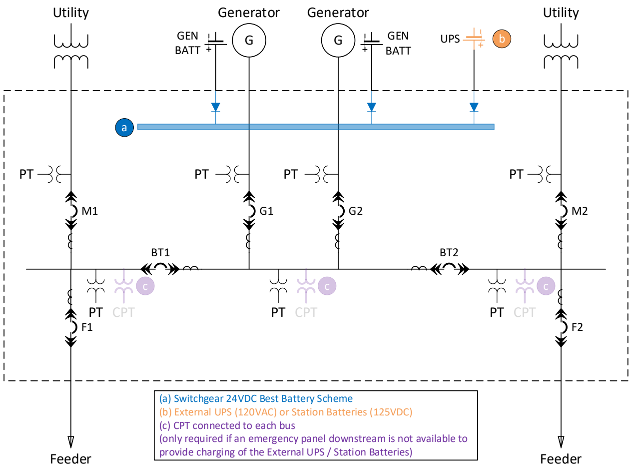


Figure 19 - Requirements for a control power scheme typically found in medium-voltage switchgear applications.

Note that in medium-voltage switchgear applications it is more common to find external station batteries or UPS backed control power supplying the switchgear. Because of this, additional CPTs are not typically required inside of the switchgear. The devices inside the switchgear are powered as follows:

- 120VAC or 125VDC powered hardware: All Breaker Hardware (spring charge motor, shunt trip, spring release, trip unit), breaker status pilot lights, protective relays.
- 24VDC powered hardware: Power Meters, HMIs, Automation Controllers, Ethernet Switches, Automation Pilot Lights

Note, that the station battery charger should be fed from an emergency panel (similar to the generator battery chargers), but if an emergency panel circuit is not available it may be necessary to add bus connected CPTs to feed the input of the station battery charger.

For additional information on Eaton VCP-W circuit breakers and control power considerations review Application Paper AP083012EN.

Sizing of External Station Batteries

The information provided in this section is meant to provide high level guidance for sizing lead acid station battery systems or UPSs in support of switchgear. It is recommended to consult IEEE 485 (Recommended Practice for Sizing Lead-Acid Batteries for Stationary Applications) for more detailed guidance and background. In general, it is important to consider the following factors when sizing the battery system: load profile, ambient temperature, battery aging, and spare capacity for future expansion. This section provides the information that a battery manufacturer needs to size the batteries and battery charger. The general steps are:

1. Calculate Total Momentary Loads
2. Calculate Total Continuous Loads
3. Define the Load Profile
4. Submit Details to Acquire Amp-Hour and Battery Charger Sizing

1. Calculate Total Momentary Loads

Momentary Loads are loads lasting less than 1 minute such as Breaker Spring Charge Motors (<10 sec), Breaker Shunt Trip (<1 sec), Breaker Spring Release(<1 sec). When taking these loads into account in lead acid battery applications it is typical to account for the largest load contribution for a period of 1 minute per event even though these loads will last for much shorter lengths of time. There are two unique momentary load events, a breaker tripping event and a breaker closing event. The load associated with the tripping event is the sum of all shunt trip currents from each automatically controlled breaker. The load associated with the breaker closing event includes the spring release current and the spring charge motor current, but considering these currents happen in quick succession, the loading on the batteries is predominately from the spring charge motor. That said, only the spring charge motor will be considered for the breaker closing event. It is also acceptable to consider any regulation built into the automation system that will limit how many automatically controlled breakers can be closed simultaneously. If applying a regulation like this, it is best practice to consider that all generator main breakers, tie breakers, and <10sec load breakers be operable simultaneously.

Table 8 - LV and MV Breaker Control Power Current Draw

Low-voltage Breaker	**Control Power (Voltage)**	**Motor Running Current (Amps)**	**Motor In-Rush Current (Amps)**	**Motor Duration (Seconds)**	**Trip / Close Current (Amps)**	**Trip / Close Duration (Seconds)**
Magnum Breaker (Reference Instructional Booklet IB2C12060H12)	120VAC/VDC	2	12	5	4	0.04
	48VDC	5	25	5	5	0.04
	24VDC	12	36	5	11	0.04
Medium-voltage Breaker	**Control Power (Voltage)**	**Motor Running Current (Amps)**	**Motor In-Rush Current (Amps)**	**Motor Duration (Seconds)**	**Trip / Close Current (Amps)**	**Trip / Close Duration (Seconds)**
VCP-W Breaker (Reference Application Paper AP083012EN)	120VAC/VDC	4	16	6	7	0.05
	48VDC	9	36	6	16	0.05

Tripping Event Current=(#Simult.Auto Brkrs)*(Trip Coil Current)

Closing Event Current=(#Simult.Auto Brkrs)*(Motor In Rush Current)

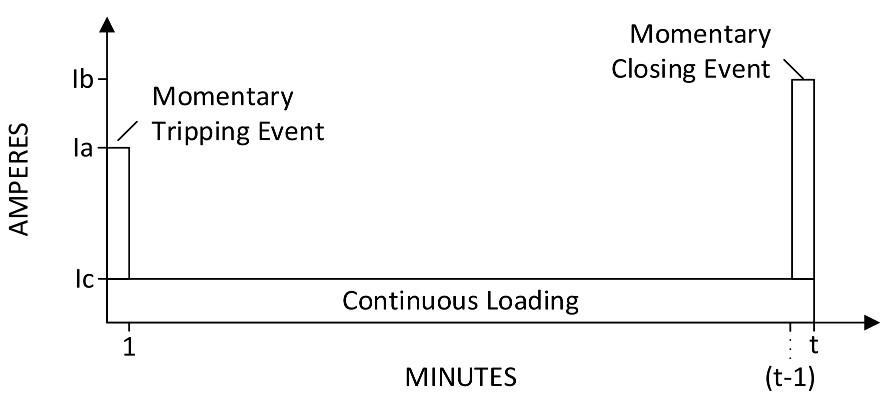
2. Calculate Total Continuous Loads

Continuous Loads are the steady state loads that are always energized, such as automation controllers, protective relays, meters, pilot lights, HMIs etc. Typical values that can be used for preliminary estimation are as follows:

Typical Devices	Watts (min.)	Watts (max)	Control Power (Voltage)	Amps (min)	Amps (max)
Digital Meter Digital Protective Relay Generator Controller	20	50	120	0.17	0.42
			48	0.42	1.04
			24	0.83	2.08
PLC I/O Drop	24	100	120	0.2	0.83
			48	0.5	2.08
			24	1	4.17
HMI	25	50	120	0.21	0.42
			48	0.52	1.04
			24	1.04	2.08
Communication Gateways Ethernet Switches	8	30	120	0.07	0.25
			48	0.17	0.63
			24	0.33	1.25
Indicating Lights Auxiliary Control Relays	1	1	120	0.01	0.01
			48	0.02	0.02
			24	0.04	0.04

3. Define the Load Profile

Once the total momentary loads and continuous loads are identified, a load profile can be created. The load profile is built based on defining the duration and frequency of the Momentary and Continuous Loads. A typical switchgear load profile is shown below:



Ia (trip) =	Amps	(Momentary Tripping Event Current)
Ib(close) =	Amps	(Momentary Closing Event Current)
Ic (continuous)=	Amps	(Continuous Load Current)
t =	Minutes	(Battery Charge Duration)

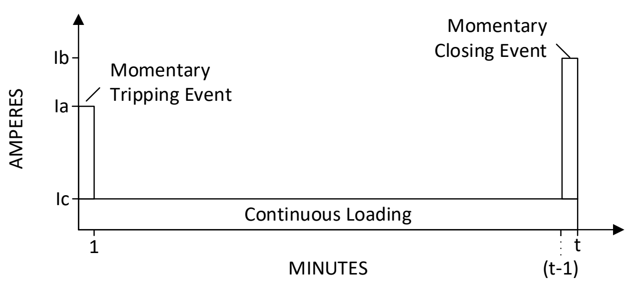
4. Submit Details to Acquire Amp-Hour and Battery Charger Sizing

When calculating the total amp-hour capacity required it is recommended to design in 15% spare capacity and an additional 25% oversizing to account for battery aging. Note that the battery performance will decrease as the ambient temperature decreases from nominal (77 degrees) so it is important to specify the ambient temperature the batteries will be exposed to.
The battery manufacturer will calculate the station battery amp hour capacity and battery charger based on the following equation:

Battery Size=(Calculated size based on load profile & battery properties)*(Ambient Temperature Factor)*(Capacity Factor)*(Aging Factor)

An example submission to station battery manufacturers used for defining the station battery and battery charger sizes is shown below:

Ia(trip)=	70	Amps	(Momentary Tripping Event Current)
Ib(trip) =	160	Amps	(Momentary Closing Event Current)
Ic(continuous) =	5	Amps	(Continuous Load Current)
t =	480	Minutes	(Battery Charge Duration)
Vin =	240 AC	Volts	(Battery Charger Input Voltage)
Vout =	125 DC	Volts	(Battery Charger Output Voltage)
Amb. Temp =	77	Deg F	(Ambient Temperature of Batteries)
Cap. Factor =	15	% (Ah)	(Percent Spare Capacity Required)
Aging Factor =	25	% (Ah)	(Percent Oversizing / Degradation)
Altitude =	100	ft	(Altitude Above Sea Level)
Batt Type =	VRLA	(VRLA/NiCd)	(Battery Type)
Seismic =	yes	(yes/no)	(Seismic Requirements)
Spill Cont. =	yes	(yes/no)	(Spill Containment)
Location =	Indoor	(Indoor/Outdoor)	(Location - Indoor or Outdoor)



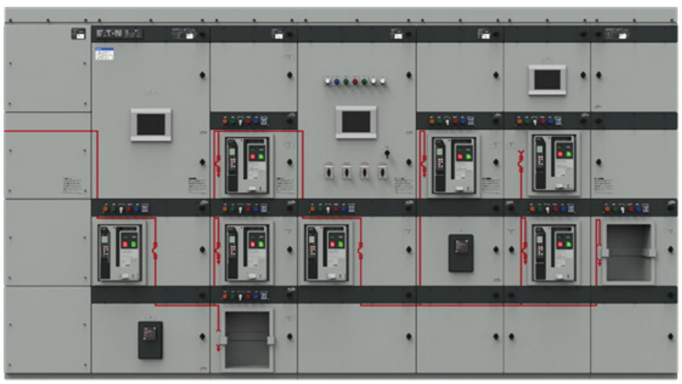
Please provide the following details for the station battery system that will meet the above requirements.

Battery Bank Size (Ah) and Manufacturer Model:_______________________

Battery Charger Size (Amps) and Manufacturer Model:____________________

Instrumentation

Intuitive operator feedback and control are focal points of the Eaton design. Instrumentation hardware includes industrial control switches, pilot lights, pushbuttons, and graphical user interfaces (GUIs). The combination of these devices provides the user instantaneous high-level status of the power system and the ability to dive deeper into events or take manual control as necessary. Eaton's design ensures system maintainability and uptime by using high quality off-the-shelf hardware, redundancy, and distributed controllers / autonomy to remove dependencies that would otherwise compromise the entire control system.



Industrial Control Switches

1. **Primary Mode Control Switch [default: Auto] –** action: maintained
    - a. **Auto –** All breakers and generators will be commanded by the Primary controller based on the soft modes selected in the Primary GUI.
    - b. **Manual –** All breakers and generators will remain in the existing state, the Primary controller will not initiate commands. All breaker and generators must be manually controlled using local controls.
1. **Breaker Mode Switch [default: Remote] – action: maintained**
    - a. **Local –** Enables operator breaker control using the breaker control switch; this disables breaker control by the Primary controller.
    - b. **Remote –** Enables the Primary controller for breaker control; this disables commands from the breaker control switch.
1. **Breaker Control Switch [default: Neutral] – action: momentary spring return to center**
    - a. **Open –** sends an open command to the breaker when the breaker mode switch in in Local.
    - b. **Neutral –** normal, center position
    - c. **Close –** sends a close command to the breaker when the breaker mode switch in in Local.
1. **Maintenance Mode [default: Disabled] – action: maintained**
    - a. **Enabled –** reduces the instantaneous trip setting of the associated breaker, thus reducing the incident energy experienced in case of an arcing fault.
    - b. **Disabled –** restores the instantaneous trip settings in the breaker to the normal coordination settings provided from the coordination study.

Pilot Lights / Pushbuttons / Horn

1. **Auto Light [White] –** Indicates that the Primary controller is in Auto.
2. **Alarm Light [Amber] –** Indicates that there is an abnormal condition present in the automation system, prompting the operator to consult the Primary GUI to diagnose and correct the abnormal condition. This light can be found in the following states:
    - a. OFF – No alarms present
    - b. ON blinking – New unacknowledged alarm present
    - c. ON solid – Alarms present, but alarms have been acknowledged
3. **Alarm Horn –** Indicates that there is an unacknowledged alarm present in the Primary GUI.
4. **E-Stop Pushbutton (each generator breaker) –** Initiates a hard shutdown of the engine and opens the generator breaker.
5. **Alarm Acknowledge/Reset Pushbutton -** Pressing this button acknowledges all active alarms. To Reset alarms, the Primary controller must first be disabled or the Primary Mode in the Primary GUI needs to be in HMI Manual Mode, then pressing and holding this button for two seconds will reset any latched alarms. If alarms are still present after initiating a Reset, then the condition is still present and needs to be addressed before attempting to Reset again.
6. **Breaker Status Lights (each breaker)**
    - a. Open [Green]
    - b. Closed [Red]
    - c. Tripped [Amber]
    - d. Maintenance Mode [Blue]

Graphical User Interfaces (GUIs)

1. Primary Graphical User Interface (GUI)
    - a. (see Primary Graphical User Interface Section)
2. Generator Graphical User Interface (GUI)
    - a. (see Generator Graphical User Interface Section)

Optional Instrumentation

While in most commercial and industrial applications it is not necessary or advisable to introduce additional components into the design, there are some applications that require the use of analog instrumentation. Eaton offers the following optional features:

1. **Annunciator Panels –** Before digital screens (HMIs, GUIs, etc) the best way to organize and visualize binary statuses was through individual incandescent lights covered by colored and engraved glass with a status message engraved upon it. More than just tiled lights, these annunciators had some "intelligence" built into them that involve various illumination sequences, allowing the operator to diagnose the status of the system or quickly evaluate alarm priority. The same information is now displayed redundantly through a dedicated generator GUI (at each generator breaker) as well as in the Primary GUI (one or more locations). GUIs also provide additional information such as sequence of events, time and date stamping, sorting of events and alarms, and of course visualization of binary statuses in the same familiar tiled annunciator view that

some operators are accustomed to. Every design comes with these features built into the GUIs. If the customer prefers having additional hardware annunciators above each generator breaker and at the Primary control panel, the following hardware can be provided as an add-on option.

a. **Lighted Primary Annunciator –** Standard system statuses / alarms will be annunciated and are customizable during the submittal process.

b. **Lighted Generator Annunciator –** Standard generator statuses / alarms will be annunciated and are customizable during the submittal process.

2. **Manual Synchronization (Sync) Control Panel –** Somewhat of a misnomer, manual sync control panels only provide a redundant way to observe differences between two power sources that are not in parallel. In the past, this was the best way for an operator to observe two sources being manually manipulated by other means before paralleling the sources together. Now, all synchronizing activities are controlled automatically by dedicated synchronizing and load share controllers and the same visuals are provided through graphical screens for the operator so that if deemed necessary, the voltage and frequency setpoints can be adjusted through the synchronizing and load share controllers. The sync panel in and of itself does not provide a means for controlling the two sources. The generator controller that is used for synchronizing and load sharing must be viable to continue to run the generators isochronously while in parallel. If the customer prefers having a sync panel, the following hardware can be provided as an add-on option:

    a. **Synchroscope –** Phase Angle Difference, Frequency Slip Speed, Frequency Fast/Slow

    b. **Sync Lights –** Redundant incandescent bulbs provide voltage magnitude difference feedback, comparing the generator source and the bus.

        1. Bright sync lights indicate a large voltage difference between the generator source and the bus. When used in concert with the synchroscope the lights are brightest when the synchroscope is at the 6 o'clock (out of phase) position.

        2. Dim or off sync lights indicate a low or minimal voltage difference between the generator source and the bus. When used in concert with the synchroscope the lights should extinguish when the synchroscope is at the 12 o'clock (in-phase) position.

    c. **Generator Voltage Analog Meter –** Measured in Volts or Kilovolts, indicates the real time AC voltage magnitude of the generator source that is to be paralleled to the bus.

    d. **Bus Voltage Analog Meter –** Measured in Volts or Kilovolts, indicates the real time AC voltage magnitude of the referenced bus that the generator is to be paralleled to.

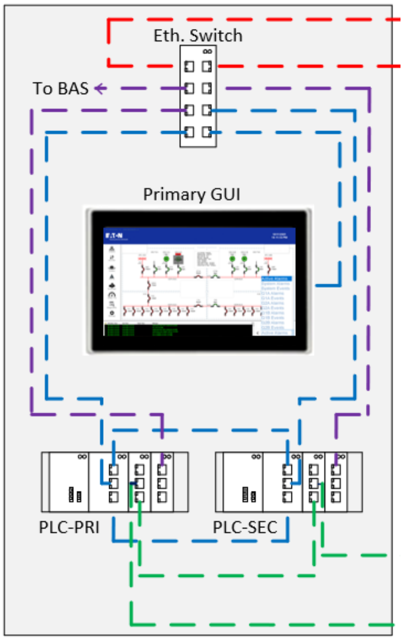
    e. **Generator Frequency Analog Meter –** Measured in Hz, indicates the real time frequency of the generator source that is to be paralleled to the bus.

    f. **Bus Frequency Analog Meter –** Measured in Hz, indicates the real time frequency of the referenced bus that the generator is to be paralleled to.

    g. **Sync Control Switch (at each generator source) –** A single keyed handle is provided that can be inserted into any one of the sync control switches located near each generator breaker. The handle is removable in the off position to only allow a single sync control switch to be enabled at a time. When enabled, the associated generator source voltage and the bus voltage is linked to the instruments on the sync panel for observation.

Primary Graphical User Interface (GUI)

Primary Control



Eaton's paralleling switchgear design takes the features found in legacy generator paralleling switchgear and updates the components to the latest technology. Traditional components are consolidated into a single GUI, eliminating components and simplifying control circuits, thereby minimizing points of failure. Additionally, high-performance HMI principles are implemented to make the system as intuitive as possible without compromising on feedback to the operator. Example screenshots from the Primary HMI are provided in this section. It is important to note that the Primary HMI is designed to serve as the main interface for an operator to interact with the entire system. Instead of adding a separate tiled primary annunciator and a primary sync panel, those features are integrated into the Primary HMI. Moreover, the system can accommodate more than one Primary HMI, running the same program, for redundancy or for the convenience of operating from multiple locations. Typically, the Primary HMI is mounted to the door of the Primary Control Section within the switchgear, however it is also common to remove the HMI from the switchgear Primary Control Section entirely and instead locate it in a wall-mount or free-standing NEMA enclosure for personnel arc flash safety.

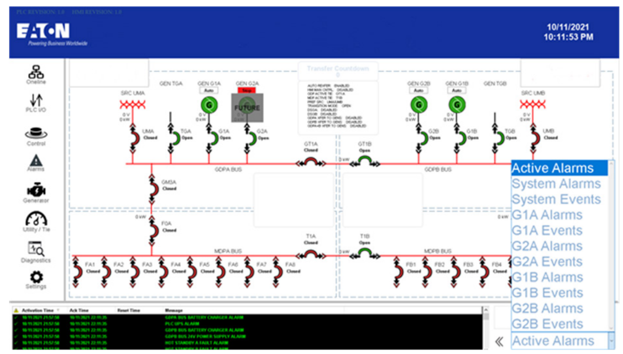
The easy-to-use HMI touchscreen makes it possible to view, monitor and perform multiple functions including:

1. Metering
2. Engine data
3. Protective relay settings
4. Annunciation
5. Active alarms/Event history
6. Adjust/View load shed controls and generator demand priority
7. Synchronization and paralleling
8. Set modes of operation, adjust timers, and settings
9. Manual operation of circuit breakers

With Eaton Paralleling Switchgear, it is simple - all the critical information you need is displayed in a manner that is easy to understand. At a glance, users can easily review how the system is performing and based on real-time information, quickly modify system operation to change or optimize system performance. The Primary GUI features standard password protection for all control and setpoint adjustment. The operator must log in to the HMI for access to certain functionality as detailed below. All users can acknowledge alarms. Additional user levels/permissions can be added, but by default each system is provided with two users:

1. **Guest (no password required) –** This user can reset alarms, but otherwise is restricted to view access only. [Default User]
2. **Operator (password: TBD) –** Access to all HMI mode switches, breaker operation, time delays and default settings. This user can reset alarms and can close the application. Auto log-out back to Guest access occurs after 5 minutes from last screen touch.

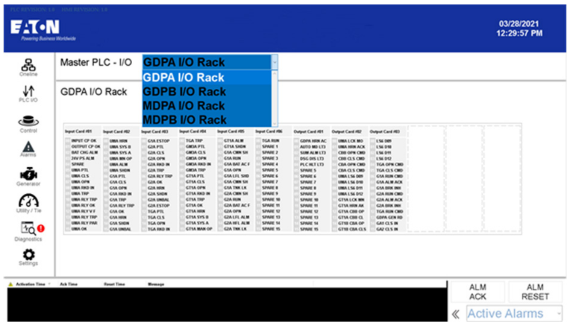
System Single-line Screen



The System Single-line Screen monitors all automatically controlled breakers within the switchgear and provides real-time feedback regarding the primary controller's mode of operation and generator status(es). Abbreviated kW metering is displayed across each source and tie breaker, eliminating the need to navigate away from the single-line screen until more detailed metering is necessary. Note: The Header (top of the screen), Navigation Menu (left of the screen), and Alarm/Event Bar (bottom of the screen) are consistently visible. The alarms and events in the Alarm/Event Bar are filtered based on the selection in the drop-down menu.

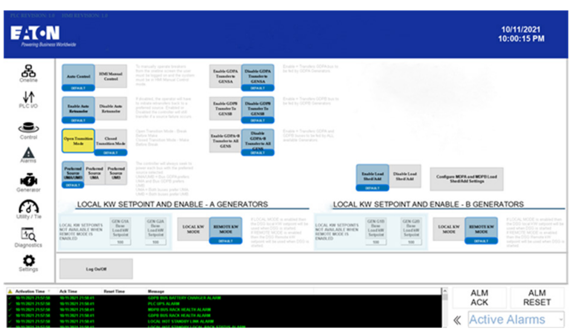
Navigation to the Control screen and selection of "HMI Manual Control" will permit manual control of the system for the operator. Upon return to the Single-line screen, the breakers are highlighted in blue, indicating that the breakers are now selectable for operation. Selecting a breaker will trigger a pop-up screen, facilitating the breaker's operation through a two-step confirmation process. Note: Following any command issued via the HMI, a countdown timer will be displayed, providing the operator ample time to move to a safe distance from the front of the switchgear before the breaker is activated. This feature allows the operator to move outside the arc flash boundary before the breaker operates.

PLC I/O Screen



Access the PLC I/O Screen to monitor the digital inputs (feedback to the Primary Controller) and digital outputs (commands and status issued by the Primary Controller), during commissioning or troubleshooting activities. The PLC I/O racks are typically distributed throughout the control system and this interface provides the operator with immediate access to the live status of each point. To monitor a specific PLC I/O rack, the operator can select it from the drop-down menu at the top of the screen, prompting the corresponding I/O statuses and descriptions to appear below. Note: Active digital input and output points will be highlighted in blue.

Control Screen



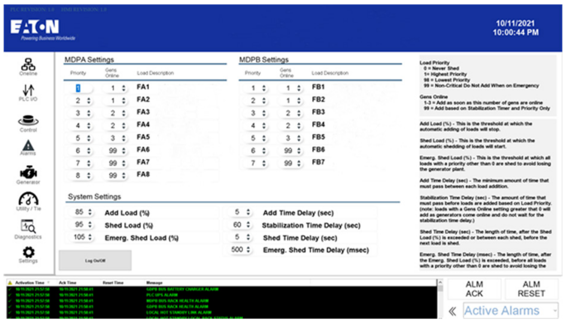
The Control Screen is where all user mode selections and descriptions are shown and can be configured by an operator logged in with the appropriate credentials. Typical modes include:

1. **Primary Mode [default: Auto Control]**
   a. **Auto Control –** PLC initiated automatic transfer operations are permitted (assuming no other automatic mode lockout alarms are present), and the HMI pushbuttons for remotely operating breakers are disabled.
   b. **HMI Manual Control –** PLC initiated automatic transfer operations are inhibited and breakers can be manually operated via pushbuttons on the remote HMIs. Latched alarm conditions may be reset via remote HMIs when this mode is enabled.
2. **Generator Test [default: Disabled] (provide a generator test mode for each generator)**
   a. **Enabled –** The PLC will call the generator to start and connect to the bus.
   b. **Disabled –** The PLC will disconnect the generator and the generator will enter cooldown.
3. **Retransfer Mode [default: Manual]**
   a. **Auto –** Retransfer to preferred utility source will occur automatically.
   b. **Manual –**The system will wait for an operator to manually initiate a retransfer back to the preferred system configuration via an “Initiate Retransfer” HMI pushbutton.
4. **Transition Mode [default: Closed]**
   a. **Open –** All Generator to Utility retransfers and Utility to Utility retransfers will cause a momentary dead bus on the associated switchgear bus during retransfer.
   b. **Closed –** All Generator to Utility retransfers will parallel the Utility and Generator and soft load/unload the generators, no dead bus will occur. All Utility to Utility retransfers will still cause a momentary dead bus on the associated switchgear bus during retransfer.
5. **Load Shed/Add [default: Enabled] (each bus)**
   a. **Enabled –** The PLC will open and close feeder breakers or inhibit ATSs according to the settings defined in the Load Shed/Add configuration screen.
   b. **Disabled –** The plc will not automatically open and close feeder breakers or inhibit ATSs.

Another common / optional mode often provided but dependent on customer preference and power system configuration is the preferred source selector switch, for example in a MTGGGTM system might include:

6. **Preferred Source Selector [default: UA/UB]**
   a. **UA –** If utility source A is healthy, the PLC will prefer to have UA, TA and TB breakers closed and the UB and G1/G2/G3 breakers open.
   b. **UA/UB –** As long as utility source A and utility source B are healthy, the PLC will prefer to have UA, UB and one of the TA/TB breakers closed, the other TA/TB breaker will be open and G1/G2/G3 breakers are open.
   c. **UB –** If utility source B is healthy, the PLC will prefer to have UB, TA and TB breakers closed and the UA and G1/G2/G3 breakers open.
   d. **GENS –** As long as generator power is available, the PLC will prefer to have G1/G2/G3, TA, and TB breakers closed and the UA and UB breakers open.

Load Shed / Add Control Screen



The Load Shed / Add Control Screen allows the operator to view and edit settings. Each feeder breaker included in the load shed / add scheme can be assigned a separate load priority level. Additionally, all load shed/add levels of the connected generator capacity and hysteresis timers are configured here. For operator reference a complete description on how to configure load shed/add levels is shown at the right of the screen.

1. **Each ATS fed by the generator paralleling switchgear must be configured with Load Priority and Gens Online setpoints.**
   a. Load Priority (assigned to each load)
      1. 0 = Never Shed
      2. 1 = Highest Priority
      3. 98 = Lowest Priority
      4. 99 = Non-Critical Do Not Add When on Emergency
   b. Generators Online (assigned to each load)
      1. 0 = Add based on Stabilization Timer and Priority Only
      2. (1..2...3...X) = Add as soon as this number of gens are online and connected
2. **Add Load (%) [default: 85%]–** This is the threshold at which the automatic adding of loads will stop.
3. **Shed Load (%) [default: 95%]–** This is the threshold at which the automatic shedding of loads will start.
4. **Emergency Shed Load (%) [default: 105%]–** This is the threshold at which all loads with a priority other than 0 are shed to avoid overloading the generator plant.
5. **Add Time Delay (sec) [default: 30sec]–** The minimum amount of time that must pass between each load addition.
6. **Stabilization Time Delay (sec) [default: 60sec]–** The amount of time that must pass before loads are added based on Load Priority. (note: loads with a Gens Online setting greater than 0 will add as generators come online and do not wait for the stabilization time delay.)
7. **Shed Time Delay (sec) [default:5sec]–**The length of time, after the Shed Load (%) is exceeded or between each shed before the next load is shed.
8. **Load Shed Sequence**
   a. When an ATS run request is received all non-priority ATSs will receive an inhibit command. This will consist of any breakers not programmed as Shed Priority level 0.
   b. The opening of these breakers is to avoid an overload condition when bringing generators online.
   c. Once the first Gen connects to the bus, the loads programmed as Gens Online = 1 are closed, constrained by the Add Time Delay.
   d. Once the second Gen connects to the bus, the loads programmed at Gens Online = 2 are closed, constrained by the Add Time Delay.
   e. Once the third Gen connects to the bus, the loads programmed at Gens Online = 3 are closed, constrained by the Add Time Delay.
   f. Once the Stabilization Time Delay completes, all remaining feeder breakers with Shed Priority between 1 and 98 are closed, constrained by the Add Time Delay.
   g. Note: Feeder breakers with Shed Priority = 99 remain open while on generator
   h. If the Add Load (%) threshold is exceeded, the automatic adding of loads will stop.
   i. If the Shed Load (%) threshold is exceeded, the automatic shedding of loads starts according to the Shed Time Delay.
   j. If the Emergency Shed Load (%) threshold is exceeded, then all loads with a priority other than 0 are shed following the Emergency Shed Time Delay to avoid losing the generator plant.
   k. When the load bus(es) are returned to utility power, all feeder breakers that are still open close back to the bus.

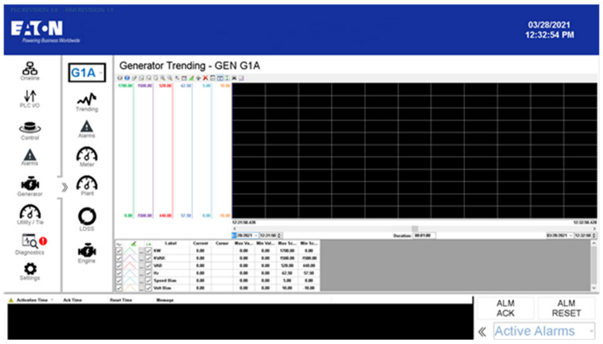
An example table is shown below as a reference to customers for how to convey load shed/add priority in design drawings:

SWITCHGEAR DESIGNATION	BREAKER DESIGNATION	DOWNSTREAM EQUIPMENT	SHED PRIORITY	GENERATORS ONLINE
MDSA	F1A	PNL1A	3	0
MDSA	F2A	SPARE	0	0
MDSA	F3A	SWBD1A	2	2
MDSA	F4A	UPSA	1	1
MDSA	F5A	PNL2A	4	0
MDSB	F1B	PNL1B	5	0
MDSB	F2B	UPSB	1	1
MDSB	F3B	PNL2B	3	0
MDSB	F4B	SWBD1B	2	0
MDSB	F5B	PNL3B	4	0

Generator Sub Menu Navigation

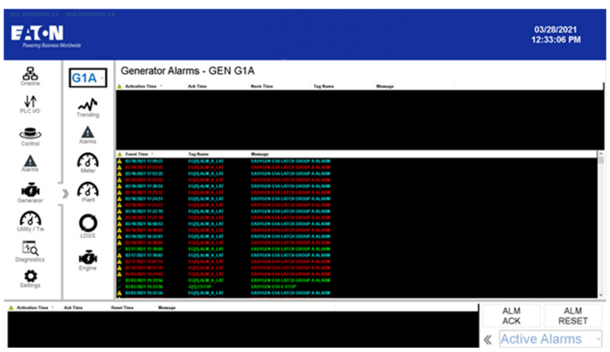
Upon selection of the generator icon in the primary navigation menu, a secondary navigation menu will be displayed. This Generator Sub Menu Navigation includes a drop-down list allowing the user to choose which generator to observe. Once a generator is chosen, the operator can use the navigation buttons within the sub menu to fill the main display area with more information about the chosen generator. Additional details for each generator screen are provided further in this document.

Generator Trending Screen



The Generator Trending Screen shows real time trended values for the generator selected. This is useful for monitoring an individual generator during load steps to see the reaction of the automation controller (speed bias and voltage bias signals) and subsequent frequency and voltage response by the generator. This screen might be used during generator tuning activities or during scheduled system testing if abnormal behavior of the generator is observed.

Generator Alarms Screen



The Generator Alarms Screen displays active alarms in the top section of the screen and the alarm/event history in the bottom section of the screen for the selected generator. This interface is essential for tracing the chronological order of events and ensuring that abnormalities in the system are promptly identified and rectified. Each Alarm/Event type is distinguished by a unique color, marked with the exact time and date, and listed with a descriptive message.

Color Coding

Red Text / Black Background = Alarm Activated

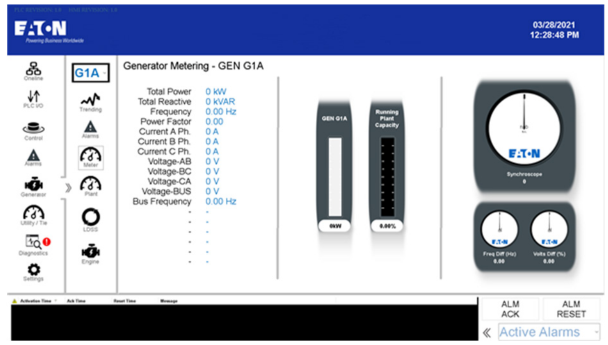
Blue Text / Black Background = Alarm Reset

Green Text / Black Background = Alarm Acknowledged

Black Text / White Background = Event (non-alarm)

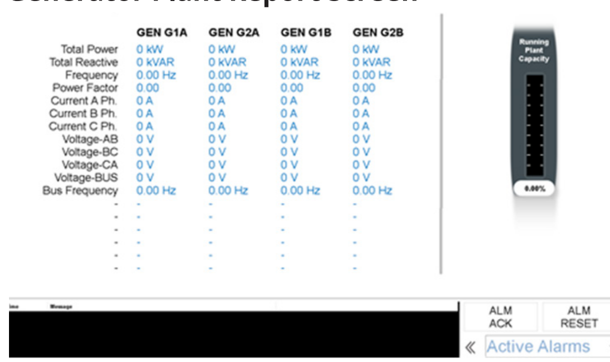
A similar screen is provided for viewing system level events and alarms. To export Alarm/Event records from the Human-Machine Interface (HMI), the operator inserts a USB drive into the HMIs rear port. Upon doing so, a button will become visible. Pressing this button will initiate the transfer of all alarm/event data to a designated directory on the USB drive. A confirmation screen will subsequently appear to confirm completion of the file transfer.

Generator Metering Screen



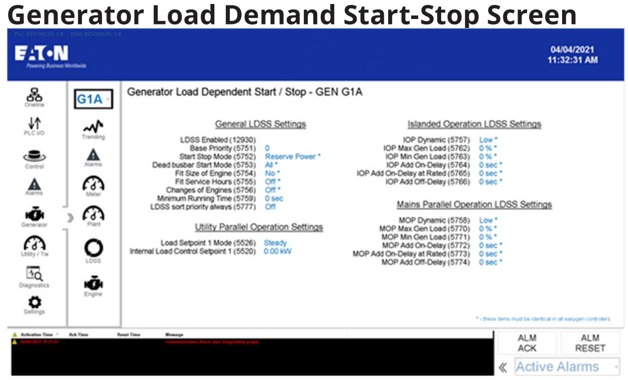
The Generator Metering Screen displays metered values for the chosen generator. The left column is dedicated to real-time metrics. The central column illustrates bus load relative to the generator's maximum capacity. The rightmost column features digital depictions of standard analog instruments that measure voltage difference, frequency difference, and phase angle difference at the generator breaker during synchronization. Note that the voltage, frequency, and synchroscope displayed on this screen are redundant to the graphical display above each generator breaker.

Generator Plant Report Screen



The Generator Plant Report Screen displays real-time metered values for each generator. It also offers a comparative overview of the total system demand versus the standby power capacity of the generator plant. Typically utilized during initial commissioning or step-load testing, this screen is critical for observing the kW and kVAR load sharing response of each generator.

Generator Load Demand Start-Stop Screen



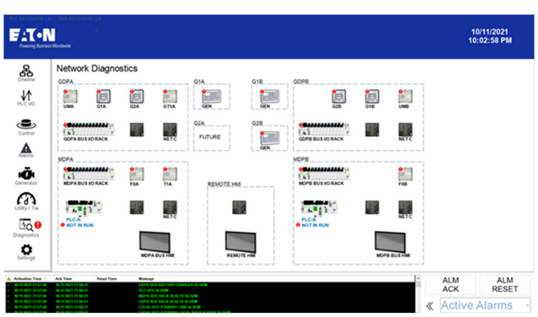
The Generator Load Demand Start-Stop Screen displays the setpoints programmed into each generator controller. The primary function of Generator Load Demand Start-Stop is to regulate the number of generators to real-time load demand, prevent underloading of generators, and ensure sufficient reserve power is available to handle load fluctuations. A typical Generator Load Demand Start-Stop sequence when in islanded operation is offered below:

Following a utility failure, the utility breaker is opened, and all generators are commanded to start and connect to the bus. The Generator Load Demand Start-Stop does not engage instantaneously; instead, the generators run for a minimum of 5 minutes during which load breakers are reset and downstream operations resume. This interval allows the power system time to reach equilibrium before the Generator Load Demand Start-Stop is activated. Following the initial 5-minute period, if the aggregate load falls beneath the preset minimum load threshold for a designated duration, a generator will disconnect from the bus and commence its cooldown sequence. Conversely, if the load surpasses the maximum load threshold for a predetermined duration, an additional generator will be brought online. The selection of which generator to start or stop in these scenarios is based on cumulative engine hours, aiming to equalize operational hours among the generators.

Engine Data Screen

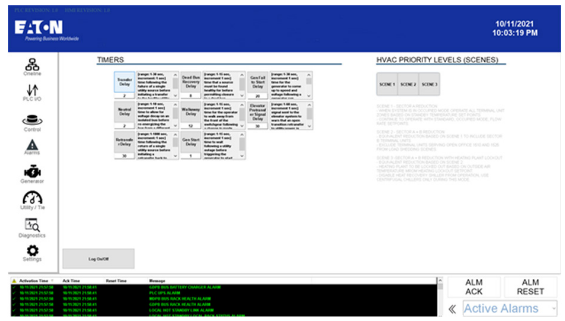
The Engine Data Screen displays real-time analog values from the engine controller attached to the engine-generator. This screen is customized based on the analog data provided by the engine controller, which depends on the sensors installed on the generator. Typically, it shows data for filtered oil pressure, engine speed, runtime, fuel consumption, oil and coolant temperatures, delivery pressure, oil pressure, boost pressure, and air temperature. If the engine generator purchased has additional analog values, Eaton will incorporate them into this screen. This allows for instant feedback to the operator, eliminating the need to access the engine generator enclosure for data collection.

Network Diagnostics Screen



The Network Diagnostics Screen serves as a vital source of feedback for the control system. Given that the system's functionality hinges on the network health, this screen alerts the operator to any communication issues with devices, allowing for preemptive action before a power event. Devices requiring attention are marked with a blinking red exclamation point. This screen is designed to offer visual feedback, illustrating both the location and status of the problematic hardware. Additionally, the alarm event screen records the time and date of any changes in device health, providing the operator with actionable information for swift assessment and resolution. Note: For easy identification, a visual representation of each device is displayed, facilitating quick recognition within the control cabinets.

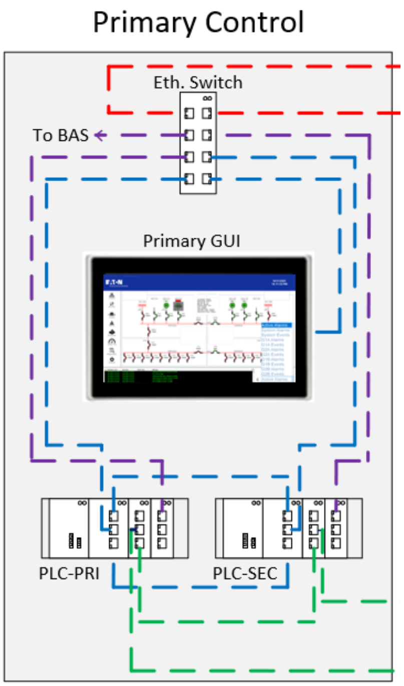
Settings Screen



The Settings Screen enables operators to modify timer setpoints, which are essential for the timing of automatic transfer sequences. Each timer is accompanied by a description and its permissible range of values. Users with the appropriate security clearance can alter timer values by pressing the designated button above each timer display. Additionally, this screen serves as a convenient hub for interfacing with a building management system (BMS), should there be a need for additional feedback or control. For example, operators can use this screen to transition the HVAC controller to a low power mode, provided the primary controller is networked with the BMS. Typical timers and descriptions are offered below:

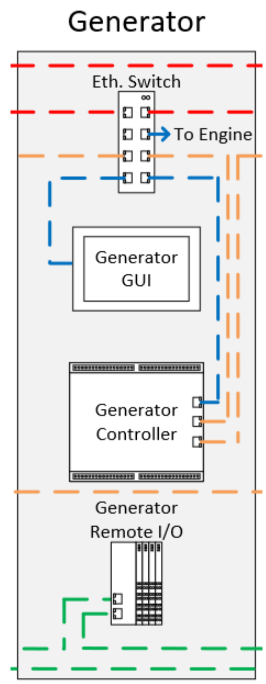
1) Transfer Delay [range: 1-30 sec, default: 2 sec] Time following the failure of a single utility source before initiating a transfer to the healthy utility source.
2) Neutral Delay [range: 1-10 sec, default: 2 sec] Time to allow for voltage decay on an isolated bus before re-energizing the bus from a different source.
3) Retransfer Delay [range: 1-3600 sec, default: 3600 sec] Time following the return of a single utility source before initiating a retransfer back to the preferred healthy utility source.
4) Dead Bus Recovery Delay [range: 1-15 sec, default: 8 sec] Time that a source must be found healthy for before permitting closure to a dead bus.
5) Walkaway Delay [range: 1-15 sec, default: 12 sec] Time for the operator to walk away from the front of the switchgear following a change in mode.
6) Gen Start Delay [range: 0-15 sec, default: 0 sec] Time to wait after a utility outage before triggering the generator to start.
7) Gen Fail to Start Delay [range: 1-30 sec, default: 30 sec] Time for the generator to come up to speed and voltage following a generator run request. If the generator does not come up to speed and voltage in this amount of time the run request will drop out.
8) Elevator Pre-Transfer Signal [range: 1-60 sec, default: 30 sec] signal sent to the elevator system to warn that an open transition retransfer to utility power is imminent.

Primary Controller



The primary controller continuously monitors each generator automation controller, each engine mounted controller, all switchgear breakers, and all I/O drops to provide complete status of the system. If the primary controller should fail it is not required for manual operation of the generators through interaction with each respective generator automation controller. The primary controller executes the Load Shed / Add logic defined by the user selections made in the Primary Graphical User Interface. The primary controller sequences all automatic transfers and commands all main and tie breakers. The primary controller is equipped with a dedicated ethernet port that is programmed for a separate ethernet subnet than the rest of the switchgear automation equipment. This port is provided for integrating primary controller data into a Building Management System (BMS) / Distributed Control System (DCS) / or Supervisory Control And Data Acquisition (SCADA) and supports a fixed Modbus TCP data map of all switchgear and generator statuses. An optional hot-standby primary automation controller can be added for redundancy, consisting of two PLC Central Processing Units (CPUs), one Primary CPU and one Standby CPU, that continuously communicate via a dedicated hot standby link. If the Primary CPU should fail, there is a seamless switchover of all controls to the Standby CPU. Each CPU, Primary and Standby, resides in its own dedicated PLC rack and connects to remote racks via a redundant ethernet ring. The hot-standby controller will continuously monitor each generator automation controller, each engine mounted controller, and all I/O drops to provide complete status of the system. I/O drops allow for monitoring and control of all breakers and for monitoring and control of the generators. The I/O drops house digital input and digital output cards wired out to the components of the system to be monitored and controlled.

Generator Automation Controllers and Graphical User Interface (GUI)



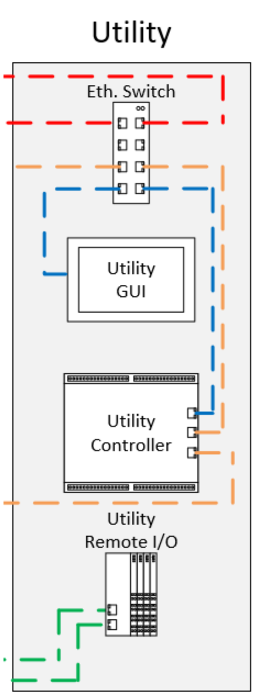
Mounted throughout the switchgear above each generator breaker are generator GUIs that focus the operator on the specific details and control of the corresponding generator. The display is an off the shelf product that does not require special software programming or graphics development in order to be deployed or replaced in the field. Eaton's paralleling switchgear design takes the features found in legacy generator paralleling switchgear and updates the components to the latest technology. Traditional components are consolidated into a single GUI, eliminating components and simplifying control circuits, thereby minimizing points of failure. It is important to note that the Generator GUI is designed to serve as the main interface for an operator to interact with the individual generator asset. Instead of adding a separate tiled primary annunciator and a primary sync panel, those features are integrated into the Generator GUI.

The generator automation controllers include the following features:

1) A display with buttons for settings navigation and generator mode control.
2) All settings within the automation controller can be viewed/edited from the display.
3) Editing software is provided with the automation controller to allow monitoring and editing of all logic and set points from a computer.
4) The display is password protected.
5) The controller is non-proprietary such that the customer can purchase a replacement controller and program and install the new controller without relying on any single service provider.
6) Provides synchronizing of the generator to the bus across the generator main breaker.
7) Regulates voltage and frequency of the generator.
8) Provides kW and kVAR load sharing with up to 32 other generator automation controllers.

9) Has three ethernet ports; one ethernet port connects to a dedicated monitoring and control network via Modbus TCP, while the other two ethernet ports are programmed as hot redundant load share ports connected to redundant networks.
10) Provides three-phase true RMS power sensing with Class I accuracy
11) Provides the following operation modes: AUTO, STOP, MANUAL, and TEST - accessible from the controller.
12) Provides adjustable breaker control settings for slip frequency or phase matching synchronization, automatic and manual open / close control, and breaker monitoring.
13) Provides stand-alone load transfer capability or direct coordination with other automation controllers to accomplish open / closed transition, interchange, soft loading / unloading, and Utility parallel.
14) Provides for remote control via Modbus TCP interface and via discrete/analog inputs for adjusting speed, frequency, voltage, power, reactive power, and power factor set points
15) Provides built-in system diagnostics that ensure every automation unit recognizes other automation units in the network and can isolate root-cause networking issues.
16) Provides Time / Date synchronization over Simple Network Time Protocol (SNTP)
17) A failure of any singular generator automation controller only affects the generator that it controls, all other generator automation controllers and associated generators are unaffected.

Utility and Tie Automation Controllers and Graphical User Interface (GUI)



In the case where the generators must be paralleled across multiple buses or paralleled to a utility source, dedicated tie and utility automation controllers are used. Each automation controller is supplied with a GUI that provides local monitoring and control of the breaker. The automation controller has a similar form factor to the generator automation controller and includes the same types of features. The only exception is that the voltage and current measurements in the Utility/Tie automation controller are shared over the sync/load share network with the generator plant and the generator automation controller provides the active control of the generator.

The Utility/Tie automation controllers include the following features:

1) A display with buttons for settings navigation and mode control.
2) All settings within the automation controller can be viewed/edited from the display.
3) Editing software is provided with the automation controller to allow monitoring and editing of all logic and set points from a computer.
4) The display is password protected.
5) The controller is non-proprietary such that the customer can purchase a replacement controller and program and install the new controller without relying on any single service provider.
6) Provides synchronizing data to generator automation controllers.
7) Provides kW and kVAR data to generator automation controllers.
8) Has three ethernet ports; one ethernet port connects to a dedicated monitoring and control network via Modbus TCP, while the other two ethernet ports are programmed as hot redundant load share ports connected to redundant networks.
9) Provides three-phase true RMS power sensing with Class I accuracy
10) Provides the following operation modes: AUTO, STOP, MANUAL, and TEST - accessible from the controller.
11) Provides adjustable breaker control settings for slip frequency or phase matching synchronization, automatic and manual open / close control, and breaker monitoring.
12) Provides stand-alone load transfer capability or direct coordination with other automation controllers to accomplish open / closed transition, interchange, soft loading / unloading, and Utility parallel.
13) Provides for remote control via Modbus TCP interface.
14) Provides built-in system diagnostics that ensure every automation unit recognizes other automation units in the network and can isolate root-cause networking issues.
15) Provides Time / Date synchronization over Simple Network Time Protocol (SNTP)
16) A failure of any singular generator automation controller only affects the generator that it controls, all other generator automation controllers and associated generators are unaffected.

Auxiliary Control Options

The generator paralleling switchgear control system can accommodate additional auxiliary control needs including integrating louver control, fuel control, load bank control, etc. Contact Eaton for additional guidance/coordination with these requirements.

Typical Control Circuit Interconnect Wiring

Function	(Quantity)/Size/Type of Cable①②	Signal Type③	Description
Generator Control (Conduit: Switchgear to each Generator)			
Engine Generator Data Interface	(qty.1) Shielded CAT6 Ethernet	Signal	Network communications for monitoring of engine data.
Engine Generator Digital I/O	(qty.16) #14 AWG	DC <= 30VDC	Discrete monitoring and control (start signal, e-stop, critical alarms, etc.)
Control Power (24VDC)	(qty.4) #10 AWG	DC <= 30VDC	24VDC from generator battery system to supplement switchgear 24VDC control power
Speed/kW Control	(qty.1) #16 AWG Shielded-Twisted Pair	Signal Level	Analog bias signal to the engine governor
Voltage/VAR Control	(qty.1) #16 AWG Shielded-Twisted Pair	Signal Level	Analog bias signal to the generator's voltage regulator
Battery Systems (Conduit: Switchgear to Station Batteries, except Charging Power which is Emergency Circuit to Station Batteries)			
120VAC Charging Power for 24VDC Station Battery or Switchgear 24VDC UPS	(qty.3) #12 AWG	AC Control	120VAC / 20A emergency circuit to charge station batteries or switchgear UPS
24VDC Station Battery Output	(qty.4) #10 AWG	DC <= 30VDC	24VDC supply from station batteries to switchgear controls
24VDC Station Battery Digital I/O	(qty.2) #14 AWG	DC <= 30VDC	Station battery alarm to switchgear controls
120VAC Charging Power for 125VDC Station Battery④	(qty.3) #10 AWG	AC Control	120VAC / 40A emergency circuit to charge station batteries
125VDC Station Battery Outpud④	(qty.4) #10 AWG	125VDC	125VDC supply from station batteries to switchgear controls
125VDC Station Battery Digital I/O④	(qty.2) #14 AWG	DC <= 30VDC	Station battery alarm to switchgear controls
Generator Protection Systems			
Generator Mounted Breaker Status⑤	(qty.2) #14 AWG	DC <= 30VDC	Breaker status & alarm (if open)
Generator Differential CTs	(qty.6) #10 AWG	AC Control	87G relay alarm/shutdown
Neutral Grounding Resistor CT④	(qty.2) #10 AWG	AC Control	51G relay alarm/shutdown
Automatic Transfer Switch Interface (Per ATS) (Conduit: Switchgear to each ATS)			
ATS Data Interface	(qty.1) #16 AWG Shielded-Twisted Pair	Signal	Modbus communication for monitor / control of ATS
Engine Start ATS Position ATS Load Shed	(qty.2) #14 AWG (qty.4) #14 AWG (qty.2) #14 AWG	DC <= 30VDC	Engine Start Request Normal and emergency status Load shed/load add
Miscellaneous (Optional) (Conduit: Switchgear to each ATS)			
Misc. Alarms	(qty.2) #14 AWG (each)	DC <= 30VDC	Additional alarms/shutdowns
Space heaters	(qty.3) #10 AWG	AC Control	120VAC / 30A for switchgear space heaters. (per 10 structures)
Remote HMIs	(qty.2) #14 AWG (qty.1) Shielded CAT6 Ethernet	DC <= 30VDC Signal	DC Control Power Network Communications
BMS / SCADA	(qty.1) Shielded CAT6 Ethernet	Signal	Network Communications

Table 9 – Typical Control Circuit Interconnect Wiring

① All control wiring to be stranded copper unless specified otherwise. Conductor size may have to be increased for Voltage Drop over long distances.

② Recommend 20% spares of each size single conductor and one of each multi-conductor cable.

③ Separate metallic conduits should be used for each Signal Type. "Signal Level" and "DC Control Signal m 30 Vdc" wires may be combined in the same conduit.

④ Typical of most Medium-Voltage applications.

⑤ Not applicable for medium-voltage applications.

Note: Specific project and equipment requirements will determine exact number and type of control wiring required.

Typical Generator Structure Field Wiring

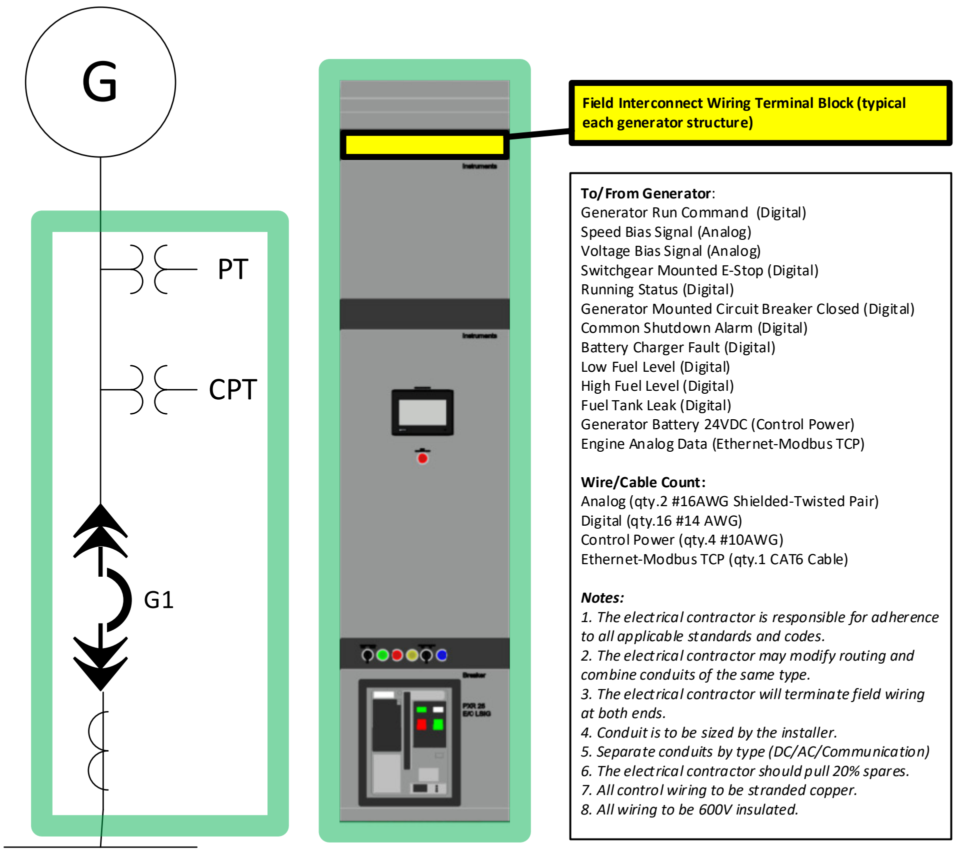


Figure 20 – Typical Conduit for Control and Communication Wiring

Reference the detail shown in this diagram while planning for control and communication wiring requirements between the switchgear and the generator. While this interface definition is typical of most systems it should be used for guidance only and the final wiring interface will be provided/defined during the project submittal process.

Other References

About Eaton

Every day, all around the world, people depend on technology, transportation, energy and infrastructure to live and work. At Eaton, we are dedicated to improving the quality of life and the environment with sustainable power management technologies that are more reliable, efficient, and safe. With rapid growth in electrification, an energy transition driven by climate change, and explosive growth in connectivity, we are well positioned to solve some of the world's toughest electrical, hydraulic, and mechanical power management challenges. Because that is what really matters. And we are here to make sure it works.

We are an intelligent power management company made up of approximately 85,000 employees, doing business in more than 175 countries. We work to make a positive impact on the world by giving people the tools to use power more efficiently, helping companies do business more sustainably and encouraging every Eaton employee to think differently about our business, our communities and how we can help create a better future. For more information, visit Eaton.com.

Engineering Services

Eaton's engineering services team focuses on all matters concerning power systems and has dedicated engineers focused on each power system specialty. This document was provided by Eaton's Power Systems Controls (PSC) engineers; a nationally organized team within engineering services that specializes in power automation and control and are conveniently located throughout Eaton's engineering services offices to meet local industry needs.

All Eaton field engineers receive multiple weeks of formal training at an Eaton Power System Experience Center (PSEC). Eaton has two PSEC facilities, one in Warrendale, PA and one in Houston, TX. The PSEC facilities showcase all of Eaton's products through real power demonstrations. Eaton employees learn through both classroom and hands on training at these facilities covering topics on job safety analysis (JSA), hazardous energy control (HEC), personal protective equipment (PPE), tools, test equipment, electrical drawings, and troubleshooting of electrical systems. Eaton values safety and qualifies its field personnel through a mentoring program that extends past initial training.

Eaton provides site startup services to ensure proper inspection and functional verification of the switchgear and control system before handing off to the customer. A dedicated project manager specialized in power systems controls is assigned prior to project kick-off and ensures proper coordination of the switchgear control system with other trades. All controls project managers have or are working toward Project Management Professional (PMP) certification and uphold the processes and best practices of our Project Management Office (PMO) organization. In addition to a dedicated project manager, each paralleling switchgear is also assigned a dedicated lead controls engineer who designs, programs, documents, and tests the system to assure proper delivery of the Eaton switchgear offering.

Eaton is dedicated to being a reliable manufacturer and solutions provider, upholding high safety and quality standards. We commit to:

1. To ensure compliance with quality control standards, Eaton conducts periodic audits of test procedures and test record forms to ensure compliance with industry standards. A Quality Assurance Manager, not reporting to the operation center of Eaton, completes such audits.
2. Tools, equipment, and personal protective equipment utilized by Eaton comply with the requirements of OSHA Standard 29 CFR 1910, Subpart I, and NFPA 70E.
3. The instruments and test equipment utilized by Eaton are calibrated by an accredited ISO/IEC 17025 laboratory. This laboratory is audited regularly by the National Voluntary Laboratory Accreditation Program (NVLAP).
   a. The accuracy is traceable to the National Bureau of Standards in an unbroken chain.
   b. Instruments are calibrated in accordance with the following frequency schedule:
      i. Field instruments – six to twelve months
      ii. Laboratory instruments – twelve months
   c. Dated calibration labels are visible on all instruments and test equipment.

For more information, please contact an Eaton DOC (District Operations Center).

Product Specification Guides for Generator Paralleling Switchgear

Generator Common Bus Paralleling Switchgear Guide Spec

Main-Tie-GenBus-Tie-Main Paralleling Switchgear Guide Spec

Power Systems Controls (PSC) Services

www.Eaton.com/PSC

PSC Capabilities (change the PLC platform/brand to match owner/operator preference)

Product Specification and Design Guides for LV and MV switchgear

Low-voltage Switchgear

Medium-voltage Switchgear

Features to consider include integral racking, bus differential protection, generator differential protection, neutral grounding resistors, tie breakers, surge arresters, and surge capacitors.

Definitions

The terms and acronyms below are referenced throughout this section on Generator Paralleling Switchgear. These definitions can help the reader fully understand the topics discussed.

- **Alternator:** A device for converting mechanical energy into alternating current electrical energy. It may also be called an AC or synchronous generator.
- **ATS:** Automatic Transfer Switch: A switch designed to sense the loss of one power source and automatically transfer the load to another source of power.
- **Closed-Transition Transfer:** A transfer between sources that provides a momentary paralleling of both power sources during a transfer in either direction. This results in no interruption of power to the loads during the transfer. The closed transition transfer is only possible when the sources are properly synchronized and interfaced.
- **CPT:** Control Power Transformer
- **DGPS Distributed Generation Power System:** Typically a local engine genset and automation connected to the utility system to peak shave or export power.
- **GCB-PS (Generator Common Bus Switchgear):** Parallels multiple engine/gensets to serve emergency loads transferred.
- **Emergency Generator Bus Tie:** A bus tie breaker used in GPS type systems to segregate groups of generators and/or loads. Emergency Generator Bus Tie breakers are used where critical loads, required to be powered in 10 seconds, exceed the capacity of a single genset.
- **EPS Emergency Power System:** The emergency power sources and emergency distribution to down-stream loads.
- **Emergency Standby Power Application:** Typical usage of 50 hours per year with a maximum of 200 hours per year. Generators can be applied at the Standby rating with a typical variable load factor of 70%.
- **Emergency Tie Breaker:** A feeder breaker that is used to connect an GPS type system to a separate piece of Normal (utility) switchgear.
- **Feeder Breaker Controls:** Automation controls to allow control of the distribution feeder devices for load shed/load add control and monitoring.
- **Generator:** A machine for converting mechanical energy into electrical energy. The electrical energy may be direct current (DC) or alternating current (AC).
- **Generator Bus Tie:** A bus tie used in GPS type systems for separating the generator bus and/or loads from the normal utility fed bus and/or loads.
- **Generator Start/Stop Priority:** Controls that automatically match the online engine generator capacity to the load to avoid unnecessary engine genset operation when loads are low.
- **Generator Tie Breaker:** A feeder breaker that is used to connect a GPS type system to a separate piece of Normal (utility) switchgear.
- **Governor:** A device that regulates prime mover speed by adjusting the fuel input to maintain constant speed.
- **HMI Human Machine Interface:** Typically a touchscreen used by the operator for interfacing with the paralleling generator system.
- **Co-Generation and Extended Paralleling Switchgear:** A single generator used in distributed generation power systems. Includes automation controls that allow for the load to be served simultaneously by both utility and generator power sources while managing how much each source contributes.
- **Load Shed/Load Add:** Automation controls to control distribution devices (turn OFF and restore ON) when only partial emergency engine gensets are available for duty. Typically accomplished by assigning Priority levels to each controlled distribution device.
- **Primary Controls:** All processors, HMI and programming to implement the desired modes of operation of engine gensets in a paralleling switchgear system.
- **NFPA 110 – Standard for Emergency and Standby Power Systems:** Standard for the assembly, installation and performance of electrical power systems to supply critical and essential needs during outages of the primary power source. NPS Normal Power System: The utility service entrance equipment and distribution circuits to down-stream loads.
- **NPSS Normal Power System Supplier:** Supplier of all the components of the NPS, such as the distribution equipment vendor's authorized distributor.
- **Paralleling:** The procedure of connecting two or more generators, or other power sources, of the same phase, voltage and frequency characteristics supplying the same load.
- **Peak Shaving:** Process by which utility customers minimize peak demand utility charges or exports power to the utility grid.t
- **PT:** Potential Transformer
- **Prime Power Application:** Prime Power is when the genset is the only power source.
- **Processor:** A specially configured logic controller with appropriate input-output capability and programming.
- **Station Battery:** A power supply used for control of switchgear.
- **Synchronizer:** A device that will synchronize an on-coming electric generator set with the bus or another electric generator set, and allows multiple power sources to be connected in parallel.

- **Synchroscope:** An instrument that provides a visual indication of proper time for closing of the breaker when synchronizing generators to connect them in parallel with another source.
- **Utility Protection:** A collection of protective relays or a multifunction relay required by the utility to detect abnormal conditions and open the utility breaker.
- **MG-PS (Main-Gen) Paralleling Switchgear and MTGBTM-PS (Main-Tie-GenBus-Tie-Main) Paralleling Switchgear:** Parallels multiple engine/gensets and the utility to serve downstream loads. Typically does not include downstream ATS units.

Appendix A - Example Low-voltage Switchgear Layouts

In all of the example switchgear layouts shown it is assumed that extended parallel operation is required across all source and tie breakers. It is important to note that when generator to utility paralleling is required, additional coordination is required with the power company to establish the terms of interconnect. Often power companies require specific protective relaying at generator breakers and at utility breakers and may also require transfer trip capability, allowing the utility substation relay to directly trip the main breaker to a customers facility. These requirements vary between power companies and are important to define in the bid specification to ensure these requirements are accounted for during switchgear manufacturing. However, in cases where generator to generator paralleling is required, but generator to utility paralleling is not required, utility interconnect agreements are less stringent. Additionally, the half high control panels shown above each utility source breaker and tie breaker are typically freed up for other uses (additional breaker or control panel space). Common switchgear layouts are presented in this section. Example system single-lines are depicted, followed by the corresponding switchgear layout. Each switchgear layout is assembled using the same Modular Building Blocks that were presented in the Switchgear Layout section.

Low Voltage Layout Example #1

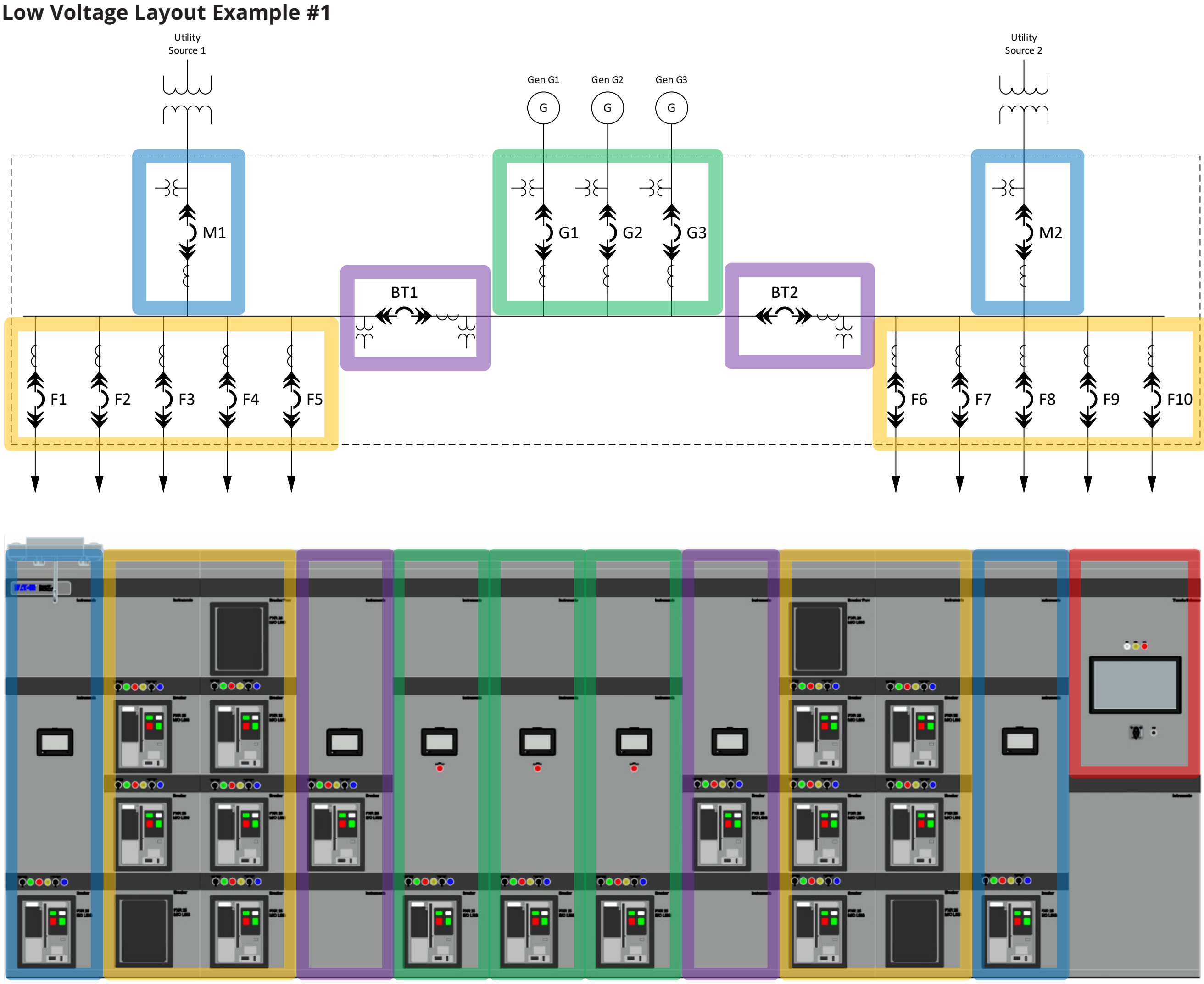
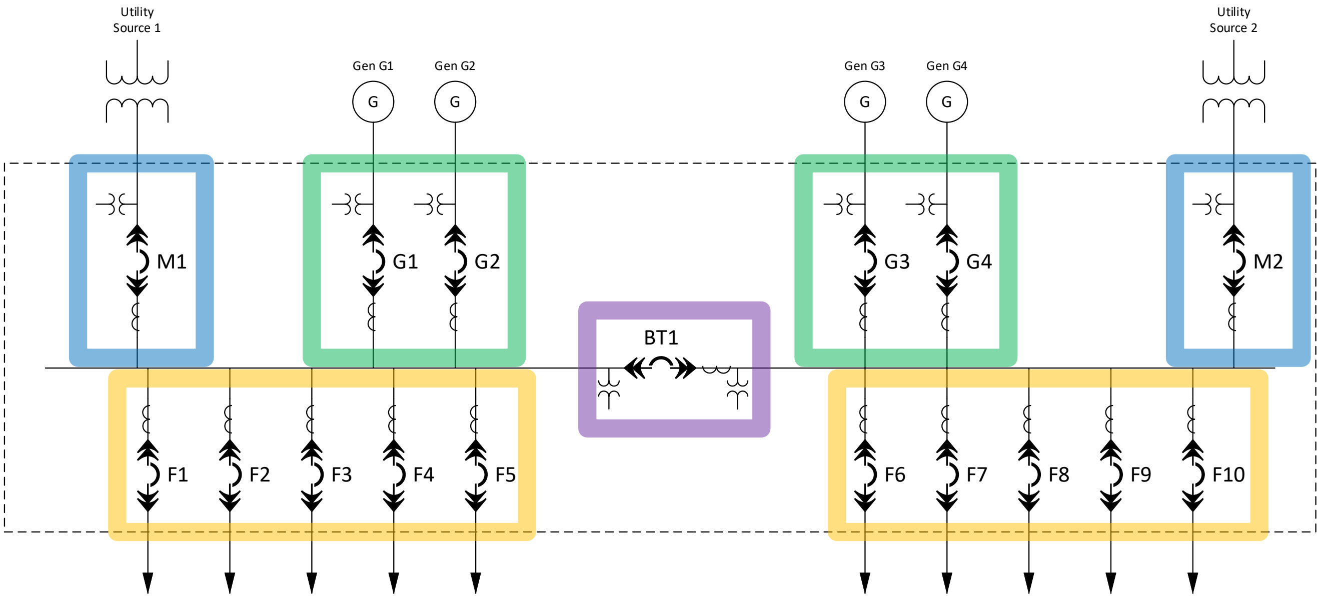


Figure 21 – MTG3TM–GPS – Low-voltage Main–Tie–Gen–Gen–Gen–Tie–Main Single–line and Switchgear Layout – Using Modular Building Blocks

Low Voltage Layout Example #2



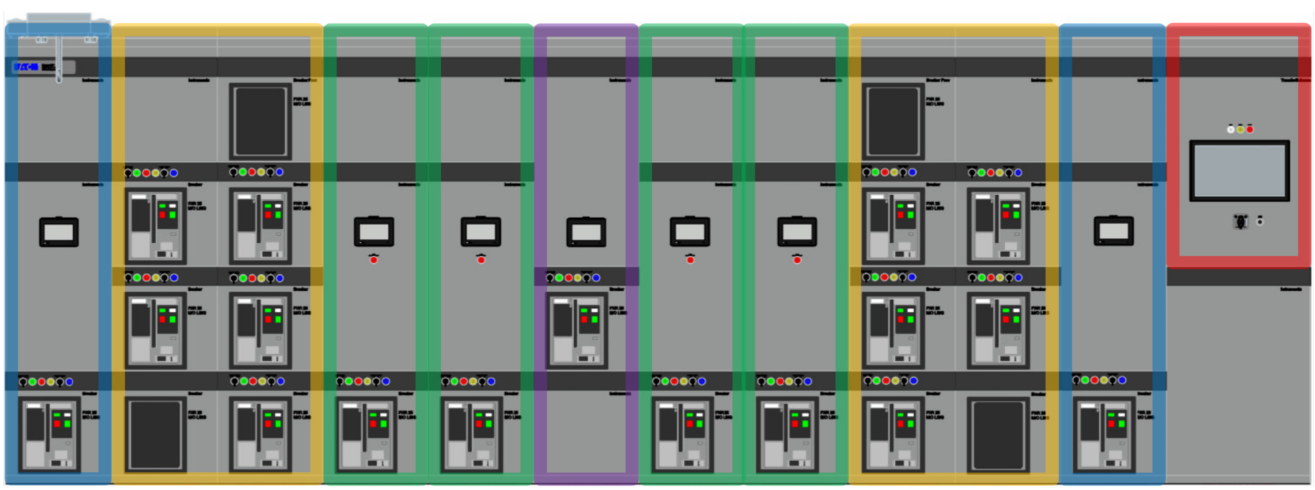


Figure 22 – MG2TG2M–GPS – Low–Voltage Main–Gen–Gen Tie–Gen–Gen–Main Single–line and Switchgear Layout – Using Modular Building Blocks

Low Voltage Layout Example #3

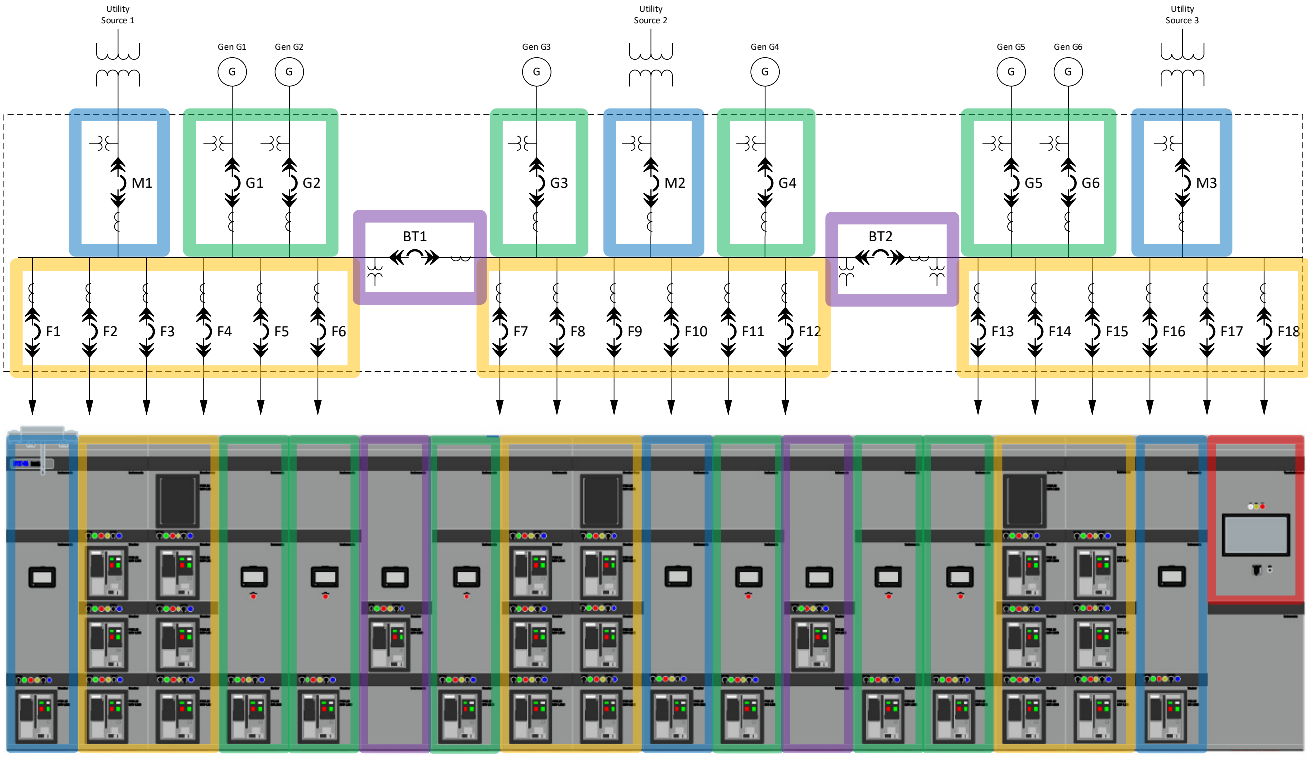


Figure 23 – MG2TMG2TMG2–GPS – Main–Gen–Gen–Tie–Main–Gen–Gen–Tie–Main–Gen–Gen Single-line and Switchgear Layout – Using Modular Building Blocks

Low Voltage Layout Example #4

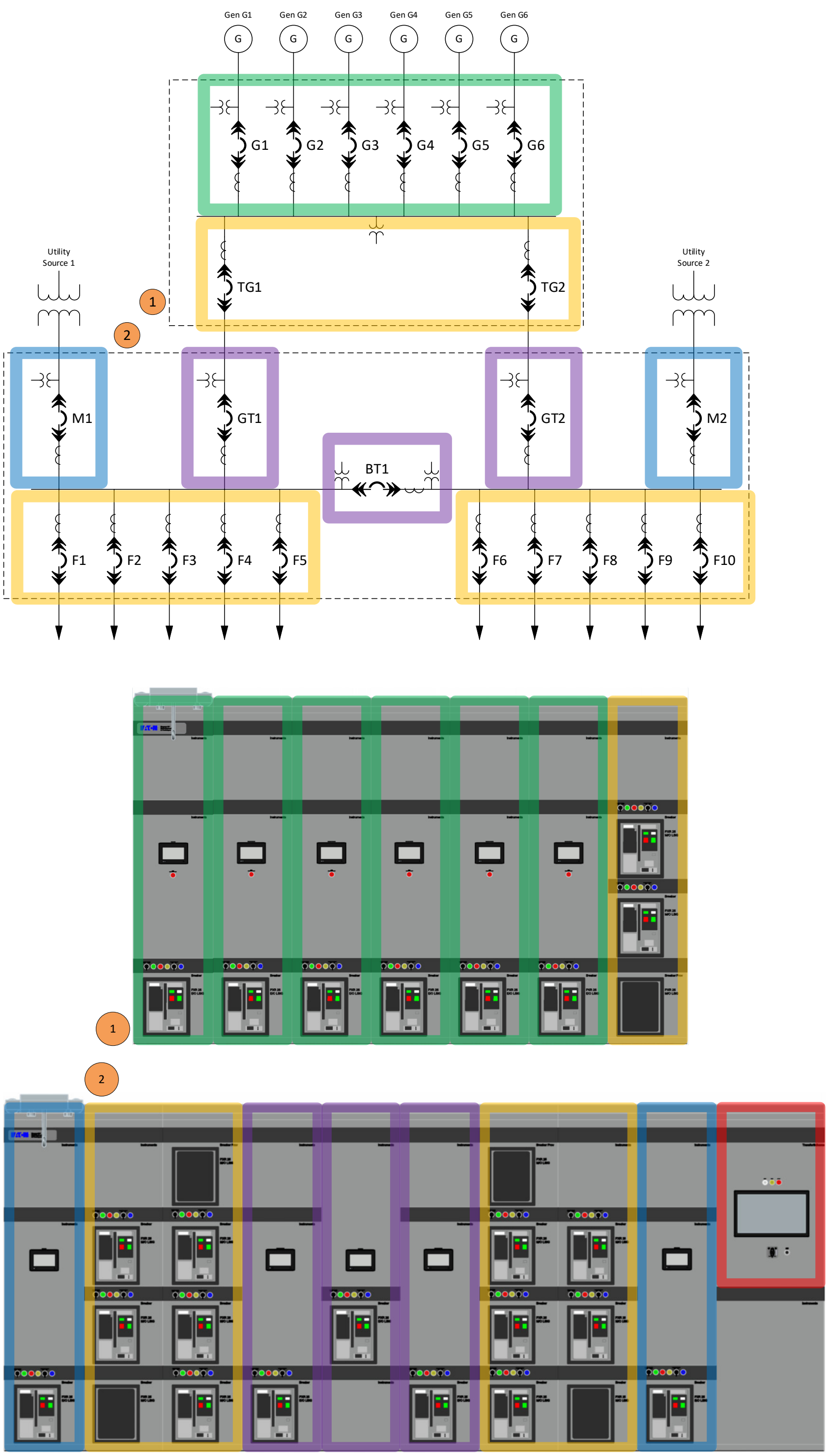


Figure 24 – GCB6-MGTGM–GPS – Generator Common Bus (6 Gen) Feeding a Main–Gen–Tie–Gen–Main Single–line and Switchgear Layout – Using Modular Building Blocks

Appendix B – Example Medium-voltage Switchgear Layouts

In all of the example switchgear layouts shown it is assumed that extended parallel operation is required across all source and tie breakers. It is important to note that when generator to utility paralleling is required, additional coordination is required with the power company to establish the terms of interconnect. Often power companies require specific protective relaying at generator breakers and at utility breakers and may also require transfer trip capability, allowing the utility substation relay to directly trip the main breaker to a customers facility. These requirements vary between power companies and are important to define in the bid specification to ensure they are accounted for during switchgear manufacturing. However, in cases where generator to generator paralleling is required, but generator to utility paralleling is not required, utility interconnect agreements are less stringent. Additionally, the control panels shown above each utility source breaker and tie breaker are typically freed up for other uses (additional control panel or PT space). Common switchgear layouts are presented in this section. Example system single-lines are depicted, followed by the corresponding switchgear layout. Each switchgear layout is assembled using the same Modular Building Blocks that were presented in the Switchgear Layout section.

Medium Voltage Layout Example #1

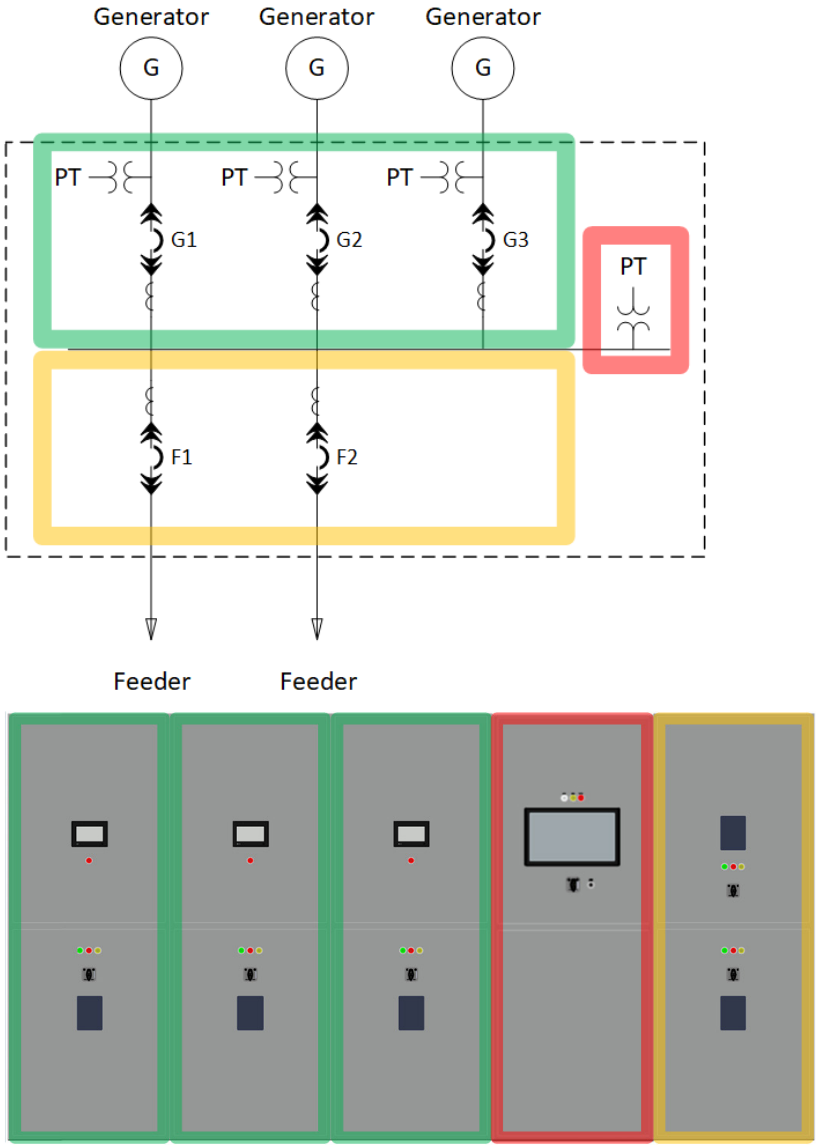


Figure 25 – GCB3–GPS – Medium–voltage Generator Common Bus (3 Gen) Single–line and Switchgear Layout – Using Modular Building Blocks

Medium Voltage Layout Example #2

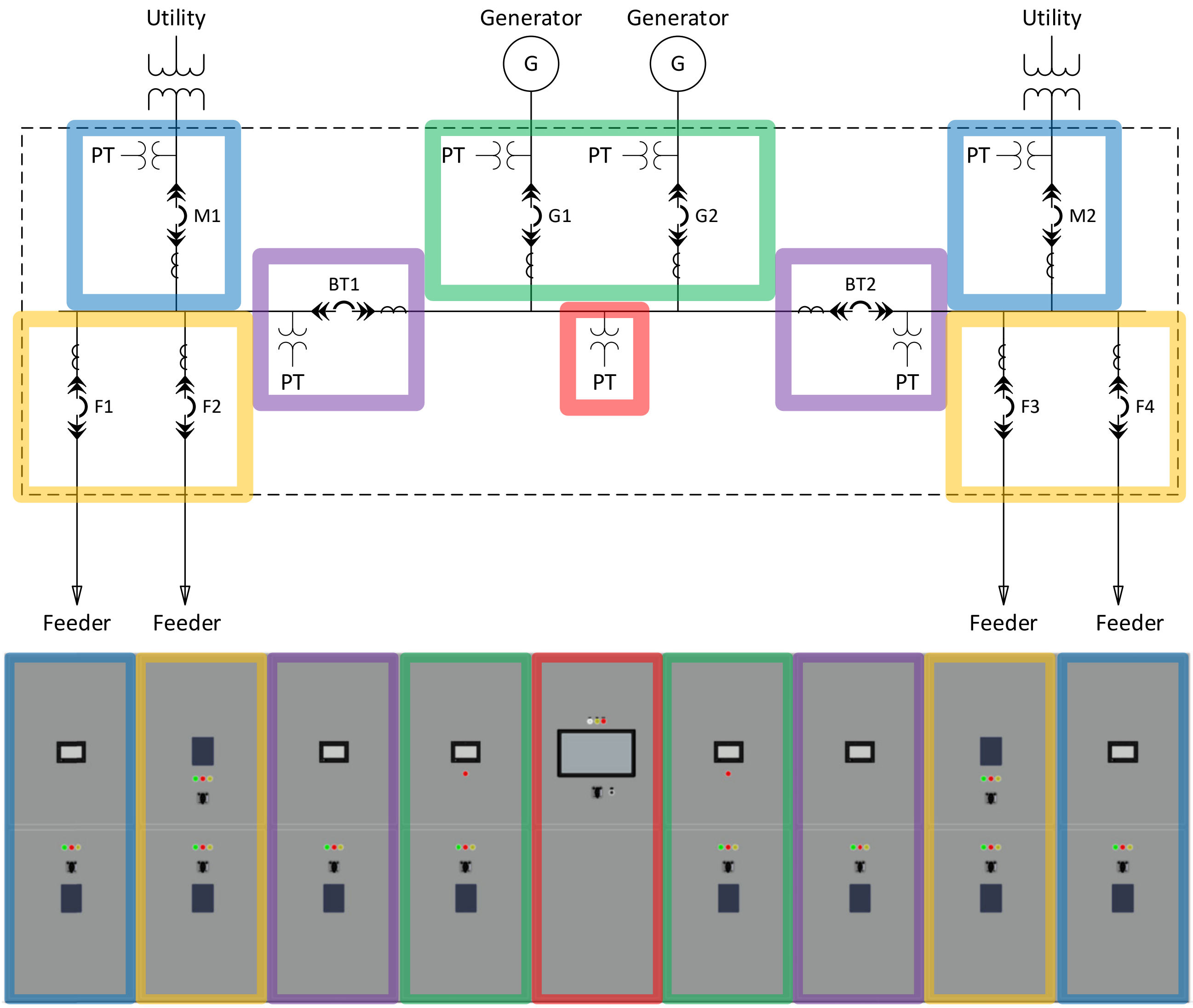


Figure 26 – MTG2TM-GPS – Medium-voltage Main–Tie–Gen–Gen–Tie–Main Single-line and Switchgear Layout – Using Modular Building Blocks

Space Savings Using Ohmic Voltage Sensing (OVS)

Medium Voltage Layout Example #3

A compelling benefit to the use of Ohmic Voltage Sensing (OVS) is the ability to accomplish a reduced switchgear footprint. For demonstration of the change review the MTGGTM-GPS switchgear lineup that uses traditional VT sensing as an example. Adding up all the space occupied by VTs (highlighted in blue) amounts to 2 structures worth of space. Now compare this to the figure depicting a MTGGTM-GPS switchgear lineup using OVS sensing (highlighted in green). By re-arranging the location of the automation equipment / control panel space, 2 vertical structures are eliminated from the lineup. That is because OVS sensing is in the rear of the switchgear and frees up valuable space in the front of the switchgear.

It is important to note that OVS sensing cannot be used in utility revenue metering applications and that the OVS voltage amplifier is burden limited. Multifunction protective relays are typically supported in OVS applications because these relays are equipped with high impedance (low burden) voltage sensing inputs. However, it is still important to account for the number of relays that will be fed from any one OVS amplifier. Consult Eaton application engineering to ensure compatibility of using OVS sensing in a design.

For additional information regarding OVS and the benefits of using OVS over traditional VTs please visit the following link: Voltage sensing | Resistive voltage divider | Eaton

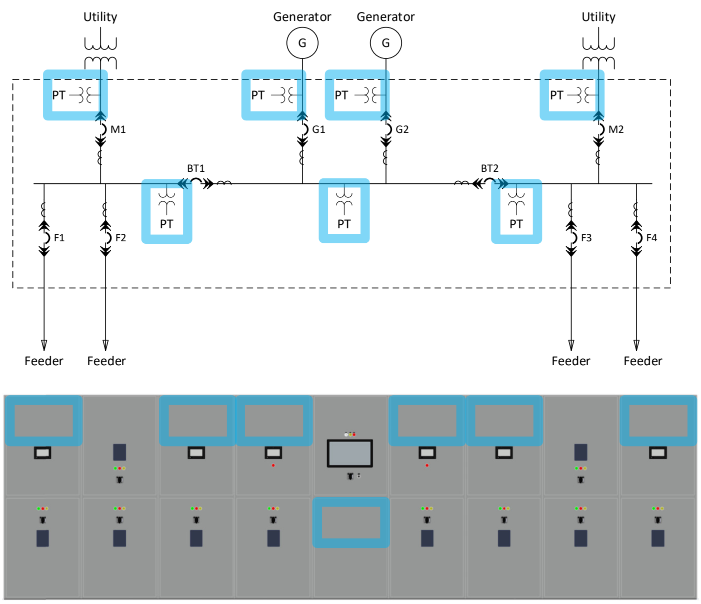


Figure 27 – MTGGTM–GPS with traditional PT voltage sensing

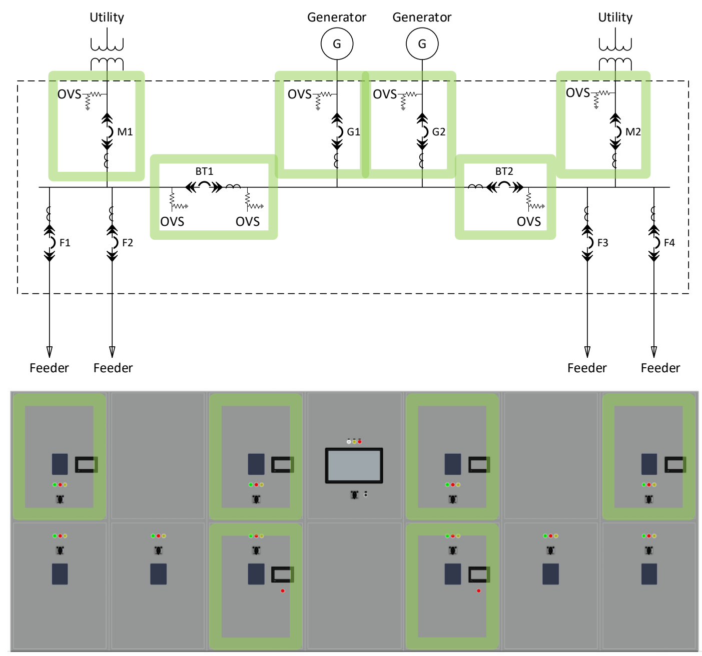


Figure 28 – MTGGTM–GPS using OVS instead of PT voltage sensing

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