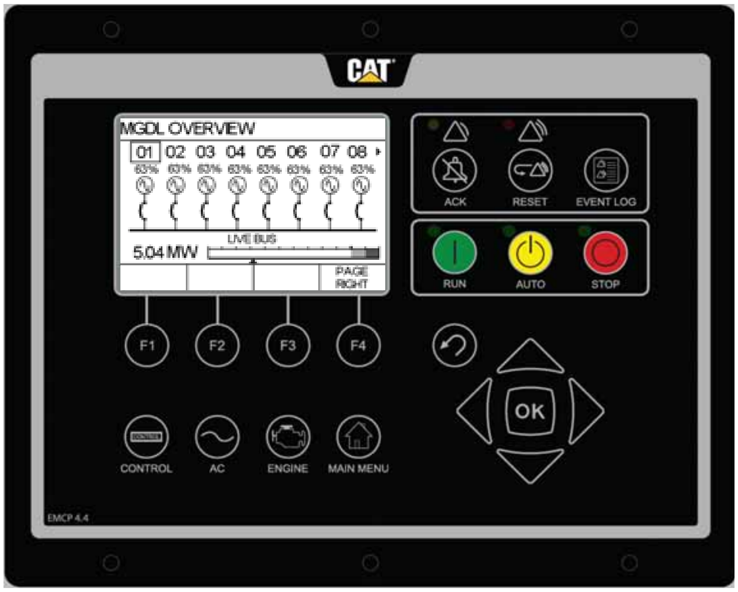
APPLICATION AND INSTALLATION GUIDE

EMCP 4.4

MULTIPLE GENSET DATA LINK



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1 General Information

1.1 INTRODUCTION

The EMCP 4.4 Multiple Genset Data Link (MGDL) feature is an Ethernet data link used between engine-generator sets for on-package paralleling and control. The EMCP 4.4 MGDL feature does NOT employ a master controller strategy for paralleling operation. The EMCP 4.4 controller uses a proprietary protocol to communicate information between generator sets to control paralleling features like dead bus arbitration, synchronizing, load sharing and load sequencing. The EMCP 4.4 is not designed or intended to connect to third-party products over this data link.

The MGDL feature requires EMCP 4.4 controllers with at least v4.3 PROD software installed. MGDL capability does NOT exist in EMCP 4.4 controller software versions prior to v4.3 PROD. Up to sixteen (16) EMCP 4.4 controllers can be networked together in a single system via MGDL. MGDL provides a view of the entire system as well as visibility to all other units in the system from a single EMCP 4.4 display (Figure 1).

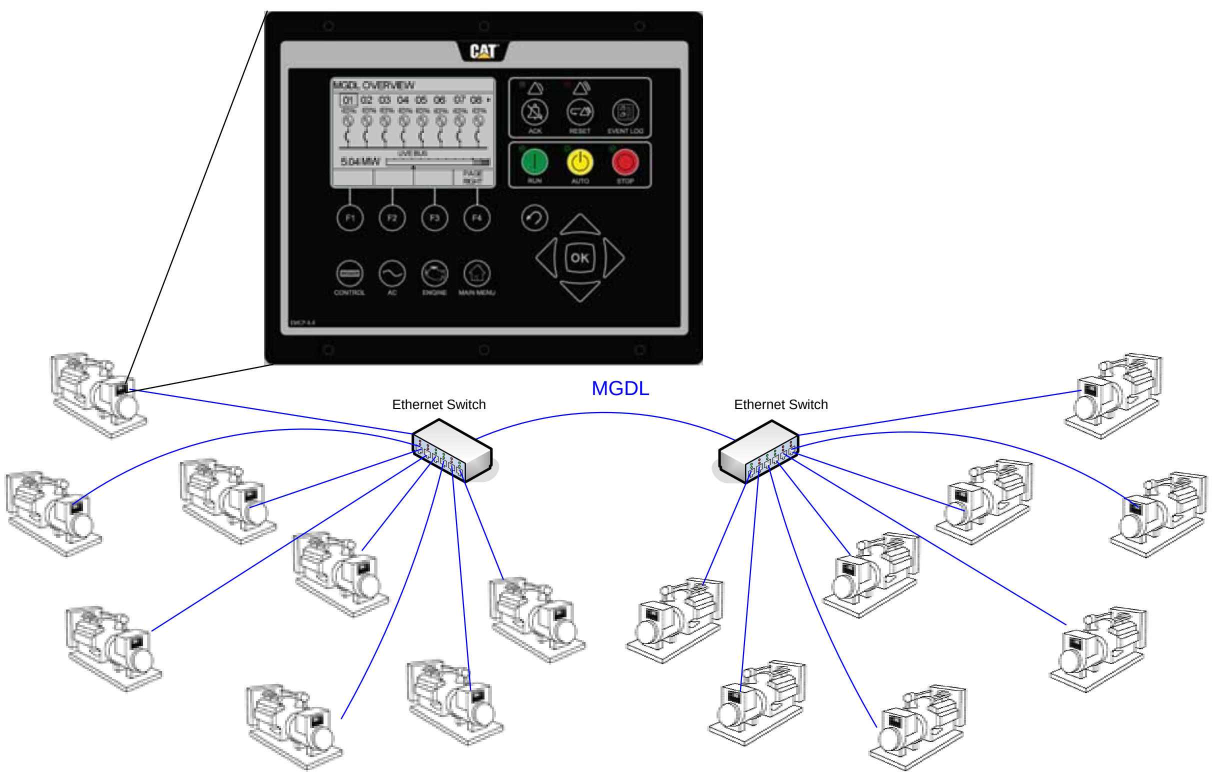


Figure 1: Multiple Genset Data Link (MGDL)

The "Multiple Genset" load topology example shown in Figure 2 is a representation of a system application in which the EMCP 4.4 MGDL feature can be used. A degree of flexibility is built into the

MGDL control system to allow for additional topology support (such as feeder breaker control). The EMCP 4.4 MGDL feature does not support utility paralleling or intelligent automatic transfer switch capabilities with the initial version of Prod v4.3 software.

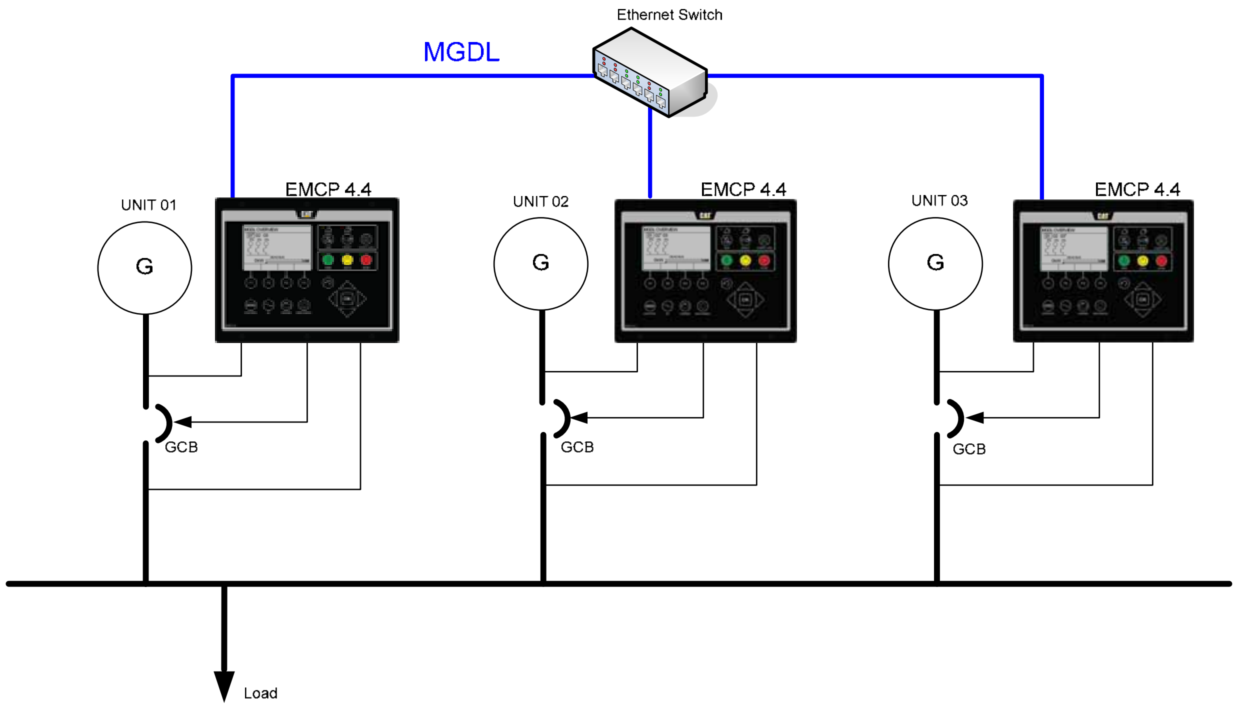


Figure 2: Multiple Genset, Topology Example

The following guide describes the installation, configuration, and operation of the EMCP 4.4 Multiple Genset Data Link (MGDL) feature.

1.2 REFERENCES

1. LEBE0007: EMCP 4.3, 4.4 Generator Set Control, Application and Installation Guide
2. UENR1210: EMCP 4.3/4.4 Systems Operation Troubleshooting and Adjusting (SOTA) Guide
3. LEBE0010: EMCP 4 SCADA Data Links, Application and Installation Guide

2 Important Safety Information

Most accidents that involve product operation, maintenance and repair are caused by failure to observe basic safety rules or precautions. An accident can often be avoided by recognizing potentially hazardous situations before an accident occurs. A person must be alert to potential hazards. This person should also have the necessary training, skills and tools to perform these functions properly.

Improper operation, lubrication, maintenance or repair of this product can be dangerous and could result in injury or death.

Do not operate or perform any maintenance or repair on this product, until you have read and understood the operation, maintenance and repair information.

Safety precautions and warnings are provided in this guide and on the product. If these hazard warnings are not heeded, bodily injury or death could occur to you or to other persons.

The hazards are identified by the “Safety Alert Symbol” and followed by a “Signal Word” such as “DANGER”, “WARNING” or “CAUTION”. The Safety Alert “WARNING” label is shown below.

The meaning of this safety alert symbol is as follows:

Attention! Become Alert! Your Safety is Involved.

The message that appears under the warning explains the hazard and can be either written or pictorially presented.

Operations that may cause product damage are identified by “NOTICE” labels on the product and in this publication.

Caterpillar cannot anticipate every possible circumstance that might involve a potential hazard. The warnings in this publication and on the product are, therefore, not all inclusive. If a tool, procedure, work method or operating technique that is not specifically recommended by Caterpillar is used, you must satisfy yourself that it is safe for you and for others. You should also ensure that the product will not be damaged or be made unsafe by the operation, lubrication, maintenance or repair procedures that you choose.

The information, specifications, and illustrations in this publication are on the basis of information that was available at the time that the publication was written. The specifications, torques, pressures, measurements, adjustments, illustrations, and other items can change at any time. These changes can affect the service that is given to the product. Obtain the complete and most current information before you start any job. Cat® dealers have the most current information available.

⚠ WARNING

When replacement parts are required for this product Caterpillar recommends using Cat replacement parts or parts with equivalent specifications including, but not limited to, physical dimensions, type, strength and material.

Failure to heed this warning can lead to premature failures, product damage, personal injury or death.

3 MGDL Hardware Installation

3.1 EMCP 4.4 MGDL CONNECTIONS

The Multiple Genset Data Link uses a 10BaseT connection to an Ethernet network. It requires a minimum of Category-5 (Cat5) cable, but Category-5e or Category-6 are also permitted. It uses four-wire communications. It requires two twisted pairs of conductors (Rx+ and Rx-, Tx+ and Tx-) and may be terminated in a connection such as RJ-45 jack. See Table 1 for the Ethernet pins on the EMCP 4.4.

Table 1: EMCP 4.4 MGDL (Ethernet) Connections

Pin #	Name	Description
87	ETH1-3	Ethernet differential non-inverting transmit line (Tx+)
88	ETH1-1	Ethernet differential non-inverting receive line (Rx+)
97	ETH1-2	Ethernet differential inverting receive line (Rx-)
98	ETH1-4	Ethernet differential inverting transmit line (Tx-)

The MGDL connection is the same connection as the Modbus TCP/IP connection. While the same connection is used, the protocols are different and do not interfere with each other under normal conditions. Because the receiving lines on one device need to be connected to the sending lines on another, it is possible, that a crossover cable will be required. Fortunately, many Ethernet adapters automatically detect and internally crossover; the EMCP 4 also automatically detects and does an internal crossover. See Figure 3 for an illustration of connecting the EMCP 4.4 to a typical RJ-45 connector or device.

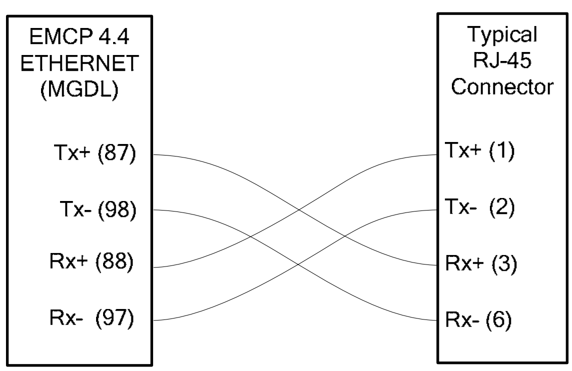


Figure 3: EMCP 4.4 Wiring to RJ-45 connector/device

3.2 MGDL NETWORK TOPOLOGIES

The Multiple Genset Data link is Ethernet-based and supports the 10BT topologies. The recommended topologies for MGDL are the star or tree topology using a hub, switch, or repeater Ethernet device. See Figure 4 for an illustration of a star network topology and a tree network topology.

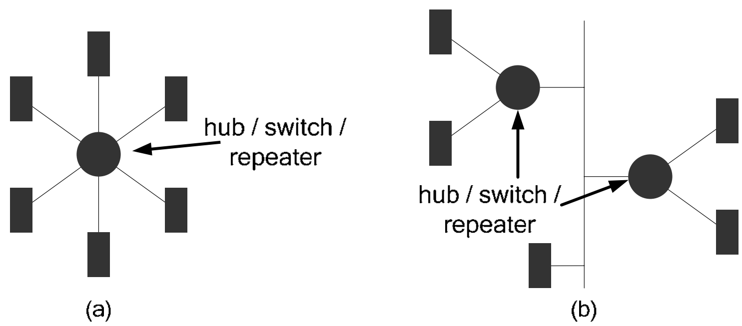


Figure 4: Recommended MGDL Ethernet Network Topologies

(a) Star network and (b) Tree network

For maximum redundancy, using the dual connections available on some EMCP 4.4 hardware to daisy chain connections is NOT recommended for an MGDL network since a single wire break can cause loss of communications between large portions of the network. See Figure 5 for an illustration of a daisy-chained network topology.

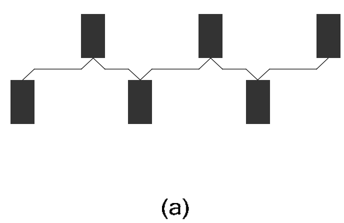


Figure 5: Non-recommended MGDL Ethernet Network Topologies

(a) Daisy-chain network between internal EMCP 4.4 hubs

The limits on the length are 330ft (100m) between each device (controller, computer, hub, or switch). Fiber optic converters are recommended for any network section length greater than 330 feet (100 m), but may be worthwhile in order to give greater electrical immunity for all connections.

3.3 ETHERNET SWITCH/HUB/REPEATER CONSIDERATIONS

Because of the wide range of installation scenarios and large number of Ethernet hubs, switches, or repeaters available, specific devices are not called out in this document. However, certain characteristics should be considered when choosing an Ethernet hub, switch or repeater to install with an MGDL network. Switches are always preferable over hubs in order to minimize communication conflicts. In addition, if the MGDL network is being connected to any other network, a switch is strongly recommended. The hub/switch/repeater characteristics to consider for a specific application include:

- Power Supply Requirements
- Availability of Power Supply with and without Utility Power
- Environmental Specifications (Temperature, Humidity, Pressure, EMC…etc.)
- Transmission Speed/Length Requirements
- Maximum Number of Ports Required
- Troubleshooting Signal LEDs

Two examples of Ethernet switches that were tested with an MGDL network system are provided in Table 2. These devices are NOT Cat serviceable parts, but are provided here for reference.

Table 2: Example Ethernet Switch Devices

Ethernet Switch Device	Image
B&B Electronics – ESW205-T	
Phoenix Contact - 2832849 FL Switch SF16TX	

3.4 MGDL AND TCP/IP SCADA MONITORING

It should be noted that the EMCP 4.4 Ethernet MGDL connection points are the same as the Ethernet TCP connection points used for SCADA monitoring. The EMCP 4.4 dual purpose Ethernet port lends itself to convenient wiring and reduced connection points. However, MGDL and TCP/IP SCADA datalinks are separate in their operation and function.

NOTE: The same Ethernet network used for MGDL can also be used for TCP/IP SCADA monitoring.

In order to perform TCP/IP SCADA monitoring of all EMCP 4.4 controllers that are connected to an MGDL network, connect to the existing Ethernet network and follow standard TCP/IP SCADA monitoring setup procedures.
Figure 6 illustrates an example of a TCP/IP SCADA network connected to an EMCP 4.4 MGDL network.

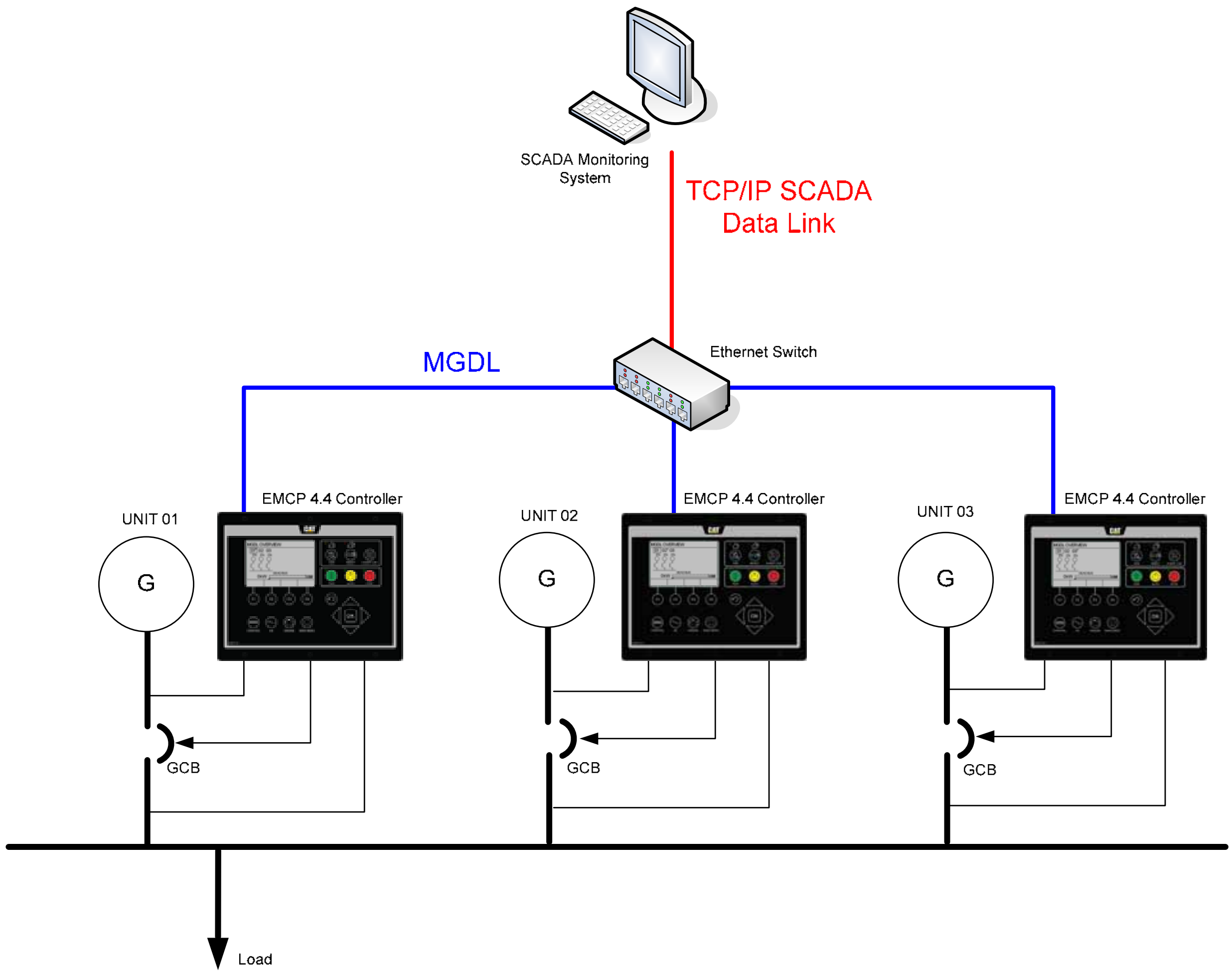


Figure 6: Concurrent MGDL and TCP/IP Network Overview

Separate IP addresses exist for EMCP 4.4 controllers on the MGDL network and on a TCP/IP SCADA network. The EMCP 4.4 TCP IP address, subnet and gateway used for SCADA monitoring are configurable by the user where as the EMCP 4.4 MGDL IP address is NOT configurable. The EMCP 4.4 MGDL IP address is dynamically assigned at the time the unit connects to an MGDL network. Therefore, the EMCP 4.4 MGDL IP address MAY change based on existing MGDL network nodes. The EMCP 4.4 MGDL IP address is provided on the EMCP 4.4 display screen for reference only and is described in the MGDL Network Status Screens section of this manual (Section 7.7). Due to the criticality of the MGDL communications, care should be taken in the routing of the signals to be sure other network traffic does not interfere in the transmission of these critical control parameters.

For more information on EMCP 4 SCADA data links including TCP/IP SCADA monitoring refer to the EMCP 4 SCADA Data Links, Application and Installation Guide (LEBE0010).

4 MGDL Software Configuration

The Multiple Genset Data Link (MGDL) feature setpoints can be accessed using either the Cat ET Service tool, or directly through the EMCP display. Some setpoints are locked at ET only or at Security Level 3 and cannot be changed from the EMCP display or will require a level 3 password. Please note that ET Service Tool version 2013A or later is recommended for accessing and adjusting MGDL setpoints.

4.1 MGDL SYSTEM CONFIGURATION

To access the MGDL system configuration setpoints using the ET Service Tool, connect to the EMCP 4.4 Genset Control and click on the ‘Configuration Tool’ button (alternatively press F5) to enter the configuration menu. Select ‘Data Link: Multiple Genset Control’ from the menu on the left to display the following default settings shown in Figure 7:

NOTE: If any combination of Hardwired and MGDL setpoint configuration exists, a shutdown will be triggered on the EMCP 4.4 controller until the configuration is corrected.

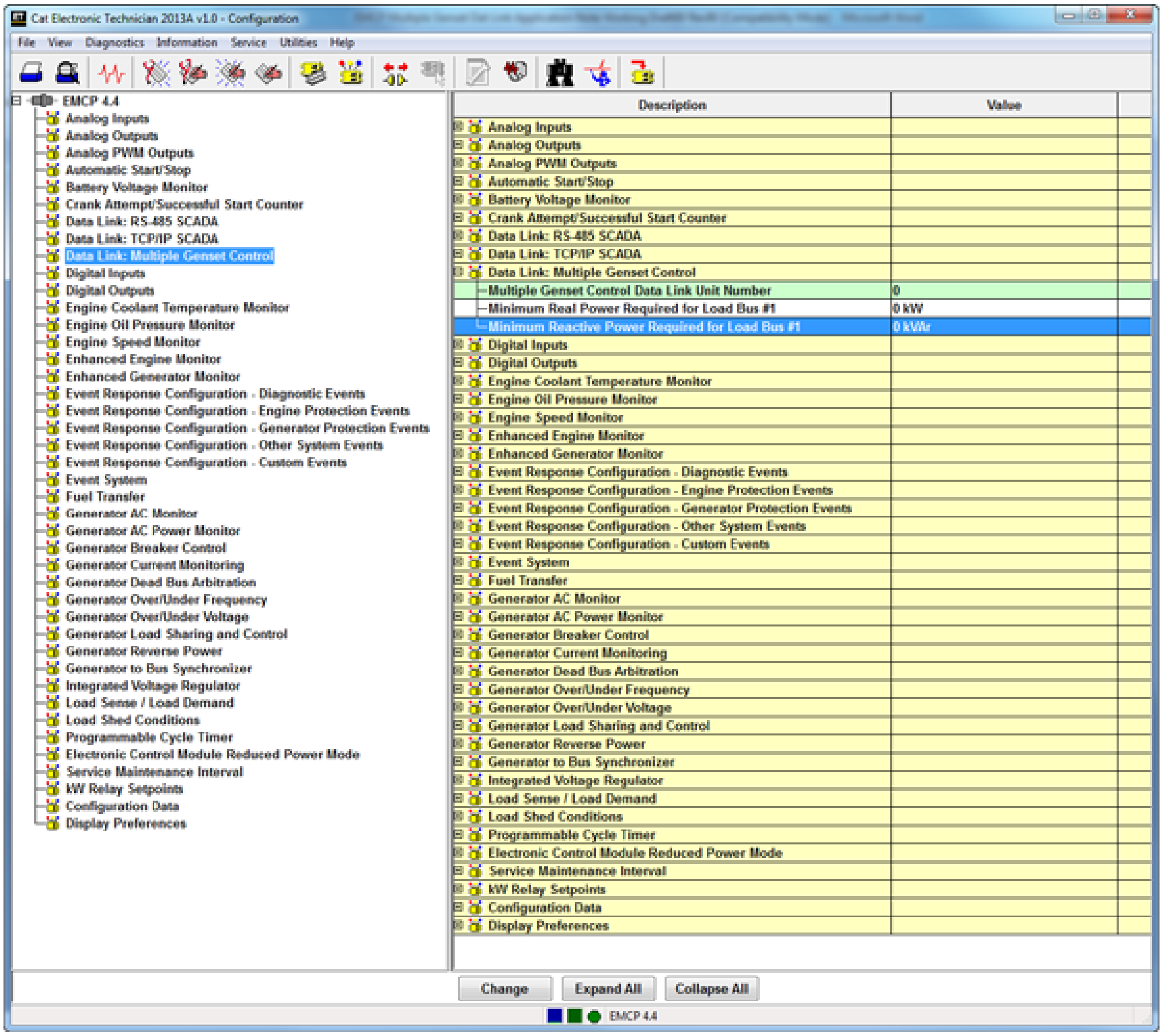


Figure 7: MGDL System Configuration View in ET

To access the MGDL setpoints through the EMCP display, navigate to the following sub-menu:

MAIN MENU

→ CONFIGURE

→ PARALLELING

→ MULTIPLE GENSET DATA LINK

The minimum, maximum, resolution, units and default for each setpoint along with a brief description of the purpose of each setpoint are provided below.

4.1.1 Multiple Genset Control Data Link Unit Number

Name	Min	Max	Resolution	Units	Default Value	Access
Multiple Genset Control Data Link Unit Number	0	64	1	N/A	0	ET Service Tool or EMCP Display

The *Multiple Genset Control Data Link Unit Number* (setpoint) is used to assign a unit number to the controller on the MGDL network as well as enable or disable communication of the EMCP 4.4 controller on the MGDL network. All EMCP 4.4 controllers configured to operate using MGDL should be assigned a unique MGDL Unit Number.

- If set to 'zero' the MGDL feature is disabled and the EMCP 4.4 will not communicate over the MGDL network to other controllers.
- If set to a non-zero value (1 – 64) the MGDL feature is enabled and the EMCP 4.4 will communicate over the MGDL network to other controllers.
- While the software supports 64 different MGDL Unit Numbers, only a maximum of 16 units on the MGDL network are currently supported simultaneously.
- It is recommended to use lower numbers since under failure scenarios, higher number will slow down the operation of the unit.

NOTE: Configuring this setpoint to zero automatically hides all MGDL-related screens on the EMCP 4.4 display.

⚠ WARNING

Each unit MUST be assigned a unique MGDL unit number before operation. Updating or changing the MGDL unit number during generator set operation is NOT recommended and may cause a unit and/or system shutdown.

Failure to heed this warning can lead to loss of load, system failures, product damage, personal injury or death.

The EMCP 4.4 contains logic that does not allow two units to be configured to the same MGDL unit number. If the EMCP 4.4 detects duplicate MGDL unit numbers on the MGDL network a MULTIPLE GENSET DATA LINK CONFIGURATION ERROR (SPN-FMI: 625-14) event is triggered and the two units will shutdown. For more details on troubleshooting the MULTIPLE GENSET DATA LINK CONFIGURATION ERROR (SPN-FMI: 625-14) event refer to Section 8.1.

4.1.2 Minimum Power Required for Feeder Breaker

Name	Min	Max	Resolution	Units	Default Value	Access
Minimum Real Power Required for Load Bus #1	0	62,500,000	1	kW	0	ET Service Tool or EMCP Display
Minimum Reactive Power Required for Load Bus #1	0	62,500,000	1	kVAr	0	

The MGDL feature provides limited feeder breaker control. For control of a feeder breaker a programmable digital output must be configured for Feeder Breaker Close Command and/or Feeder Breaker Trip Command. See Section 5.5 for more information on EMCP 4.4 MGDL Feeder Breaker Control. In addition, this feature can also be used to implement load add functionality.

The *Minimum Real Power Required for Load Bus #1* (setpoint) and *Minimum Reactive Power Required for Load Bus #1* (setpoint) determine the minimum available power required before issuing a feeder breaker close command. The available power is determined by the rated power (real and reactive) of all units communicating on the MGDL network that are closed to the bus.

The following subsections provide setpoint configuration details on each of the MGDL paralleling features.

4.2 MGDL DEAD BUS ARBITRATION CONFIGURATION

To access the MGDL Dead Bus Arbitration configuration setpoints in ET, select 'Generator Dead Bus Arbitration' from the menu on the left to display the following settings:

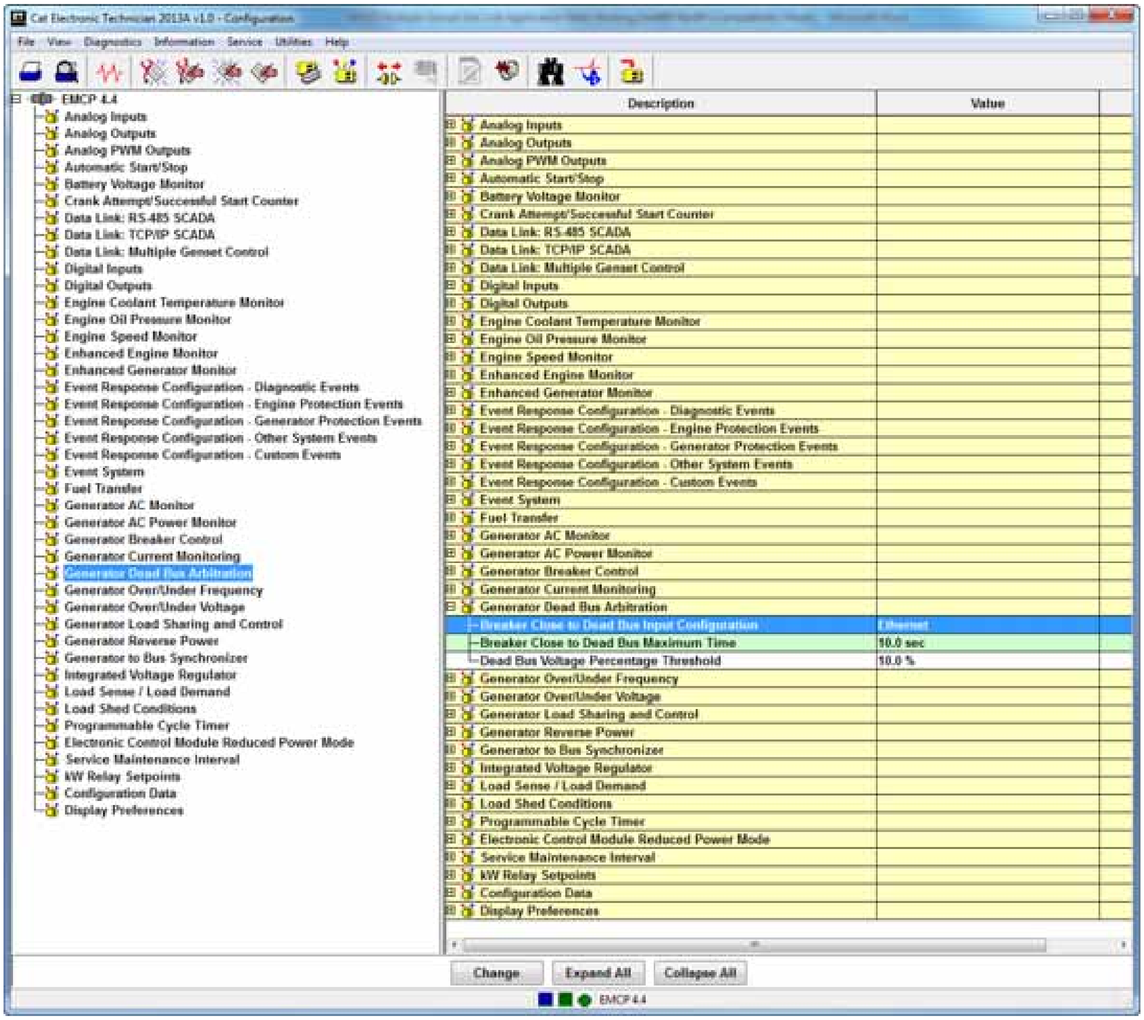


Figure 8: MGDL Dead Bus Arbitration Setpoint Configuration View in ET

To access the MGDL Dead Bus Arbitration setpoints through the EMCP display, navigate to the following sub-menu:

MAIN MENU
→ CONFIGURE
→ PARALLELING
→ DEAD BUS ARBITRATION

Each setpoint used for configuring MGDL Dead Bus Arbitration is described below.

4.2.1 Breaker Close to Dead Bus Input Configuration

Name	Options	Default Value	Access
Breaker Close to Dead Bus Input Configuration	0 = Not Installed 1 = Hardwired Input 2 = Ethernet (MGDL)	1 = Hardwired Input	ET Service Tool or EMCP Display

The *Breaker Close to Dead Bus Input Configuration* (setpoint) is used to select the method used for dead bus arbitration. Select ‘Ethernet (MGDL)’ for dead bus closing via multiple genset data link.

4.2.2 Breaker Close to Dead Bus Maximum Time

Name	Min	Max	Resolution	Units	Default Value	Access
Breaker Close to Dead Bus Maximum Time	0.1	10.0	0.1	seconds	1.0	ET Service Tool or EMCP Display

The *Breaker Close to Dead Bus Maximum Time* (setpoint) determines the maximum amount of time a unit will attempt to close to a dead bus when other units are available to dead bus close.

When no other units are available to dead bus close, *Breaker Close to Dead Bus Maximum Time* is not enforced. Instead the *Generator Breaker Maximum Closing Time* (setpoint) found in the Generator Breaker Control setpoints group is enforced.

4.2.3 Dead Bus Voltage Percentage Threshold

Name	Min	Max	Resolution	Units	Default Value	Access
Dead Bus Voltage Percentage Threshold	5	50	1	%	10	ET Service Tool or EMCP Display

The *Dead Bus Voltage Percentage Threshold* (setpoint) is a percentage of rated voltage used to determine a live bus or dead bus status. If average bus voltage is measured below this threshold, the bus is considered dead and a unit may close to the bus without synchronizing.

4.3 MGDL LOAD SHARING CONFIGURATION

To access the MGDL Load Sharing configuration setpoints in ET, select 'Generator Load Sharing and Control' from the menu on the left to display the following settings:

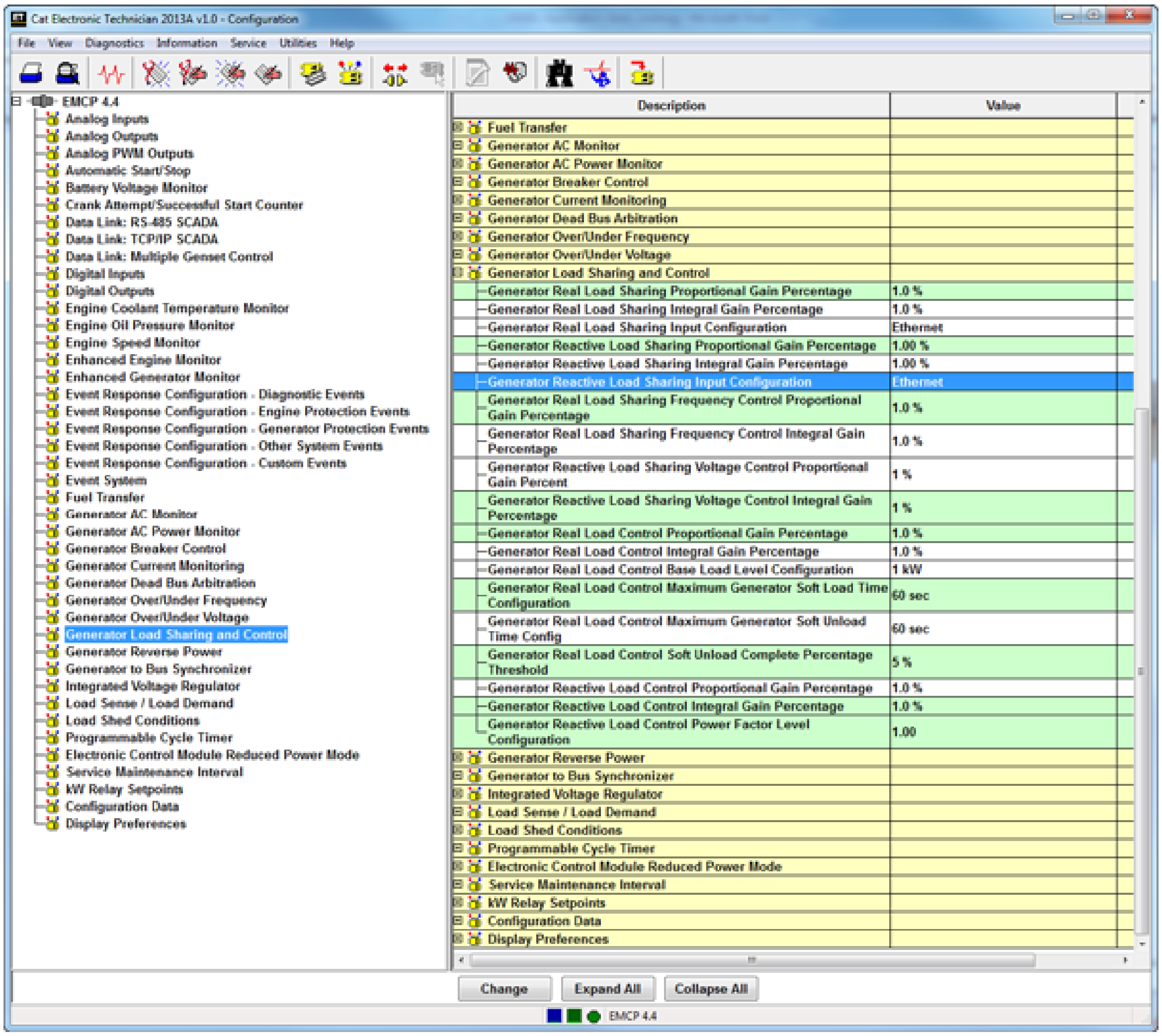


Figure 9: MGDL Load Sharing Setpoint Configuration View in ET

To access the MGDL Generator Load Sharing setpoints through the EMCP display, navigate to the following sub-menu:

MAIN MENU
→ CONFIGURE
→ PARALLELING
→ GEN LOAD SHARING

Each setpoint used for configuring MGDL Load Sharing is described below.

4.3.1 Generator Real Load Sharing Input Configuration

Name	Options	Default Value	Access
Generator Real Load Sharing Input Configuration	0 = Disabled 1 = 0 to 10 V 2 = 0 to 3 V 3 = Ethernet (MGDL)	0 = Disabled	ET Service Tool or EMCP Display

The *Generator Real Load Sharing Input Configuration* (setpoint) is used to select the method used for real load sharing between generator sets. Select 'Ethernet (MGDL)' for real load sharing via multiple genset data link.

4.3.2 Generator Real Load Sharing PI Gains

Name	Min	Max	Resolution	Units	Default Value	Access
Generator Real Load Sharing Proportional Gain Percentage	0.0	100.0	0.1	%	1.0	ET Service Tool or EMCP Display
Generator Real Load Sharing Integral Gain Percentage	0.0	100.0	0.1	%	1.0	

Real Load Sharing PI gains control how equally real power is shared between generator sets operating in parallel. The *Generator Real Load Sharing Proportional Gain Percentage* (setpoint) and *Generator Real Load Sharing Integral Gain Percentage* (setpoint) can be tuned to achieve the desired load sharing response depending on the application and generator set configuration. Some optimization and tuning may be required from default values.

Please refer to the MGDL Paralleling Tuning Guide section of this manual (Section 6) for further information on tuning the controller gains.

4.3.3 Generator Real Load Sharing Frequency Control PI Gains

Name	Min	Max	Resolution	Units	Default Value	Access
Generator Real Load Sharing Frequency Control Proportional Gain Percentage	0.0	100.0	0.1	%	1.0	ET Service Tool or EMCP Display
Generator Real Load Sharing Frequency Control Integral Gain Percentage	0.0	100.0	0.1	%	1.0	

Real Load Sharing Frequency Control PI gains control how closely bus frequency is regulated to the desired value when generator sets are load sharing in parallel.

The *Generator Real Load Sharing Frequency Control Proportional Gain Percentage* (setpoint) and *Real Load Sharing Frequency Control Integral Gain Percentage* (setpoint) can be tuned to control to the desired bus frequency based on the application type and generator set configuration. Some optimization may be required from default values.

Please refer to the MGDL Paralleling Tuning Guide section of this manual (Section 6) for further information on tuning the controller gains.

4.3.4 Generator Real Load Sharing Soft Loading/Unloading

Name	Min	Max	Resolution	Units	Default Value	Access
Generator Real Load Control Maximum Generator Soft Load Time Configuration	0	600	1	seconds	60	ET Service Tool or EMCP Display
Generator Real Load Control Maximum Generator Soft Unload Time Configuration	0	600	1	seconds	60	
Generator Real Load Control Soft Unload Complete Percentage Threshold	1	50	1	%	5	

When load sharing, soft loading and soft unloading reduces instability and risk to equipment by increasing or decreasing load in a controlled manner before closing or opening the generator breaker.

The *Generator Real Load Control Maximum Generator Soft Load Time Configuration* (setpoint) is the amount of time a unit will take to increase real power from 0% to 100% real power when coming on the bus. The *Generator Real Load Control Maximum Generator Soft Unload Time Configuration* (setpoint) is the amount of time a unit will take to decrease real power from 100% to 0% real power when going off the bus. The *Generator Real Load Control Soft Unload Complete Percentage Threshold* (setpoint) is the percentage of rated real power at which a unit completes soft unloading and opens the generator breaker.

For example, if *Generator Real Load Control Maximum Generator Soft Unload Time Configuration* is set to 60 seconds and *Generator Real Load Control Soft Unload Complete Percentage Threshold* is set to 5%, a unit decreasing load from 50% of rated real power should be expected to soft unload for approximately 27 seconds (or 1.67%/sec) before opening the generator breaker.

Similarly, if *Generator Real Load Control Maximum Generator Soft Load Time Configuration* is set to 30 seconds, a unit that is increasing load to 50% of rated real power should be expected to soft load for approximately 15 seconds (or 3.33%/second) before closing the generator breaker. Refer to Figure 10 for an illustration of this example of soft unloading and soft loading.

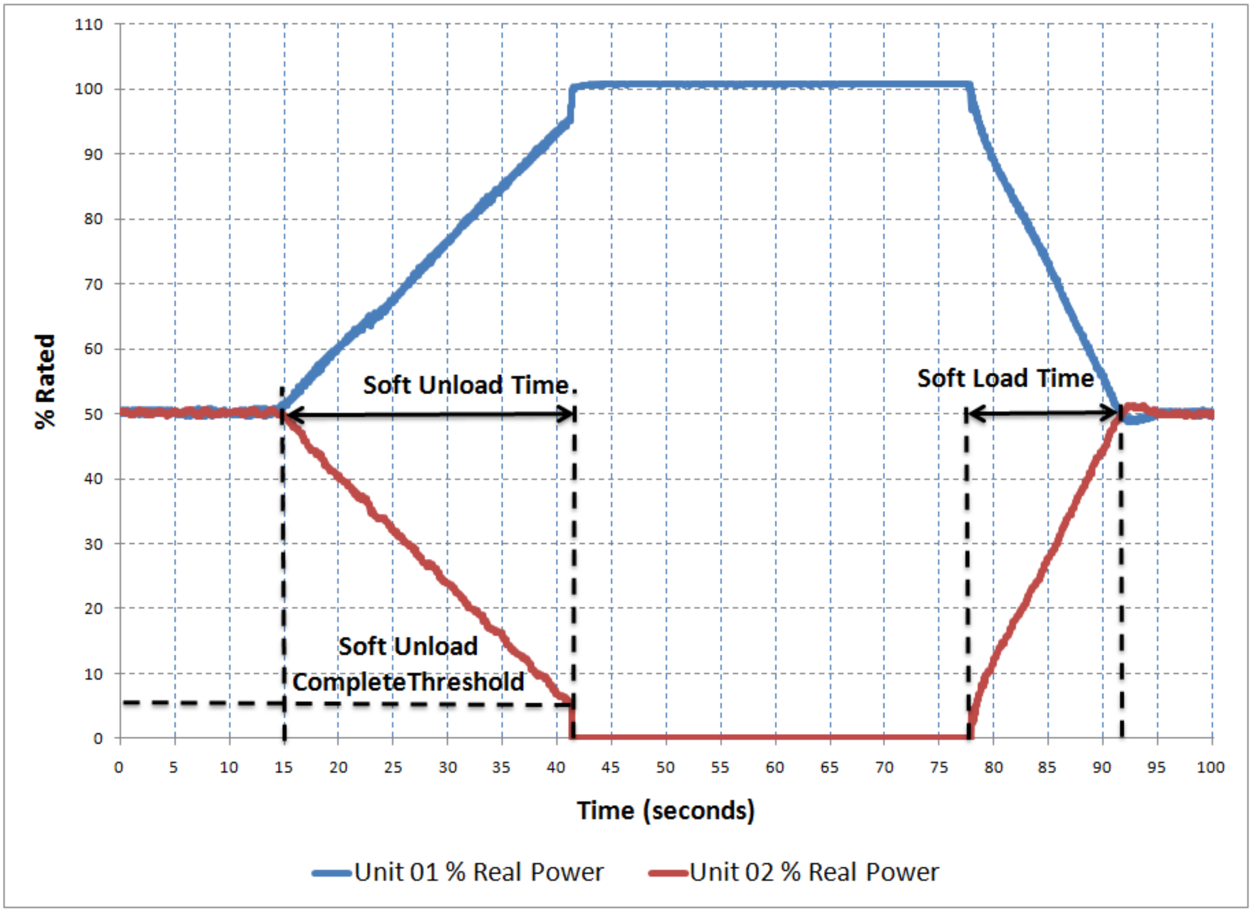


Figure 10: Soft Loading/Unloading Profile with Soft Unload Time Setpoint = 60 sec, Soft Load Time Setpoint = 30 sec, and Soft Unload Complete % Threshold Setpoint = 5%

4.3.5 Generator Reactive Load Sharing Input Configuration

Name	Options	Default Value	Access
Generator Reactive Load Sharing Input Configuration	0 = Disabled 1 = 0 to 10 V 2 = Ethernet (MGDL)	0 = Disabled	ET Service Tool or EMCP Display

The *Generator Reactive Load Sharing Input Configuration* (setpoint) is used to select the method used for reactive load sharing between generator sets. Select 'Ethernet (MGDL)' for reactive load sharing via multiple genset data link.

4.3.6 Generator Reactive Load Sharing PI Gains

Name	Min	Max	Resolution	Units	Default Value	Access
Generator Reactive Load Sharing Proportional Gain Percentage	0.0	100.0	0.1	%	1.0	ET Service Tool or EMCP Display
Generator Reactive Load Sharing Integral Gain Percentage	0.0	100.0	0.1	%	1.0	

Reactive Load Sharing PI gains control how equally reactive power is shared between generator sets operating in parallel. The *Generator Reactive Load Sharing Proportional Gain Percentage* (setpoint) and *Generator Reactive Load Sharing Integral Gain Percentage* (setpoint) can be tuned to achieve the desired load sharing response depending on the application and generator set configuration. Some optimization and tuning may be required from default values.

Please refer to the MGDL Paralleling Tuning Guide section of this manual (Section 6) for further information on tuning the controller gains.

4.3.7 Generator Reactive Load Sharing Voltage Control PI Gains

Name	Min	Max	Resolution	Units	Default Value	Access
Generator Reactive Load Sharing Voltage Control Proportional Gain Percentage	0.0	100.0	0.1	%	1.0	ET Service Tool or EMCP Display
Generator Reactive Load Sharing Voltage Control Integral Gain Percentage	0.0	100.0	0.1	%	1.0	

Reactive Load Sharing Voltage Control PI gains control how closely bus voltage is regulated to the desired value when generator sets are load sharing in parallel.

The *Generator Reactive Load Sharing Voltage Control Proportional Gain Percentage* (setpoint) and *Generator Reactive Load Sharing Voltage Control Integral Gain Percentage* (setpoint) can be tuned to control to the desired bus voltage based on the application type and generator set configuration. Some optimization may be required from default values.

Please refer to the MGDL Paralleling Tuning Guide section of this manual (Section 6) for further information on tuning the controller gains.

4.4 MGDL LOAD SENSE LOAD DEMAND CONFIGURATION

To access the MGDL Load Sense Load Demand configuration setpoints in ET, select 'Load Sense / Load Demand' from the menu on the left to display the following settings:

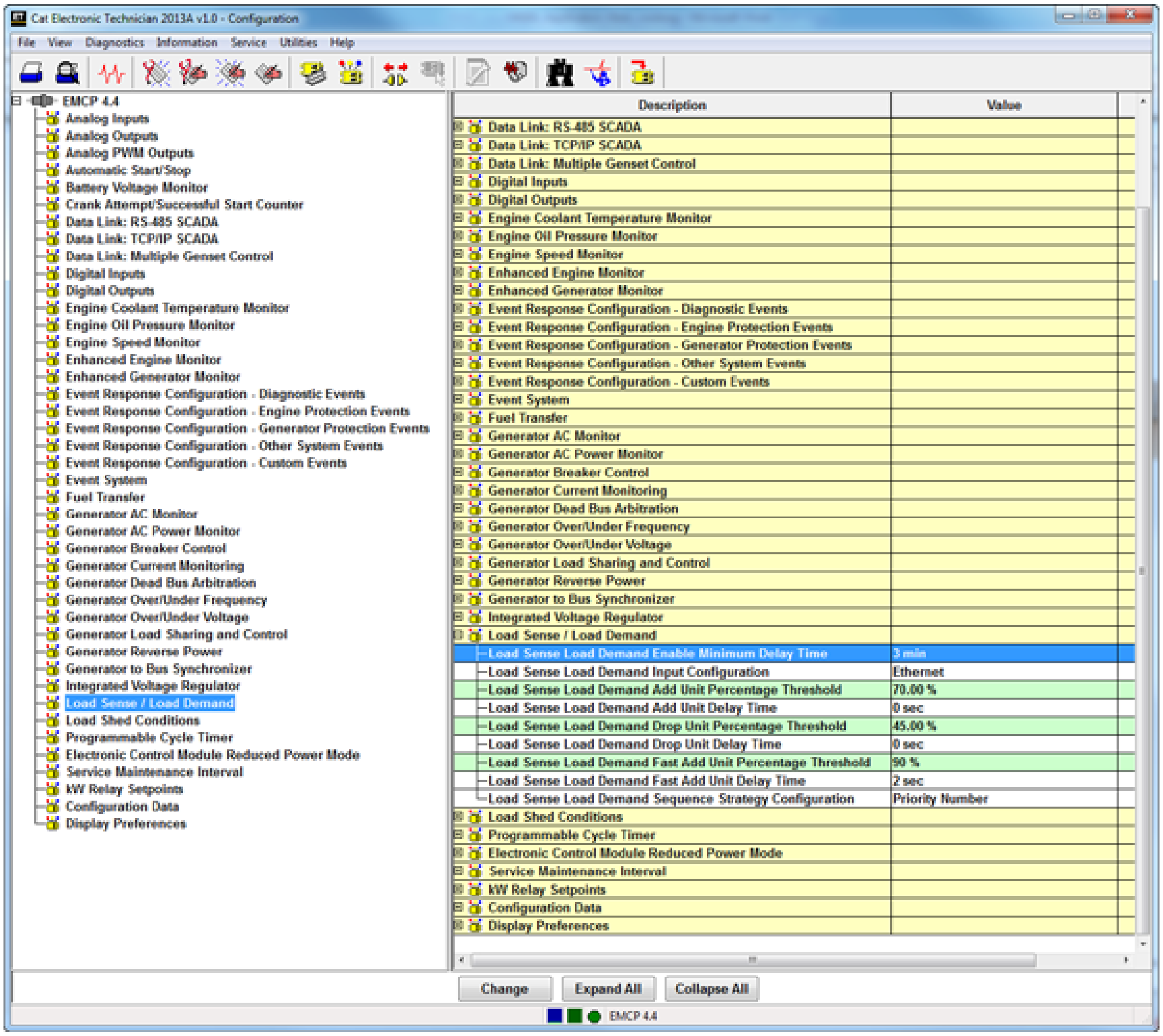


Figure 11: MGDL Load Sense Load Demand Setpoint Configuration View in ET

To access the MGDL Load Sense Load Demand setpoints through the EMCP display, navigate to the following sub-menu:

MAIN MENU

→ CONFIGURE

→ PARALLELING

→ LOAD SENSE LOAD DEMAND

Each setpoint used for configuring MGDL Load Sense Load Demand is described below.

4.4.1 Load Sense Load Demand Input Configuration

Name	Options	Default Value	Access
Load Sense Load Demand Input Configuration	0 = Disabled 1 = Hardwired Input 2 = Ethernet (MGDL)	0 = Disabled	ET Service Tool or EMCP Display

The *Load Sense Load Demand Input Configuration* (setpoint) is used to select the method used for sequencing generator sets on or off the bus based on load demand. Select 'Ethernet (MGDL)' for load sequencing via multiple genset data link.

NOTE: All LSLD system-wide setpoints are configurable via ET or EMCP Display even when Load Sense Load Demand Input Configuration is set to DISABLED. When MGDL unit number is set to zero, LSLD system-wide setpoints are configurable, but not communicated over the MGDL network.

4.4.2 Load Sense Load Demand Enable Minimum Delay Time

Name	Min	Max	Resolution	Units	Default Value	Access
Load Sense Load Demand Enable Minimum Delay Time	1	30	1	minutes	5	ET Service Tool or EMCP Display

The *Load Sense Load Demand Enable Minimum Delay Time* (setpoint) is the minimum amount of time after a live bus is detected a unit must delay before entering LSLD mode. After this time, units may sequence on or off the bus based on load demand.

NOTE: This setpoint is considered a "system-wide" setpoint and is configurable from any node in the MGDL network. The setpoint is automatically applied to all EMCP 4.4 controllers on the MGDL network (regardless of whether the LSLD is set to 'Disabled' or 'Ethernet (MGDL)') and any controller powered up will adopt the strategy of other controllers already powered up.

4.4.3 Load Sense Load Demand Add/Drop Units Configuration

Name	Min	Max	Resolution	Units	Default Value	Access
Load Sense Load Demand Add Unit Percentage Threshold	0	115	1	%	70	ET Service Tool or EMCP Display
Load Sense Load Demand Add Unit Delay Time	0	300	1	seconds	5	
Load Sense Load Demand Drop Unit Percentage Threshold	0	90	1	%	30	
Load Sense Load Demand Drop Unit Delay Time	0	900	1	seconds	30	
Load Sense Load Demand Fast Add Unit Percentage Threshold	0	150	1	%	90	
Load Sense Load Demand Fast Add Unit Delay Time	0	300	1	seconds	3	

The Load Sense Load Demand Add/Drop Unit Percentage Threshold setpoints set the percentage of system rated real power at which units will be sequenced on the bus (Add) or sequenced off the bus (Drop). The percentage of system rated real power must be above or below these thresholds for the respective Add/Drop Unit Delay Time before sequencing will occur.

NOTE: These setpoints are considered “system-wide” setpoints and are configurable from any node in the MGDL network. The setpoints are automatically applied to all EMCP 4.4 controllers on the MGDL network (regardless of whether the LSLD is set to ‘Disabled’ or ‘Ethernet (MGDL)’) and any controller powered up will adopt the strategy of other controllers already powered up.

While under LSLD control, the percentage of system real power is calculated ONLY from units on the bus (breaker closed) that are operating in LSLD mode. For example, Figure 12 depicts the loading of Unit 01, 02, and 03 in four different scenarios. Each scenario demonstrates the loading with respect to the default LSLD Add/Drop Units setpoints. The system % kW is the average % kW of Unit 01, 02, and 03 and is the value compared to the LSLD Add/Drop Unit Percentage Threshold system-wide setpoints.

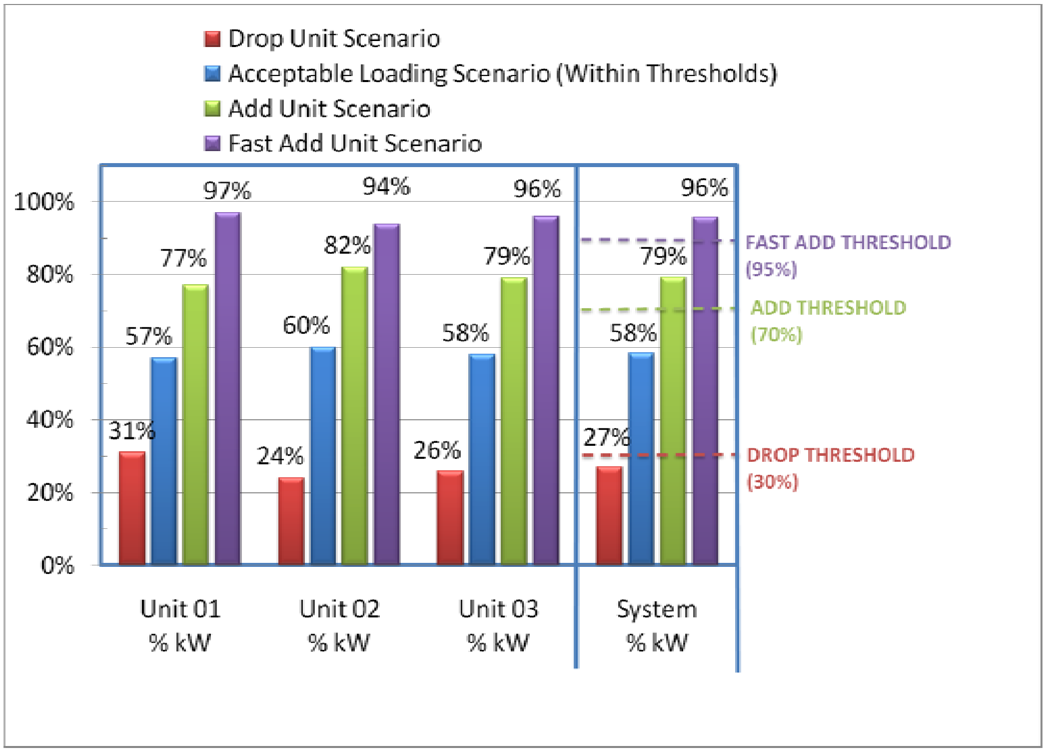


Figure 12: LSLD Add/Drop Unit Example Scenarios

4.4.4 Load Sense Load Demand Sequence Strategy Configuration

Name	Options	Default Value	Access
Load Sense Load Demand Sequence Strategy Configuration	0 = Total Operating Hours 1 = Priority Number	1 = Priority Number	ET Service Tool or EMCP Display

The *Load Sense Load Demand Sequence Strategy Configuration* (setpoint) sets the strategy used for determining the order in which units sequence on or off the bus under LSLD control.

- The 'Total Operating Hours' strategy is intended to balance the engine hours between individual generator sets.
- The 'Priority Number' strategy sequences units on or off based only on the assigned priority number.

NOTE: This setpoint is considered a "system-wide" setpoint and is configurable from any node in the MGDL network. The setpoint is automatically applied to all EMCP 4.4 controllers on the MGDL network (regardless of whether the LSLD is set to 'Disabled' or 'Ethernet (MGDL)') and any controller powered up will adopt the strategy of other controllers already powered up.

4.4.5 Load Sense Load Demand Sequence Priority Number

Name	Min	Max	Resolution	Units	Default Value	Access
Load Sense Load Demand Sequence Priority Number	1	64	1	N/A	16	EMCP Display Only

The *Load Sense Load Demand Sequence Priority Number* (setpoint) determines the priority (order) in which units sequence on or off the bus under LSLD control.

- The lowest priority number is the last unit to go off the bus and is the unit most likely to run.
- The highest priority number is the unit most likely to go off the bus first.

This setpoint is accessible ONLY through the EMCP LSLD Priority Assignment screen (Section 7.6) and is NOT configurable through Cat ET. This setpoint is also not transferred with an ECM/Fleet configuration file and must be re-programmed with any new configuration.

NOTE: LSLD sequencing priority (order) is NOT related to MGDL Unit number.

Risk of a crash parallel can occur if two or more units are assigned the same LSLD sequence priority number. Therefore, each unit MUST be assigned a unique LSLD sequence priority number. EMCP Load Sense Load Demand software provides protection from this scenario by detecting and resolving sequence priority number conflicts automatically. As a result, user programmed sequence priority numbers MAY be re-assigned automatically to avoid conflicts.

4.5 MGDL EVENT RESPONSE CONFIGURATIONS

The EMCP 4.4 response to an event being triggered can be configured in the EMCP 4.4 via setpoints called Event Response Configurations. These setpoints determine the actions the EMCP 4.4 takes when the event occurs. To access the MGDL related event response configuration setpoints in ET, select one of the 'Event Response Configuration' groups from the menu on the left to display the setpoints.

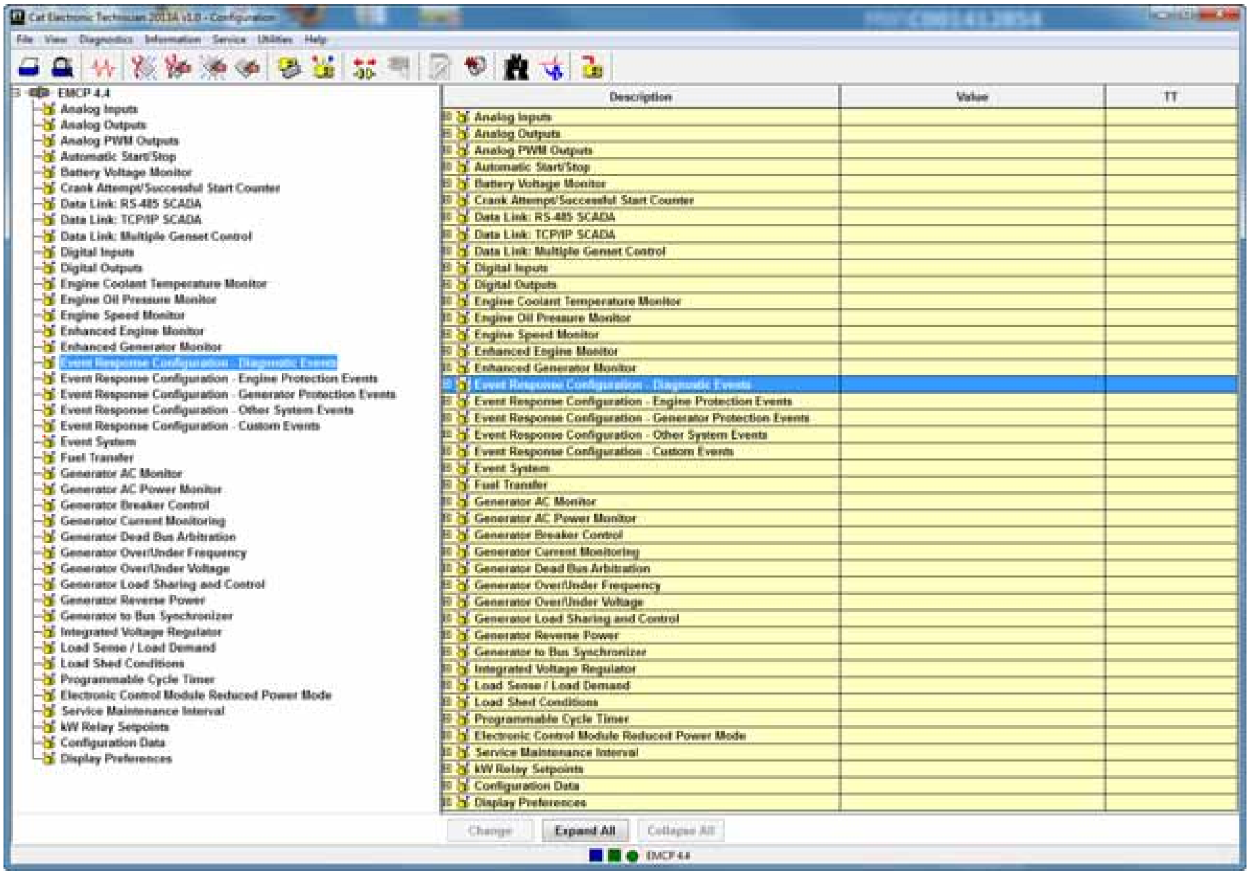


Figure 13: Event Response Configuration View in ET

To access the Event Response Configuration setpoints through the EMCP display, navigate to the following sub-menu:

MAIN MENU
→ CONFIGURE
→ ALL SETPOINTS
→ EVENTS
→ DIAGNOSTIC RESP CONFIG
→ GEN PROTECT RESP CONFIG

Each setpoint used for configuring MGDL related event response configurations is described below.

4.5.1 MGDL Network Diagnostic Response Configurations

Name	Min	Max	Default Value	Access
Multiple Genset Control Data Link Communication Failure Diagnostic Response Configuration	Disabled	Warning, Audible Alert, Soft Shutdown, Hard Shutdown, Breaker#1 Trip, Breaker #2 Trip, Fault Protection Timer Enabled, Active Only	Audible Alert, Hard Shutdown	ET Service Tool or EMCP Display
Control is Offline Multiple Genset Control Data Link Diagnostic Response Configuration	Disabled	Warning, Audible Alert, Soft Shutdown, Hard Shutdown, Breaker#1 Trip, Breaker #2 Trip, Fault Protection Timer Enabled, Active Only	Audible Alert, Warning, Active Only	

The *Multiple Genset Control Data Link Communication Failure Diagnostic Response Configuration* (setpoint) determines how the EMCP 4.4 responds to an MGDL COMMUNICATION FAILURE (SPN-FMI: 625-19) event. See Section 8.3 for further details on this event.

The *Control is Offline Multiple Genset Control Data Link Diagnostic Response Configuration* (setpoint) determines how the EMCP 4.4 responds to the loss of a communications with an expected unit on the MGDL network that triggers an MGDL CONTROL IS OFFLINE (SPN-FMI: 625-31) event. See Section 8.2 for further details on this event.

4.5.2 Dead Bus Inconsistent Sensing Event Response Configuration

Name	Min	Max	Default Value	Access
Dead Bus Inconsistent Sensing Warning Event Response Configuration	Disabled	Warning, Audible Alert, Breaker#1 Trip, Breaker #2 Trip, Active Only	Audible Alert, Warning	ET Service Tool or EMCP Display

The *Dead Bus Inconsistent Sensing Warning Event Response Configuration* (setpoint) determines how the EMCP 4.4 responds to inconsistent dead bus sensing between units on the MGDL network that triggers a DEAD BUS INCONSISTENT SENSING (SPN-FMI: 2530-2) event. See Section 8.6 for further details on this event.

5 MGDL Paralleling Features Operation

The EMCP 4.4 with MGDL has several paralleling functions including dead bus arbitration, synchronizing, load sharing, load shed, and load sense/load demand. The EMCP 4.4 with MGDL also provides for multiple modes of operation, including automatic synchronizing, manual synchronizing, and sync check mode. In the case of loss of communications, failsafe paralleling modes are also discussed here.

DEAD BUS ARBITRATION

The EMCP 4.4 with MGDL incorporates true dead bus arbitration to determine and select the primary generator set to close to a dead bus, allowing only one unit to close to the dead bus. The dead bus arbitration control minimizes the time for the first generator set to close to the dead bus. See Section 5.1.

SYNCHRONIZING

The EMCP 4.4 monitors all three phases of the generator and main bus. The proprietary synchronizing algorithms drive the generator output frequency, voltage, and phase to match another source, and close the generator circuit breaker when conditions have been met. With the addition of MGDL network feature, the synchronizing functionality on the EMCP 4.4 has not changed. Please refer to the EMCP 4.3, 4.4 Generator Set Control, Application and Installation Guide (LEBE0007) for detailed information on EMCP 4.4 synchronizing.

LOAD SHARING

The EMCP 4.4 actively monitors the real (kW) and reactive (kVAr) load requirement of all paralleled generator sets on the MGDL network, and adjusts output of the generator set to maintain a balanced loading of all generator sets. See Section 5.2.

LOAD SHED

The EMCP 4 provides a configurable signal to aid in the removal of load. With the addition of MGDL network feature, the load shed functionality on the EMCP 4.4 has not changed. Please refer to the EMCP 4.3, 4.4 Generator Set Control, Application and Installation Guide (LEBE0007) for detailed information on the EMCP 4.4 load shed feature.

MGDL GROUP START COMMAND

The EMCP 4.4 provides the ability to command all units to start and run via MGDL from a single unit's dedicated isolated group start digital input. See Section 5.3 for more information.

LOAD SENSE/LOAD DEMAND

The EMCP 4.4 includes logic to sequence generator sets based on the total load requirement of the system. If the site load exceeds a minimum reserve kW threshold, additional generator sets will automatically start, synchronize, and close the generator breaker. If the site load falls below a reserve kW threshold, a generator set will automatically unload, open the generator circuit breaker, and shut down. Generator sets can be configured to sequence on and off in order to balance engine hours or priority assignment. See Section 5.4.

FEEDER BREAKER CONTROL (LOAD ADD)

The EMCP 4.4 includes limited feeder (tie) breaker close and trip control for connecting a generator bus and a load bus in an automatic mains failure (AMF) dead bus condition. See Section 5.5.

MGDL LOSS OF COMMUNICATIONS STRATEGY

The EMCP 4.4 includes logic that provides redundancy to the MGDL paralleled system in the case of a unit being lost from the MGDL network. The loss of communications strategy groups units and alters modes in failure scenarios in order to maximize the load capability of the MGDL paralleled system but also to minimize the risk of loss of load or damage to equipment. See Section 5.6.

MGDL NETWORK CONFIGURATION (EXPECTED UNITS) RESET

The EMCP 4.4 provides the ability for updating or re-configuring the MGDL network configuration (topology) by resetting the number of expected units on the MGDL network. This capability is typically only necessary for re-defining the MGDL network node count and should be done with caution. See Section 5.7.

MGDL FAILSAFE LOAD SHARING/DROOP

The EMCP 4.4 provides a patented failsafe strategy for load sharing in loss of MGDL communication scenarios. In these failure mode scenarios, this strategy adaptively adjusts generator set operating conditions in order to maximize the amount of load the MGDL paralleled system can provide while introducing minimal disruption or instability into the system. See Section 5.8.

5.1 MGDL DEAD BUS ARBITRATION OPERATION

When multiple generator sets are simultaneously started, their outputs are not synchronized when they reach rated speed and voltage. If more than one generator set is allowed to simultaneously close to the de-energized (dead) bus an out of phase paralleling situation (crash-parallel) can occur that may cause equipment damage or failure. To avoid a crash-parallel situation, one generator must be selected to close to the dead bus and create a synchronization reference for other generator sets.

Failure of an operator or a control system to allow ONLY one generator to exclusively close to a dead bus could result in extensive damage to the generator sets. Therefore automatic circuit breaker closure is inhibited to all units except one in dead bus arbitration. The one generator set that is selected is typically the first generator to reach rated speed and voltage.

5.1.1 Purpose

MGDL Dead Bus Arbitration (DBA) is the control system used in EMCP 4.4 controllers with MGDL to determine a dead bus and select one generator set to close to the dead bus. MGDL DBA determines if a unit is the first unit ready to close to the dead bus and allows only one unit to close to a dead bus in such a way that minimizes the time required for a dead bus close. In the case of an MGDL network failure, the algorithm is designed to operate in a fail-safe mode, reducing the likelihood of two controls closing their breakers to a dead bus simultaneously.

The setpoint configuration for MGDL DBA is described in Section 4.2 and the MGDL DBA display screens are described in Section 7.5. The operation and methodology of MGDL DBA are described below.

5.1.2 Basic Operation

Dead bus arbitration between generators is accomplished using the MGDL network to communicate between generator sets. There is NO master or group controller in MGDL DBA. A virtual token-based methodology is used to arbitrate between generator sets and consists of the following rules:

- All units must agree that the bus is dead.
- All units are allowed to request the token if they are up to speed and voltage.
- Only one unit may capture (possess) the token.
- A unit that captures the token, must receive permission from all other requesting units (dead bus close grant) before it attempts to dead bus close.

This methodology minimizes the amount of time for a unit to close to a dead bus and allows a unit to detect whether to keep trying or allow a different unit to attempt to close to a dead bus. If there are no prohibiting events, arbitration between the generators is performed using the rules described above. A typical arbitration sequence consists of the following:

1. Once a unit is within thresholds for speed and voltage, the unit requests the token.
2. If no other unit has the token, the unit captures the token.
3. The unit that captures the token waits for all other requesting units to grant it permission to dead bus close.
4. The unit is granted permission from all other requesting units and issues a generator breaker close command.
5. The unit detects a generator breaker close and a live bus.

Dead bus arbitration is complete for all units when the live bus is detected. At this time, units that are off the bus may proceed to synchronize and close to the live bus. The individual unit DBA states and system DBA states are visible from the EMCP 4.4 display. Refer to Section 7.5

MGDL Dead Bus Arbitration Screens for more details.

NOTE: Automatic Dead Bus Arbitration operation requires the Sync Mode Switch (SMS) to be placed in AUTO. Dead bus arbitration is still performed with the sync mode switch in other states. The operation of dead bus arbitration with respect to all sync mode switch states is:

- If the SMS is in Auto, only automatic operation of DBA is allowed.
- If the SMS is in Manual, DBA will only attempt to dead bus arbitrate when there is a request (via digital input) to manually close the generator breaker.
- If the SMS is in Check, DBA allows a manual request to close (via digital input) if the generator set meets the voltage and frequency requirements, similar to SMS in Manual.
- If the SMS is in Off, DBA will not function.

5.1.3 Dead Bus Detection

All units (that are sensing any particular bus) need to agree that a bus is dead before a unit may dead bus close to that bus, even if that unit directly detects the bus as dead. This helps protect against a unit with blown/open bus sensing from dead bus closing to a live bus.

Each EMCP 4.4 on the MGDL unit uses bus voltage sensing inputs to measure average bus voltage. If average bus voltage is measured below the Dead Bus Voltage Percentage Threshold setpoint, the bus is considered dead and the unit communicates this status to all other units on the MGDL network.

Each EMCP 4.4 considers the bus status of ALL units on the MGDL network when determining the system bus status. The system bus status is considered live when any MGDL unit detects a live bus and is considered dead when all MGDL units detect a dead bus. If the system bus status is dead a unit may initiate dead bus arbitration and close to the bus without synchronizing.

A unit activates the Dead Bus Inconsistent Sensing Warning event (SPN-FMI: 2530-2) if two or more MGDL units do not agree on the dead bus status. The warning will be cleared only when all units on the MGDL network agree on the status of the bus. If an MGDL unit has lost communication with the rest of the group, then its dead bus detection will not be used in determining system dead bus status.

5.1.4 Generator Breaker Fail to Close to Dead Bus

One key requirement for dead bus arbitration is to minimize the time required to get a generator set on the bus. This requirement must be balanced with providing a single generator set sufficient time/attempts to close to a dead bus. Therefore, a unit will attempt to close to the dead bus immediately if all requesting units grant it permission to dead bus close. However, if the unit is granted permission but fails to close, dead bus arbitration operates such that other units are allowed to close (and re-attempt to close) to the dead bus as soon as possible. Dead bus fail to close operation for a single unit and multiple units is described below:

- If multiple units are requesting, a unit that fails to close must delay 2 seconds before re-requesting to allow other units equal chance to close. If multiple other units are requesting (up to speed and voltage) permission is passed to the unit with the next highest MGDL unit number.

(When there are no more higher MGDL unit numbers, permission is cycled back to the lowest MGDL unit number.)

NOTE: If an operator issues a manual generator breaker close command, the unit will immediately take permission and attempt to dead bus close. In automatic mode, system is designed to minimize the possibility of a simultaneous dead bus close; however, ultimately the responsibility lies with the operator issuing the manual generator breaker close command.

- If a unit fails to dead bus close after a maximum of 5 attempts, a Dead Bus Arbitration Failure Shutdown (SPN-FMI: 2530-1) is generated. The maximum failure count is reset to zero anytime a live bus is detected or the unit experiences a shutdown event.
- If multiple units are requesting, the Breaker Close to Dead Bus Maximum Time (setpoint) determines how long after issuing a breaker close a unit will try to close. If the Breaker Close to Dead Bus Maximum Time (setpoint) expires with no detection of generator breaker closed a Dead Bus Arbitration Failure Warning (SPN-FMI: 2530-17) event is triggered (Figure 14).

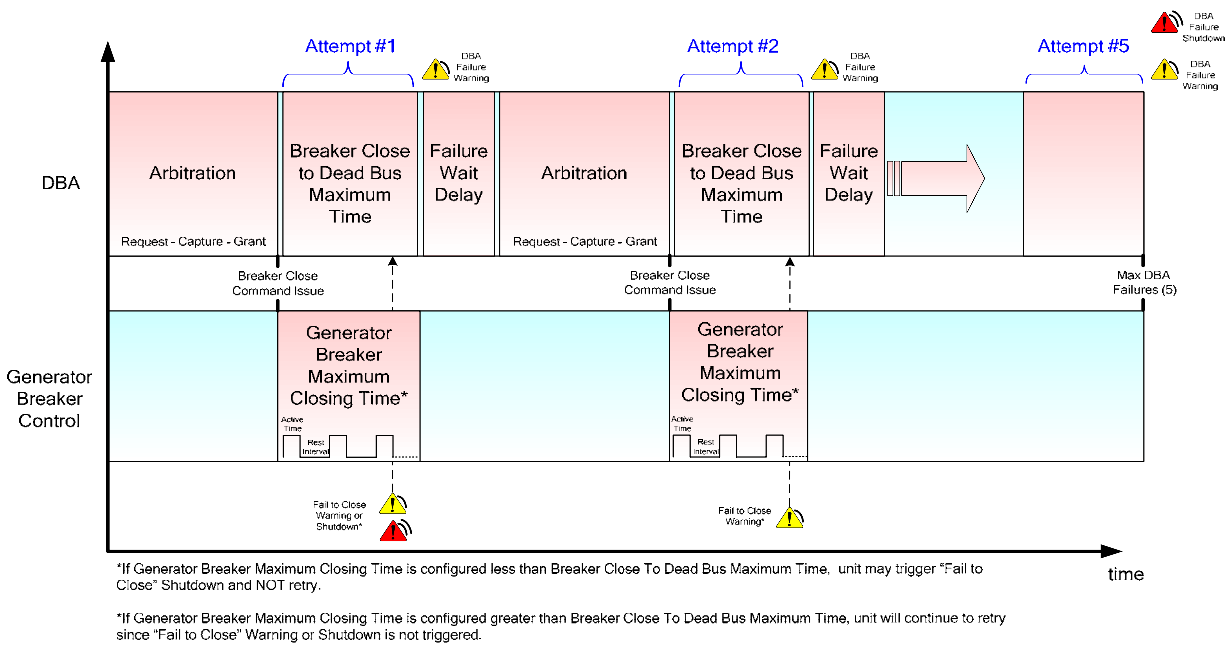


Figure 14: Dead Bus Fail to Close Scenario with Multiple Units Requesting

- If no other units are requesting, a failed unit may re-request immediately. In this scenario, the unit will re-request indefinitely if the Generator Breaker Fail to Close is configured only for a Warning.
- If no other units are requesting, the Generator Breaker Maximum Closing Time (setpoint) within the Generator Breaker Control logic determines how long after issuing a breaker close a unit can try to close. If the Generator Breaker Maximum Closing Time (setpoint) expires with no detection of breaker closed a Generator Breaker Fail to Close (SPN-FMI: 4011-31) event is triggered (Figure 15).

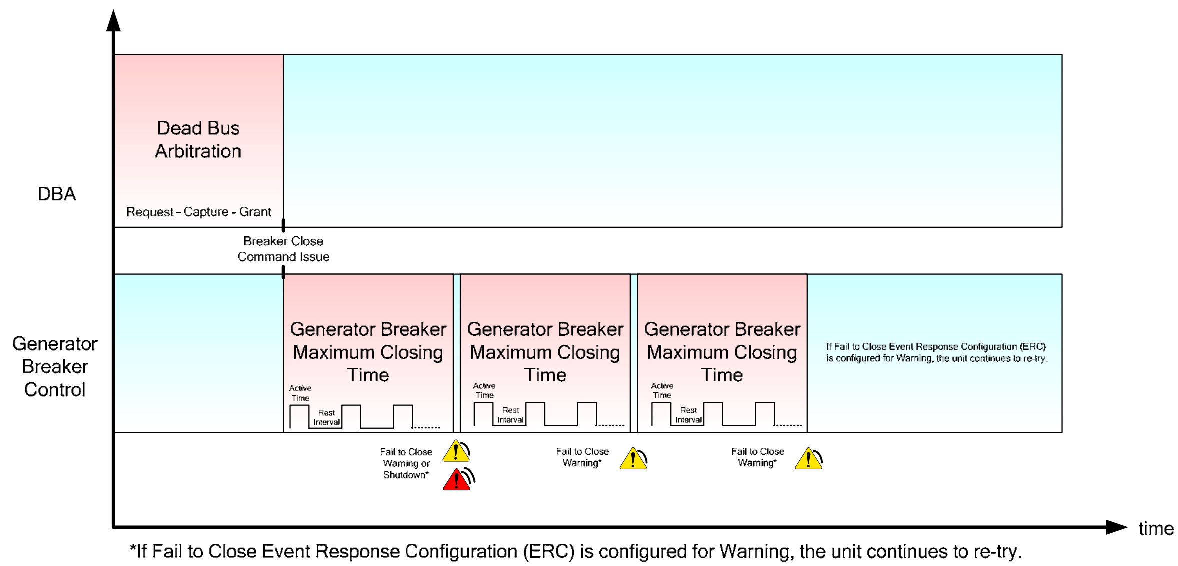


Figure 15: Dead Bus Fail to Close Scenario with a Single Unit Requesting

NOTE: *Generator Breaker Maximum Closing Time* (Generator Breaker Control setpoint) MUST be configured to a value greater than *Breaker Close to Dead Bus Maximum Time* (Dead Bus Arbitration setpoint) in order for a unit to keep trying after a failure to dead bus close. The *Breaker Close to Dead Bus Maximum Time* is meant specifically for dead bus close situations when getting a unit to close to the bus is crucial. *Generator Breaker Maximum Closing Time*, however, is NOT limited to dead bus arbitrations situations and is applied in any breaker closure attempts, such as synchronizing. Therefore the *Breaker Close to Dead Bus Maximum Time* is meant to be configured to a shorter duration than *Generator Breaker Maximum Closing Time* in order to minimize the time required for ANY single unit to dead bus close.

5.1.5 Failsafe Dead Bus Arbitration Operation

The following describes dead bus close control operation during a loss of communication on the MGDL network. The MGDL system uses knowledge of the network topology (expected number of controls online) to be 'cautious' in regards to missing or non-communicating units.

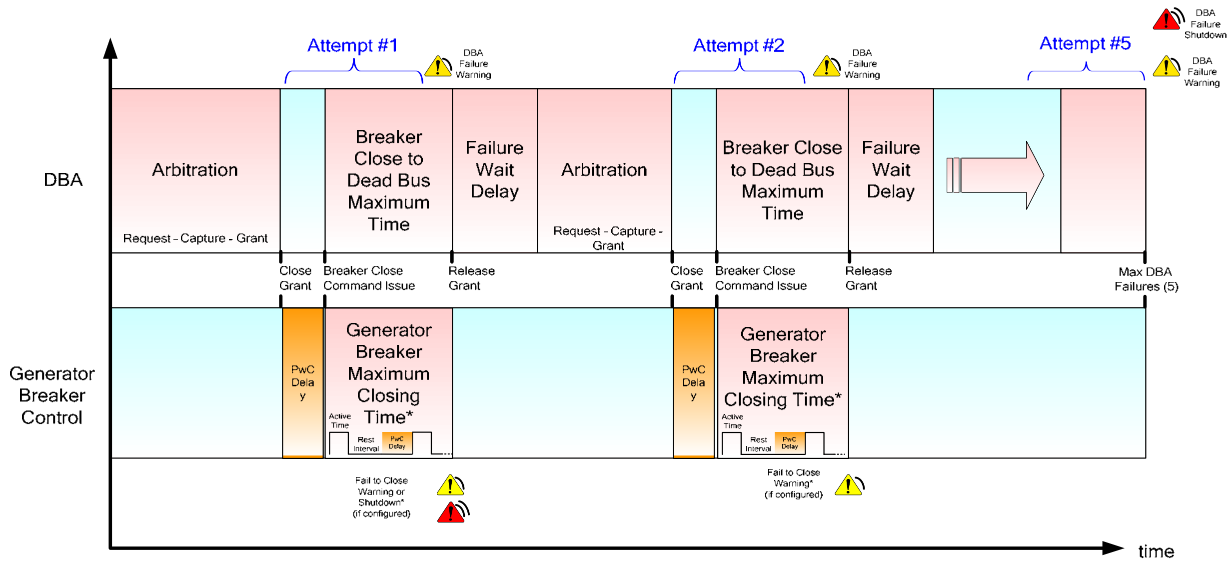
As described in Section 5.6 - MGDL Loss of Communications Strategy, units in a fragmented MGDL network are separated into a Proceed as Normal (majority) and a Proceed with Caution (minority) group. The Proceed with Caution group is forced to be cautious when dead bus closing since this group's communication is isolated from other units and other units' dead bus close status is unknown. Without knowing the dead bus close status of other units, two units that are out of synchronization could potentially close to the bus at the same time resulting in a crash parallel. While it is necessary to avoid this scenario, the downside, is forcing units to be overly cautious (not allowing units to dead bus close at all) and no unit ever closes to the dead bus.

NOTE: A unit can also be placed into a Proceed with Caution group due to a Software Version Mismatch event (SPN-FMI: 234-31) – see troubleshooting Section 8.4 for more details.

With this in mind, MGDL dead bus arbitration operates such that when a unit is placed in the Proceed with Caution mode, a failsafe dead bus arbitration rule is applied. The failsafe arbitration rule applies a unique time delay to each individual unit that attempts to dead bus close. This is done in order to attempt to differentiate each unit's dead bus close timing from other missing units and avoid simultaneous dead bus closes. No algorithm can completely remove the risk of a simultaneous dead bus close when communications are lost. However, this failsafe arbitration logic attempts to reduce this risk to an acceptable level. The Proceed with Caution failsafe arbitration rule is defined as:

- A unit in a Proceed with Caution group that has been granted permission to dead bus close, delays (5 + 1.25*MGDL Unit Number) seconds before issuing a dead bus close command to the generator breaker.

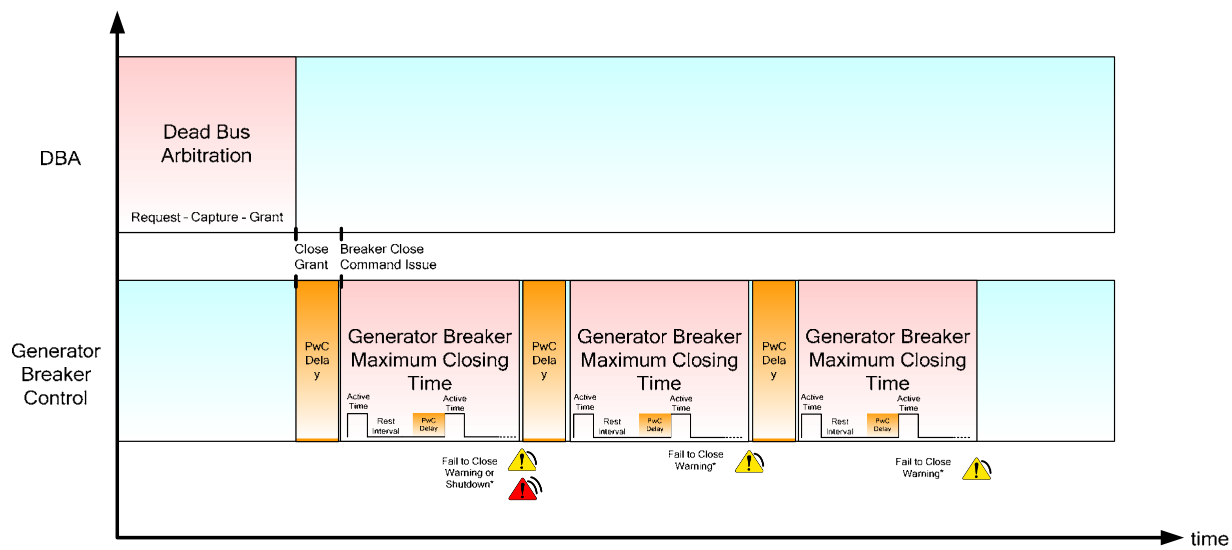
To further explain, examples of the Proceed with Caution logic have been applied to the Dead Bus Fail to Close scenarios that were previously discussed. These examples are provided in Figure 16 and Figure 17. Note that the dead bus fail to close logic is the same except a Proceed with Caution (PwC) delay is introduced prior to each time the generator breaker close command output is activated.



*If Generator Breaker Maximum Closing Time is configured less than Breaker Close To Dead Bus Maximum Time, unit may trigger "Fail to Close" Shutdown and NOT retry.

*If Generator Breaker Maximum Closing Time is configured greater than Breaker Close To Dead Bus Maximum Time, unit will continue to retry since "Fail to Close" Warning or Shutdown is not triggered.

Figure 16: Proceed with Caution Dead Bus Fail to Close Scenario with Multiple Units Requesting



*If Fail to Close Event Response Configuration (ERC) is configured for Warning, the unit continues to re-try.

Figure 17: Proceed with Caution Dead Bus Fail to Close Scenario with a Single Unit Requesting

NOTE: Any time a failsafe arbitration time delay is applied a "Dead Bus Arbitration Caution Mode Activated" status event is triggered (Section 7.8) in the EMCP 4.4 Status Event Log.

5.2 MGDL LOAD SHARING OPERATION

In order to sufficiently supply load to a system, it is beneficial for all paralleled generator sets to equally balance the load between one another. This optimizes loading capabilities of the system, increases stability and improves the system's response to transients. With balanced isochronous load sharing, even if the generator sets are of unequal ratings, the output of each generator set will be proportional to its rated output.

5.2.1 Purpose

The purpose of Real and Reactive Load Sharing is to share the real and reactive load proportionally (and equally if units are equal-sized) among all of the units on the MGDL network in an island mode (isolated from mains/utility) type configuration. This island mode configuration can be prime power, standby, or peak shaving (disconnected from the mains/utility).

5.2.2 Basic Operation

The EMCP 4.4 actively monitors the real (kW) and reactive (kVAr) load requirement of all paralleled generator sets on the MGDL Network and adjusts their output to maintain balanced loading of all generator sets at isochronous speed and voltage. As units enter or leave the system, or the load changes, the units adjust their contribution in order to contribute proportionally equal amounts. In failsafe modes, standard load sharing is exited and failsafe load sharing modes are applied (Section 5.8).

When the generator breaker is closed and the load sharing is set to Ethernet (MGDL), the unit calculates a system load sharing target based on information provided on the MGDL network. The unit controls load until the individual generator load matches the system load sharing target. As the system load sharing target changes, the EMCP 4.4 adjusts the generator set speed or voltage control to match the target.

Simultaneously, the EMCP 4.4 regulates speed and voltage setpoints to rated values in order to maintain proper bus frequency and voltage. An example of regulating real power load sharing and generator frequency through a real load transient is shown in Figure 18. The degree to which the EMCP 4.4 regulates to the system load sharing target as well as the frequency/voltage target values is based on the tune settings of the closed loop Proportional-Integral (PI) control system.

Please refer to the MGDL Paralleling Tuning Guide section of this manual (Section 6) for further information on tuning the load sharing controller gains.

NOTE: During normal MGDL operation actual kW % or kVAr % is output as voltage signals on analog load sharing lines for troubleshooting or monitoring purposes only. Hardwired Load Sharing is NOT permitted when configured for Ethernet (MGDL) load sharing.

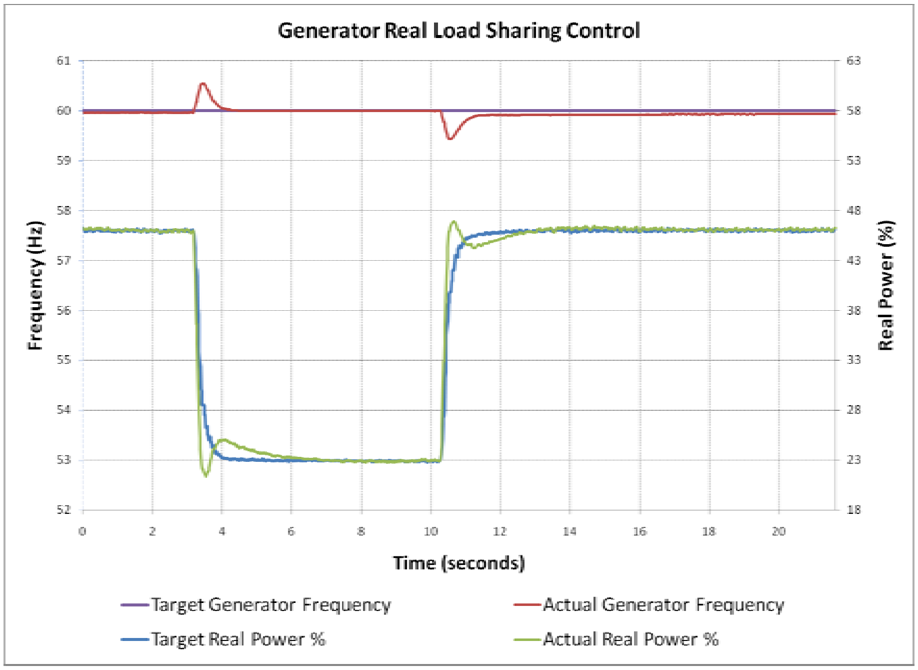


Figure 18: Generator Real Load Sharing and Frequency Regulation

Monitoring and tuning of MGDL load sharing can be done via the EMCP 4.4 display. The load sharing screens that include load sharing mode, actual/target real and reactive load sharing values as well as PI control system tuning are described further in MGDL Load Sharing Screens Section 7.4.

NOTE: If Generator Reactive Load Sharing is turned off or inhibited via programmable digital input, no reactive load sharing control signal is sent to the voltage regulator to control the voltage. This allows customers to implement voltage droop or other voltage or reactive power control methods separate from the EMCP 4.4 controller.

5.2.3 Soft Loading and Unloading

When load sharing isochronously, soft loading and soft unloading reduces instability and risk to equipment by increasing or decreasing generator output in a controlled manner before closing or opening the generator breaker.

Soft loading a generator set into an isochronous load sharing system is accomplished by controlling the rate of change of the bias signal of frequency or voltage. At the instant the generator breaker closes the generator set is electrically tied to the load sharing system. A frequency/voltage bias is applied to the oncoming generator set so that it produces little or no power, but remains in parallel with the system. The bias signals are then slowly increased, causing the generator output to increase. The rate the output increases is determined by the rate that the bias is increased and is a configurable setpoint (see Section 4.3.4 Generator Real Load Sharing Soft Loading/Unloading and Figure 10).

The oncoming generator set will pick up load until the system load sharing target is reached. At the same time, the generator sets already in isochronous load sharing, will collectively reduce their load by the amount of load picked up by the oncoming generator set. Once the oncoming generator set reaches the system target its contribution is included in the calculation of the system load sharing target and all units now will be producing their proportional share of load while maintaining isochronous frequency/voltage.

Soft unloading is accomplished in a similar, but reverse manner. An off going generator set's load is ramped down by controlling the voltage/frequency bias signals. Once the generator output is decreased to a configurable threshold, the generator set is disconnected from the load sharing system by opening the generator breaker.

While it is useful to soft load and unload units into a load sharing system, certain conditions make it necessary to abandon soft loading/unloading and proceed directly into load sharing in order to adequately supply load. The following conditions will cause soft loading or unloading to be exited:

- Oncoming unit fails to soft load (% kW/kVAr is not increasing)
- Oncoming or off going unit experiences a frequency disturbance
- Off going unit experiences a voltage disturbance
- Off going unit fails to soft unload (% kW/kVAr is not decreasing)

5.3 MGDL GROUP START COMMAND OPERATION

5.3.1 Group Start Command Assertion

The EMCP 4.4 has the ability to accept a group start signal via a dedicated isolated digital input. If this signal is activated and MGDL is enabled, the EMCP 4.4 will send a group start request over the MGDL network to all MGDL units and each unit will issue an engine start request to the engine. If the group start signal is removed, the EMCP 4.4 will remove the group start request from all MGDL units on the network and each unit will issue a stop request to the engine. This signal should be wired into pin 32 on the EMCP 4.4 controller 70-pin connector. This input will become logically active when pulled down to the isolation reference pin 118 on the EMCP 4.4 controller 120-pin connector. The physical and logical status of the group start input is visible from the I/O Status screen on EMCP 4.4 display. The group start input is Dedicated Isolated Digital Input A.

NOTE: If using group start, Reduced Power Mode is NOT recommended. An active group start input or MGDL group start command will prevent an EMCP 4.4 from entering reduced power mode, but will not wake up a unit that is already in Reduced Power Mode. If a group start input or MGDL group start command is active during the "semi-awake" period of reduced power mode, the unit will exit reduced power mode, begin broadcasting on the MGDL network, start, and run. For more information on the operation of EMCP 4.4 Reduced Power Mode, refer to the EMCP 4.3, 4.4 Generator Set Control, Application and Installation Guide (LEBE0007).

Load Sense Load Demand control is initiated only when a group start command is received by a control and at least one genset is ready to automatically parallel. If a unit receives a group start command with the engine control switch in auto, but does not meet all conditions for participating in LSLD, the unit will still start and run.

An MGDL group start command is issued to all other MGDL units regardless of the state of the control issuing the command. For example, a unit could be in STOP and still issue a group start command to all other units over MGDL. All group start commands received by a unit on the MGDL network are logically OR-ed together. Therefore wiring out group start inputs from multiple units is recommended and provides redundancy to the MGDL system (

Figure 19).

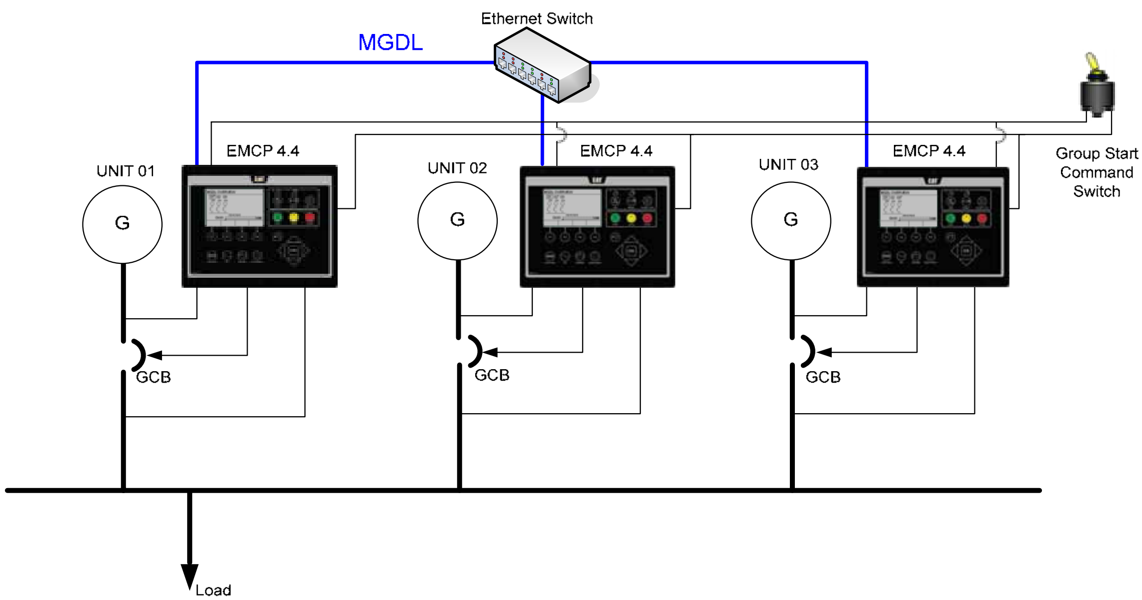


Figure 19: MGDL Network Topology with Group Start Switch

5.3.2 Group Start Command Removal

If all MGDL group start commands are removed and the unit that was sending the group start command is still on the network, then the generator sets are no longer required to run. The units soft unload, cooldown, and stop in a controlled manner. If configured, feeder breaker trip logic is followed when the last unit opens its generator breaker. (See Section 5.5 - MGDL Feeder Breaker Control).

In practice, the operator should remove load from the generator sets before removing the group start command and the above group start command removal operation will suffice. If the operator removes the group start command while generator sets are still loaded, the following logic is used in order to protect the generator set equipment as much as possible:

- If the total system load % is less than the rating of the smallest unit on the bus, units independently soft unload, open generator breakers and cooldown.

- If the total system load % is greater than the rating of the smallest unit on the bus, follow feeder breaker logic if configured (See Section 5.5 - MGDL Feeder Breaker Control) and check new total system load %.

- If the total system load % with feeder breaker trip command active (if configured) is greater than the rating of the smallest unit on the bus, all units on the MGDL network attempt to open their generator breakers as close to simultaneously as possible.

5.3.3 Group Start Command with Loss of MGDL Communications

If all MGDL group start commands are removed and the unit(s) sending the group start command are NOT on the network, all MGDL group start commands are latched. This means that a unit that loses an MGDL group start command due to loss of communications will continue to run and provide load if on the bus.

If an MGDL group start command is latched it can be unlatched by the following:

- Return of the lost MGDL unit that was sending the group start with the group start command removed
- Assertion of another group start command
- Package being removed from AUTO mode (engine control switch in manual mode, red lamp status…etc)
- Generator Breaker transitions from closed to open (but NOT as a result of normal LSLD operation)

5.4 MGDL LOAD SENSE LOAD DEMAND OPERATION

5.4.1 Purpose

MGDL Load Sense Load Demand (LSLD) is the control system used in EMCP 4.4 controllers to automatically bring generator sets on the bus or take generator sets off the bus in order to serve facility loads while maintaining fuel efficiency and adequate reserve. The LSLD control algorithm analyzes system load levels, sequence priority assignments and generator status communicated via MGDL. This information is used to compare load levels with programmable thresholds and time delays before deciding to drop under loaded generator sets or add additional available generator sets in order to efficiently match load demand. See Figure 20 for an example loading of LSLD system.

The setpoint configuration for MGDL LSLD is described in Section 4.4 and the MGDL LSLD display screens are described in Section 7.6. The operation and methodology of MGDL LSLD is described below.

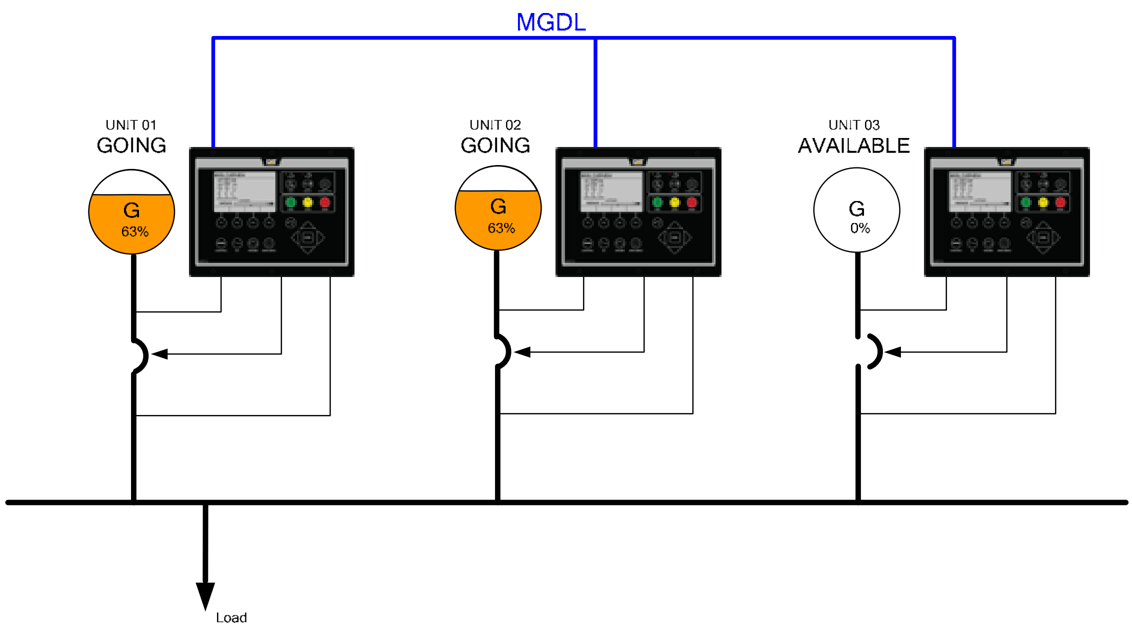


Figure 20: MGDL LSLD Loading Example

5.4.2 Basic Operation

Load sense load demand is accomplished using the MGDL network to communicate between generator sets. There is NO master or group controller in MGDL LSLD. This feature supports up to 16 generator sets operating in parallel on a common bus and performs optimally with equal sized generator sets. If generator sets are significantly different in power outputs, less flexibility of configuration and operation will occur. Sequencing of generator sets will be accomplished based on *Load Sense Load Demand Sequence Strategy Configuration* (setpoint) described in Section 4.4.4.

There are several LSLD participation conditions that a control must satisfy in order to participate in LSLD with other controllers on the network. ALL of the following conditions must be satisfied and if ANY one condition is NOT, the control is considered unable to participate in LSLD.

- *Load Sense Load Demand Enable Input Configuration* (setpoint) is set to 'Ethernet (MGDL)'
- Engine Control Switch (ECS) is in AUTO
- Sync Mode Switch (SMS) is in AUTO
- Idle/Rated is set to RATED
- Valid Group Start Signal (Dedicated Isolated Group Start Digital Input is ACTIVE or MGDL Group Start Command is received over the MGDL network)
- Inhibit Breaker Close is INACTIVE
- Following Warnings Events are not PRESENT:
    - Not Ready to Automatically Parallel Warning
    - Generator to Bus Synchronization Failure Warning
    - Generator Under Frequency Warning AND Generator Breaker is CLOSED
    - Generator Breaker Failure to Open
    - Generator Breaker Failure to Close
    - Generator Breaker FID Diagnostic
    - MGDL Communication Failure
- No Shutdown Events exist
- Load Control Mode with Utility is INACTIVE
- No Emergency All Run signals exist
- Master Control is NOT present
- Load Sharing State is NOT in LOAD SHARE – FAILSAFE DROOP

LSLD is initiated when a group start command is received by a control and at least one generator set is ready to automatically parallel. An operator can request all the sets in a group to start from any generator set via a dedicated isolated digital input only. When a Group Start (input) is ACTIVE a Group Start Command is sent over MGDL to all units. If a unit receives a Group Start Command, but does not meet all conditions for participating in LSLD, the unit will still start and run if the Engine Control Switch (ECS) is in AUTO. For more information on Group Start refer to Section 5.3 - MGDL Group Start Command Operation.

NOTE: A Group Start Signal (input or command) overrides a Remote Initiate command (digital input or modbus) and initiates LSLD control if ALL other conditions (above) are satisfied. If there is no Group Start Signal, the unit follows the Remote Initiate Command (LSLD control will not be active).

Before enabling LSLD control, the LSLD settling timer (*Load Sense Load Demand Enable Minimum Delay Time* setpoint) must expire. The settling timer is a configurable setpoint and is explained further in 4.4.2. The purpose of the settling timer is to allow sites to step system load on gradually and settle before LSLD control begins analyzing load levels and considers walking generator sets off the bus.

The settling timer is reset anytime a unit no longer detects bus voltage OR the unit receives an emergency all run message via MGDL. After the settling timer expires, normal LSLD operation commences. An emergency all run message is triggered when a loaded unit experiences a Generator Under Frequency Warning.

It is possible to have an Under Frequency Warning during an overload situation depending on how tight the conditions for triggering the warning are configured. Generator sets are walked-off/walked-on the bus based on the LSLD system % kW logic and LSLD sequencing strategy which is discussed in the following section.

5.4.3 LSLD Add/Drop Conditions

During normal load sharing, each unit communicates its % kW and rated kW to the other units on the MGDL network. Each unit is therefore capable of calculating the target % kW and load share appropriately. The LSLD system % kW calculation is done using the rated kW of all units participating in LSLD (Unit LSLD Status = GOING). Units not under LSLD control are considered zero load, therefore are not included in LSLD calculations. The Unit LSLD Status is described further in Section 5.4.4. Each controller calculates the LSLD system % kW from MGDL network information.

Below is an example of calculating LSLD system % kW:

> A 500kW set is GOING on load at 350kW (70%) and an 800kW set is GOING on load at 420kW (52.5%). Each set can calculate that the LSLD system % kW is ((350+420)/(500+800) = 59.2% (**not** (70%+52.5%)/2 = 61.3%).

The *Load Sense Load Demand Sequence Strategy Configuration* (setpoint) is configurable from any node on the network, but is a system-wide parameter that determines the sequence strategy used by all controllers in the system under LSLD control. Any controller being powered up in a group will adopt the strategy of controllers already powered up. Any change in a system-wide setpoint is broadcast to all units. The possible LSLD sequence strategies are:

- Total Operating Hours
- Priority Number (default)

When sequencing under the Total Operating Hours strategy, the unit with the least accumulated total operating hours has the highest priority. The “highest priority” unit is the one most likely to run and remain on the bus. The “lowest priority” unit is the one most likely to go off the bus.

Two controllers with identical Total Operating Hours next in sequence priority will resolve this conflict based on the MGDL unit number (highest MGDL unit number is dropped from the bus first, lowest MGDL unit number is added to the bus first).

Priority Number sequencing mode is ignored and has no impact when in Total Operating Hours sequencing mode.

To maintain hours balance, if a unit is off the bus (Unit LSLD Status = AVAILABLE) and has 10 fewer total operating hours than a unit that is GOING, the AVAILABLE unit shall come on the bus. At this point, normal LSLD sequencing shall continue to operate as configured.

When configured to Priority Number sequencing mode, the lowest Priority Number has the highest priority.

NOTE: Priority Number sequencing mode is the opposite operation of the *Generator Paralleling Priority Number* (setpoint) used in Hardwired LSLD. The *Generator Paralleling Priority Number* setpoint does NOT apply to MGDL LSLD.

Priority Number sequencing mode is the default sequence strategy for all units. Priority Number is only programmable from display on LSLD Priority Assignment screen, described in Section 7.6.

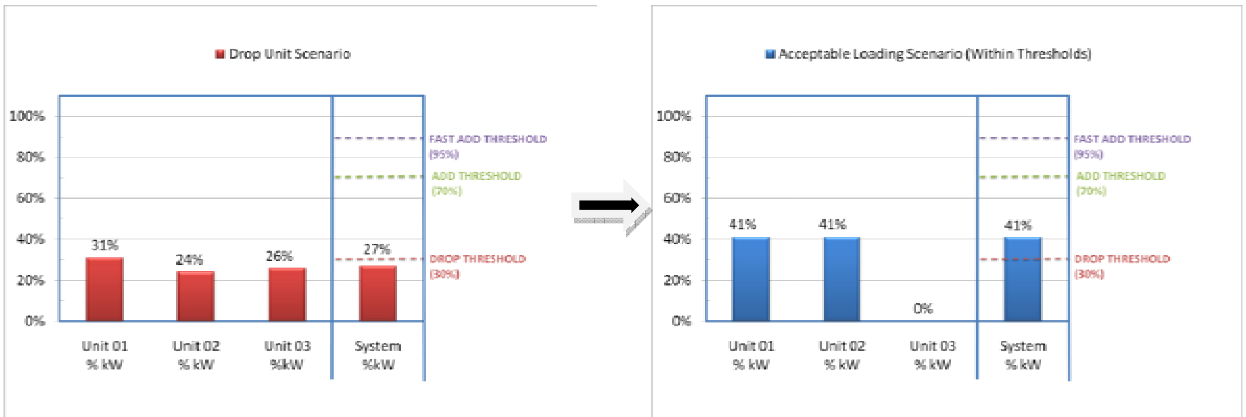


Figure 21: LSLD Drop Unit Scenario Example

A generator set will be dropped from the bus according to the following conditions:

- The LSLD system % kW falls below the *LSLD Drop Unit Percentage Threshold* (setpoint) for the *LSLD Drop Unit Delay Time* (setpoint) AND the removal of the next genset in the sequence will not cause the LSLD system % kW of the remaining generator sets to rise to within 5% of the *LSLD Add Unit Percentage Threshold* (setpoint). (Figure 21: LSLD Drop Unit Scenario)

  NOTE: This drop unit check functionally is NOT included in Hardwired LSLD

- Controllers are only allowed to be walked-off when no units are in LSLD Status = LOADING or UNLOADING states.
- At least two units must have LSLD Status = GOING and no units can be LSLD Status = SETTLING.

Generator sets will be dropped off in order of:

- Lowest priority (highest sequence priority number) with LSLD Status = GOING.

NOTE: The highest sequence priority unit with LSLD Status = GOING will not be dropped, regardless of the load level. One unit under LSLD control shall always remain on the bus.

If conditions have been met for a unit to be dropped off, the lowest priority unit online will soft unload and open its generator breaker. In a normal drop scenario, the unit’s LSLD Status will progress through the following unit LSLD states:

GOING > UNLOADING > AVAILABLE

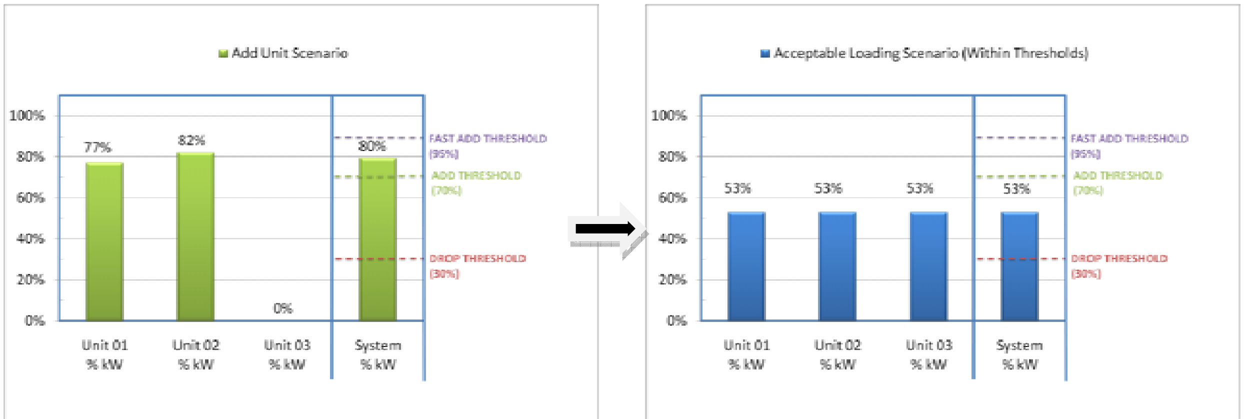


Figure 22: LSLD Add Unit Scenario Example

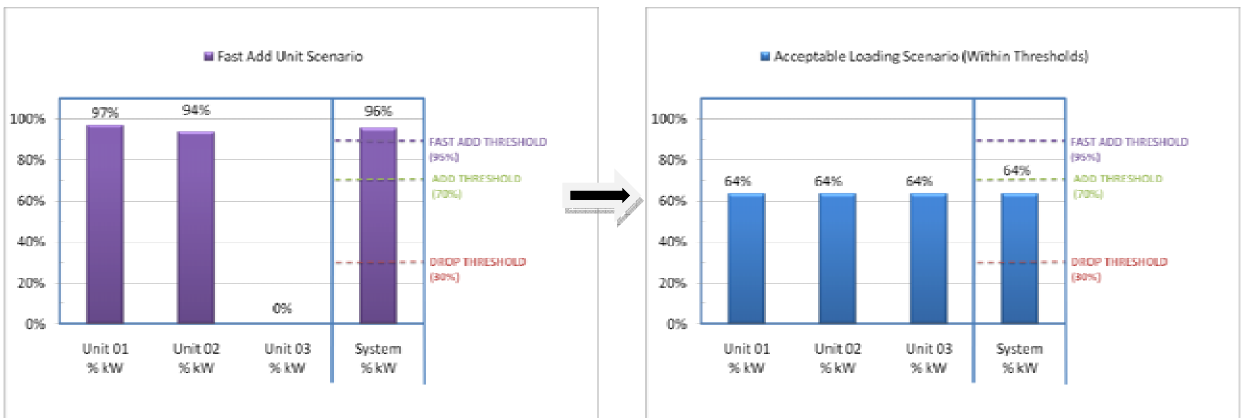


Figure 23: LSLD Fast Add Unit Scenario Example

A new generator set will be added to the bus if any one of the following conditions are met:

- The LSLD system % kW rises above the *LSLD Add Unit Percentage Threshold* (setpoint) for the corresponding time delay (*LSLD Add Unit Delay Time* (setpoint)) (Figure 22)
- The LSLD system % kW rises above the *LSLD Fast Add Unit Percentage Threshold* (setpoint) for the corresponding time delay (*LSLD Fast Add Unit Delay Time* (setpoint)) (Figure 23)
- Maintain Sequence Priority - A unit that is GOING (on the bus) has a lower priority (higher sequence priority number) than a unit that is AVAILABLE. This could result from a new sequence priority number assignment while the units are participating in LSLD. (Only when LSLD Sequence Strategy is configured to "Priority Number")
- Maintain Hours Balance - A unit that is GOING (on the bus) has 10 more engine hours than a unit that is AVAILABLE (off the bus). This could result from engine hours accumulating on units that are on the bus. (Only when LSLD Sequence Strategy is configured to "Total Operating Hours")

NOTE: No drop check protection exists, i.e checking that adding a unit results in LSLD system % kW dropping below the *LSLD Drop Unit Percentage Threshold* (setpoint).

Controllers are only allowed to be added to the bus when no units are in LSLD Status = LOADING or UNLOADING states.

Generator sets will be added to the bus in order of:

- Highest priority (lowest sequence priority number) with unit LSLD Status = AVAILABLE.

If LSLD is attempting to add a genset, and the unit's LSLD Status changes to GOING LSLD OFF or UNAVAILABLE, then the next highest priority genset in sequence will immediately be brought on the bus. In a normal add unit scenario, the unit's LSLD Status will progress through the following states:

AVAILABLE > LOADING > GOING

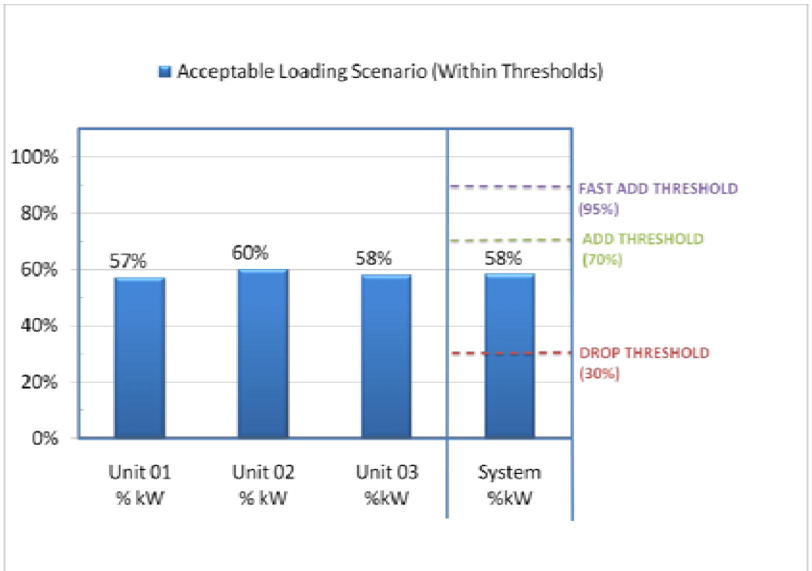


Figure 24: LSLD Acceptable Loading (Within Thresholds) Scenario Example

As long as The LSLD system % kW is maintained above the *LSLD Drop Unit Percentage Threshold* (setpoint) AND below the *LSLD Add Unit Percentage Threshold* (setpoint) and *LSLD Fast Add Unit Percentage Threshold* (setpoint) no units will be added or dropped from the bus as a result of LSLD operation (Figure 24).

5.4.4 Unit/System LSLD Status

Each controller communicates its Unit LSLD Status over the MGDL network. The Unit LSLD Status is based on the LSLD participation conditions, generator breaker status, settling timer, etc. The System LSLD Status is also communicated over the MGDL network. The System LSLD states are based off each individual unit's Unit LSLD state. The individual Unit LSLD Status and the System LSLD Status is displayed on the LSLD Screens described in Section 7.6.

5.4.5 System-wide LSLD Setpoints

When *Load Sense Load Demand Input Configuration* (setpoint) is set to "ETHERNET (MGDL)", the following setpoints are considered "system-wide" setpoints:

- *Load Sense Load Demand Add Unit Percentage Threshold*
- *Load Sense Load Demand Add Unit Delay Time*
- *Load Sense Load Demand Drop Unit Percentage Threshold*
- *Load Sense Load Demand Drop Unit Delay Time*
- *Load Sense Load Demand Fast Add Unit Percentage Threshold* **
- *Load Sense Load Demand Fast Add Unit Delay Time* **
- *Load Sense Load Demand Sequence Strategy Configuration* **

** This is a setpoint specific to MGDL Load Sense Load Demand and is NOT used for Hardwired LSLD.

System-wide setpoints are configurable from any node in the MGDL network. The setpoint is automatically applied to all EMCP 4.4 controllers on the MGDL network, and any controller powered up will adopt the configuration of other controllers already powered up.

NOTE: All LSLD system-wide setpoints are configurable via ET or EMCP Display when *Load Sense Load Demand Input Configuration* is set to "DISABLED". When MGDL Unit Number = 0, LSLD system-wide setpoints are configurable, but not communicated over the network.

Configuration of the system-wide LSLD setpoints is described in Section 4.4.

5.4.6 Failsafe LSLD Operation

The following describes LSLD control operation during a loss of communication on the MGDL network. The MGDL system uses knowledge of the network topology (expected number of controls online) to be 'cautious' in regards to missing or non-communicating units.

NOTE: A unit can also be placed into a Proceed with Caution group due to a Software Version Mismatch event (SPN-FMI: 234-31) – see troubleshooting Section 8.4 for more details.

As described in Section 5.6 - MGDL Loss of Communications Strategy, units in a fragmented MGDL network are separated into a Proceed as Normal (majority) and a Proceed with Caution (minority) group. The units grouped in the Proceed with Caution group exit LSLD, start, and go on the bus since their MGDL communication is isolated from other units that are potentially on the same electrical bus.

Units that are GOING and are grouped in the majority (Proceed as Normal) group continue to follow LSLD logic and may sequence on or off the bus. MGDL communications are still intact with these units so LSLD is allowed to continue in this failure mode.

5.5 MGDL FEEDER BREAKER CONTROL

Limited feeder breaker support for connecting a generator bus and a load bus is included with the EMCP 4.4 MGDL feature. In order for a unit to provide feeder breaker control, a programmable digital output MUST be configured for "Feeder Breaker Close Command" with "Feeder Breaker Trip Command" programmed for an additional digital output as optional. Setpoints *Minimum Real Power Required for Load Bus #1* and *Minimum Reactive Power Required for Load Bus #1* also must be configured (See Section 4.1.2).

Minimum Real Power Required for Load Bus #1 and *Minimum Reactive Power Required for Load Bus #1* setpoints determine the minimum available power required before issuing a feeder breaker close command. The available power is determined by the rated power (real and reactive) of all units communicating on the MGDL network that are closed to the bus. Each setpoint acts as a local setpoint for each controller. These setpoints are present in all modules and for redundancy, it may make sense to have multiple controllers programmed the same and wired to the feeder breaker in case a controller is powered down for routine maintenance on the engine generator set. If multiple feeder breakers exist, or the feeder breaker signal is being used to add load, each controller or group of controllers can be used to add a load step.

Available power levels are monitored and compared with *Minimum Real Power Required for Load Bus #1* and *Minimum Reactive Power Required for Load Bus #1* regardless of engine state remote initiate, or group go state. Feeder Breaker Close Command digital output and Feeder Breaker Trip Command digital output are set according to the following logic:

- If there are sufficient (real and reactive) power levels available, the unit sets Feeder Breaker Close Command digital output to active.
- If there are insufficient (real or reactive) power levels available, the unit waits for additional generators to synchronize and close to the bus during which time Feeder Breaker Close Command digital output remains inactive.
- Feeder Breaker Close Command digital output is set to inactive when the last unit on the MGDL network opens its generator breaker.
- Feeder Breaker Trip Command digital output is set to active for 1 second when the last unit on the MGDL network opens its generator breaker.

Figure 25 depicts an example of 3 MGDL units configured for Feeder Breaker Control. In this example each unit is assumed to be 1000 kW, 750 kVAr rated generator sets. Also assumed is that each unit is configured such that *Minimum Real Power Required for Load Bus #1* = 2,000 kW and *Minimum Reactive Power Required for Load Bus #1* = 1,500 kVAr. With this configuration and with Unit 01 and Unit 02 closed to the bus, the feeder breaker close command output will be active for all three (3) units.

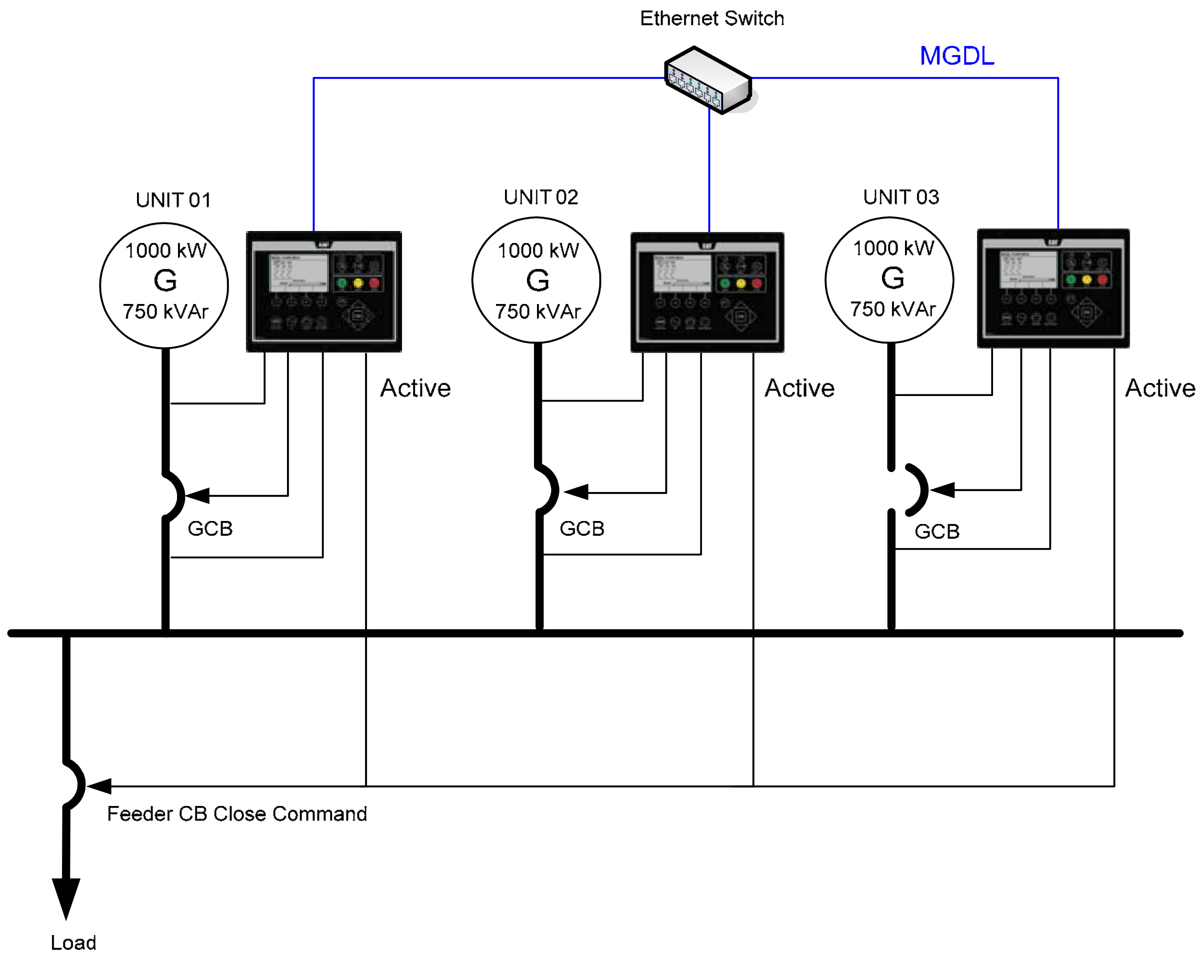


Figure 25: MGDL Feeder Breaker Control Example

5.6 MGDL LOSS OF COMMUNICATIONS STRATEGY

MGDL Loss of Communication is defined as MGDL messages from one or more of expected controls online NOT being received after a specified period of time. This can occur as a result of conditions such as broken wires, mis-configuration, or Ethernet router/switch/hub device power loss, or power loss to the EMCP 4.4, for example. If a communication loss is detected by an EMCP 4.4 on the MGDL network the following actions are taken:

- Unit Number of lost unit on the MGDL Overview screen is replaced with a question mark symbol (See Section 7.1 - MGDL System Overview Screens for full details).
- CONTROL IS OFFLINE MULTIPLE GENSET CONTROL DATA LINK diagnostic (SPN-FMI: 625-31) event is triggered (See Section 8.2 - MGDL Control Is Offline event).
- “MGDL Unit(s) Not Detected” status event is triggered if some, but not all units are lost.
- “No MGDL Units Detected” status event is triggered if ALL units are lost.

- Based on the communication status of expected number of MGDL units, Proceed with Caution or Proceed as Normal grouping is performed (as described below).
- Based on Proceed with Caution or Proceed as Normal grouping, the operational mode for MGDL features such as DBA, LSLD, and Load Sharing are updated as necessary.

The operating modes of units during a loss of communications are updated in order to best serve the generator system. For example, if the lost units are still running and on the bus it is necessary for them to behave in a safe way. The MGDL system uses knowledge of the network topology to be cautious in regards to missing units. A loss of communication on the MGDL network results in a fragmented or split network. Units in a fragmented MGDL network are separated into a Proceed as Normal (majority of the units) and a Proceed with Caution (minority of the units) group based on the following:

- Number of units still communicating out of the total expected number of controls (pre-loss of communication) AND
- The lowest MGDL Unit Number

Examples of fragmented network scenarios with Proceed as Normal and Proceed with Caution grouping are described below.

Split Network Scenario #1

If my control (Unit 05 in Figure 26) detects less than half of expected number of controls online (minority) then proceed with caution and operate in the following fail safe modes:

Table 3: Proceed with Caution (minority) Group Failsafe Operating Modes

Paralleling Feature	Proceed with Caution Failsafe Operating Mode
Dead Bus Arbitration	Proceed with Caution DBA
Real and Reactive Load Sharing	Failsafe Adaptive Droop
Load Sense Load Demand	Exit LSLD

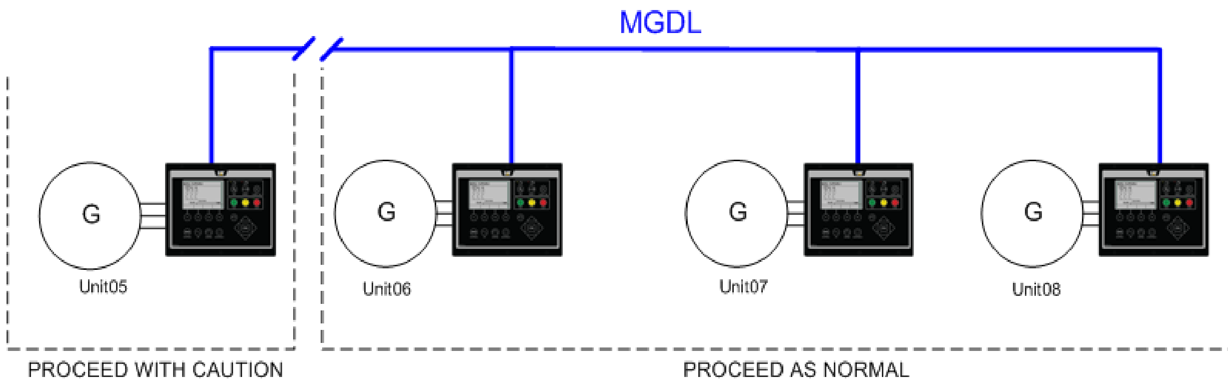


Figure 26: MGDL Loss of Communications with My Unit in Proceed with Caution (minority) Group

Split Network Scenario #2

If my control (Unit 05 in Figure 27) detects more than half of expected number of controls online (majority) then proceed as normal:

Table 4: Proceed as Normal (majority) Group Failsafe Operating Modes

Paralleling Feature	Proceed as Normal Failsafe Operating Mode
Dead Bus Arbitration	Normal DBA
Real and Reactive Load Sharing	Failsafe Isochronous Load Sharing
Load Sense Load Demand	Normal LSLD

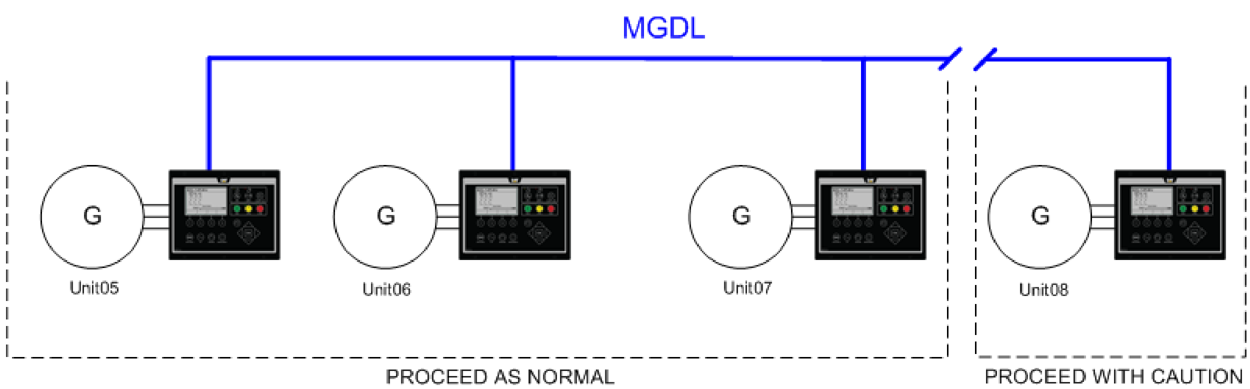


Figure 27: MGDL Loss of Communications with My Unit in Proceed as Normal (majority) Group

Split Network Scenario #3

If my control (Unit 05 in Figure 28) detects exactly half of expected number of controls online then

- If my control sees the lowest unit number: Proceed as Normal.
- If my control does NOT see the lowest unit number: Proceed with Caution.

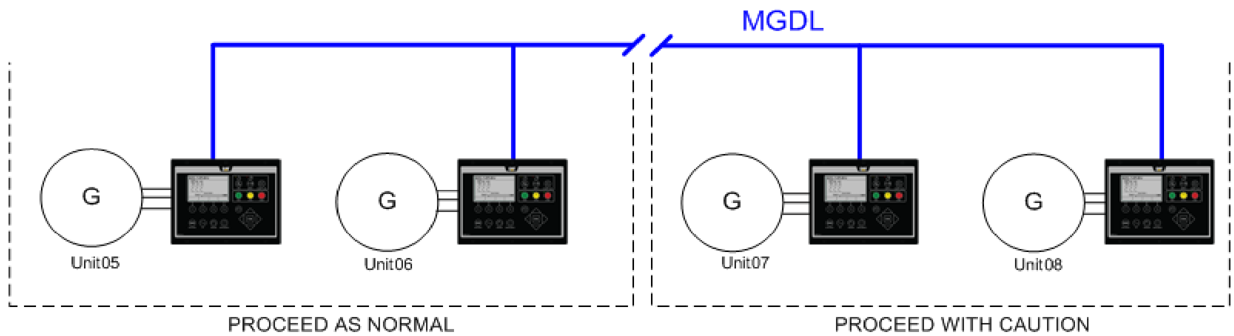


Figure 28: MGDL Loss of Communications with Evenly Split Network

NOTE: With multiple splits in the MGDL network at different times, it is possible to end up with ONLY proceed with caution groups and zero proceed as normal groups as shown in Figure 29.

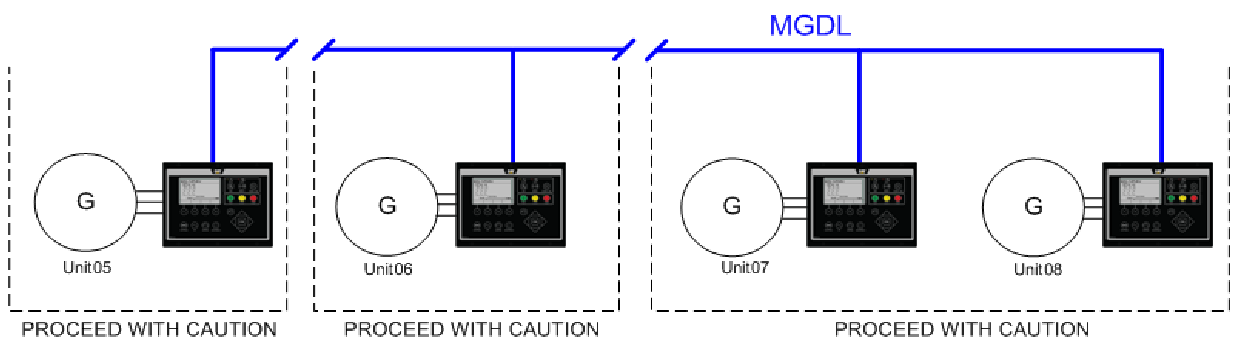


Figure 29: MGDL Loss of Communications with Only Proceed with Caution Groups

In all of the scenarios above, a group start signal being received over the MGDL network is latched on an individual unit during the loss of communications. If a unit was receiving a group start command before loss of communications and the unit that was sending the group start command is no longer on the network, the group start is latched. The latched group start command can be unlatched by the assertion of another group start command, the package being removed from automatic mode (engine control switch in manual mode, red lamp status...etc), or a generator circuit breaker transitioning from closed to open (but not as a result of normal LSLD operation). See Section 5.3 - MGDL Group Start Command Operation for more details on the operation of the group start command.

5.7 MGDL NETWORK CONFIGURATION RESET (EXPECTED UNITS)

As described above, the MGDL network configuration is determined by the number of actual controls detected (communicating) and the number of expected controls on the MGDL network. These values allow each unit to determine network topology information such as the total number of nodes in the MGDL network as well as assign the appropriate failsafe modes during loss of communications. The MGDL network configuration and each unit's understanding of the network is reliant on the accuracy of these values.

The actual number of controls detected is dynamically sensed and therefore is not user adjustable. However, the number of expected controls on the MGDL network is the critical parameter used by each unit and is user resettable. Expected number of controls is defined as the maximum number of unique MGDL unit numbers broadcasting on the MGDL network over a given period of time. The expected number of controls on the MGDL network ONLY increments and can only be reset or decremented in the following ways:

1. Forced to reset from display (MGDL Control Screen - Section 7.1 of this manual). A Reset Expected command from display is communicated to ALL units on the MGDL network. In order for all controls to agree on the network configuration, if one unit is commanded to reset expected number of controls all other units will reset expected number of controls.
2. After certain period of time being powered down the EMCP 4.4 controller will "clear" internal memory of the number of expected controls. This is done in order to benefit generator sets that are commonly relocated and are frequently powered up into new MGDL network topologies (such as rental units). The logic for this resetting of expected number of controls is after my control is powered down for >12 hours:
    a. If all other controllers on the network with mature communications agree on the expected number of controls online,
        i. Reset expected number of controls to the agreed upon expected number of controls online.
    b. If all controllers on the network with mature communications do NOT agree on the expected number of controls online,
        i. Reset expected number of controls online to zero and re-calculate the units.
    c. If all controllers on the network have immature communications,
        i. Reset expected number of controls online to zero and re-calculate the units.

NOTE: The actual detected number of controls online and the expected number of controls online is indicated on display on the MGDL Control screen described in Section 7.1 of this manual.

⚠ WARNING

Resetting expected number of controls on the MGDL network should be done with extreme caution. Resetting expected number of MGDL controls during operation may create isolated communication networks between generator sets connected to the same electrical bus.

Failure to heed this warning can lead to premature failures, product damage, personal injury or death.

Resetting expected number of controls via display should only be done as a result of proper troubleshooting or only when intentional MGDL network node adjustments are desired. It is NOT recommended to reset expected number of controls while generator sets are running and providing load. Resetting expected number of controls results in the definition of new MGDL network nodes connected to the same electrical bus that may or may not communicate with each other. Therefore resetting expected number of controls inappropriately creates a risk of system instability and/or a crash-parallel.

5.8 MGDL LOAD SHARING FAILSAFE OPERATION

A unit is considered lost from the MGDL network based on the conditions outlined in the MGDL Loss of Communications Strategy section of this manual (Section 5.6). Units that are lost from the network are expected to operate in a failsafe mode. If units are still running and on the bus when a communications failure occurs, they attempt to behave in a safe way by moving to a failsafe mode such as Failsafe Isochronous Load Sharing and/or Failsafe Adaptive Droop as outlined below.

5.8.1 Background

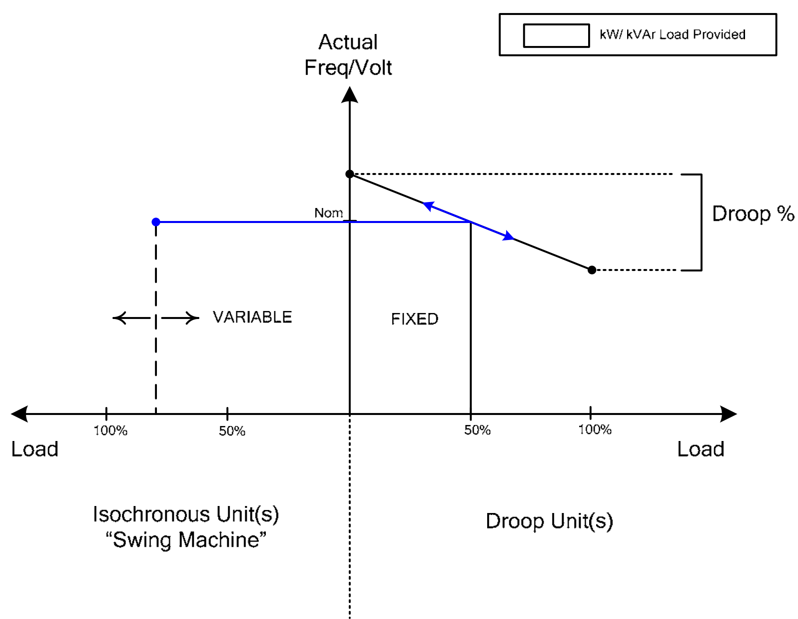


Figure 30: Standard "Swing Machine" Droop Control Scheme

In a standard (non-EMCP 4) failure implementation (Figure 30), units are divided into two modes; droop and isochronous. Failsafe droop units are automatically placed at a fixed, pre-determined target load, such as 50% load at nominal frequency. Failsafe isochronous or swing machines take on the majority of load changes. Only after isochronous units become overloaded (>100%) will the failsafe droop units tend to pick up more load. This standard control scheme implementation can introduce several issues when generator sets switch in and out of failsafe conditions.

For instance, if the droop units were operating at a different load percentage immediately prior to entering the failsafe mode, each droop generator set would abruptly shift its frequency and load point to the pre-determined target load. The abrupt change in generator set operation may cause instability in the overall system and a loss of power synchronization. In addition, the standard droop control scheme implementation does not allow for an even distribution of loads among the generator sets. For instance, the isochronous generator set may be allowed to become overloaded while the droop generator sets are under loaded. The

MGDL Failsafe Adaptive Droop control scheme (patent pending) attempts to address the issue described above.

5.8.2 Failsafe Adaptive Load Sharing/Droop Strategy

For a system that loses MGDL communications between units, the failure mode is to intelligently switch lost units to Failsafe Adaptive Droop while other units switch to Failsafe Isochronous Load Sharing. The first function of Failsafe Adaptive Droop is to seamlessly switch units into a failsafe operating mode while continuing to provide load with minimal disruption to the system. The second function of Failsafe Adaptive Droop is to provide more even distribution of loading between units as system load changes by preventing premature overloading of the isochronous units.

The Failsafe Adaptive Droop and Failsafe Isochronous Load Sharing control profiles are depicted together in Figure 31. Failsafe droop units are controlled based on adaptive droop curves that converge to a standard droop curve with each successive system load swing. This allows for a controlled migration from the droop unit's initial (last known load sharing) load level to a fixed 50% loading.

Failsafe isochronous units that experience loading beyond specified thresholds (q1% and q2%) droop benefit from the ability of failsafe droop units to provide additional load. This means at extreme(but within ratings) load levels, the failsafe isochronous units avoid premature overloading/underloading and force failsafe droop units to compensate.

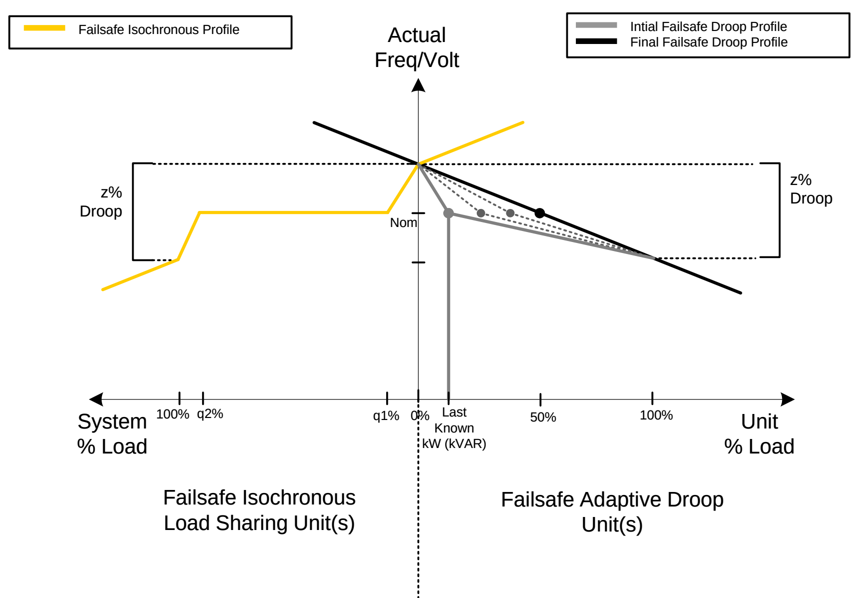


Figure 31: Failsafe Adaptive Droop Control Scheme

5.8.3 Failsafe Isochronous Load Sharing

In general, a generator set operating in isochronous mode maintains constant speed/frequency (voltage) regardless of the load it is supplying. However, Failsafe Isochronous units operate such that speed/frequency (voltage) remain the same for the majority of its load range, but droop speed/frequency (voltage) slightly at extreme load ranges. This is done to prevent premature overloading or underloading and provide more even distribution of loading during failsafe conditions. The operating ranges for units in Failsafe Isochronous Load Sharing are shown in Figure 32 and are described below.

- For system % kW (kVAr) in the middle range from q2 to q1%
  - Run isochronous load sharing at nominal frequency (voltage)

- For system % kW (kVAr) in the lower range from 0 to q1%
  - Target frequency (voltage) droop with slope (z*0.5%)/q1% applied.

- For system % kW (kVAr) in the upper range from q2 to100%
  - Target frequency (voltage) droop with slope (z*0.5%)/(100-q2%) applied.

Where reactive (kVAr) loading z% droop is fixed to 6% and for real (kW) loading z% droop is fixed to 3%. The load ranges q1 and q2 are fixed percentages of load such that:

- q1 = 20%
- q2 = 80%

NOTE: If failsafe isochronous load sharing units' %kW (kVAr) drops below 0% kW (kVAr) or rises above 100% kW (kVAr), the standard z% droop is implemented.

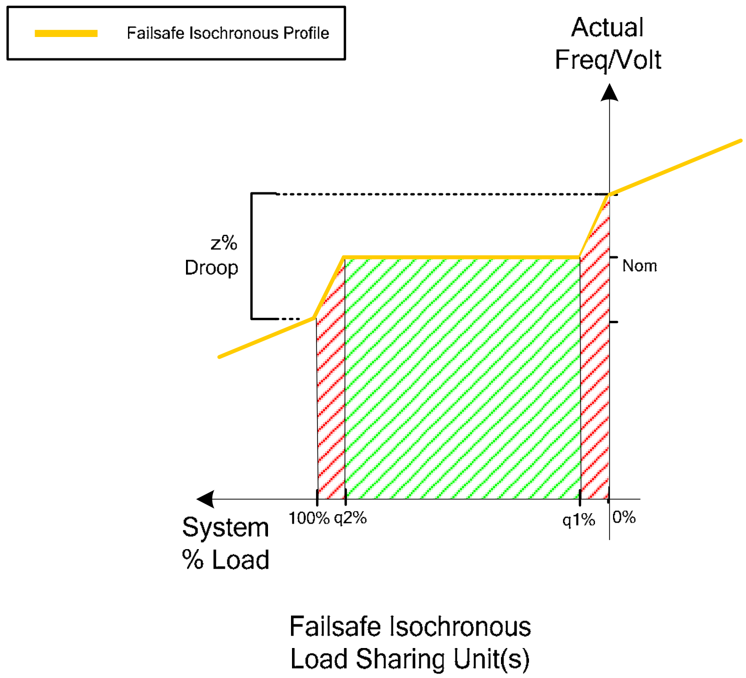


Figure 32: Failsafe Isochronous Load Sharing Operating Ranges

It should be noted that unless load sharing capabilities exist, no more than one generator set connected to the same bus may run in isochronous mode. If two generator sets, operating in isochronous mode without load sharing capabilities are supplying the same load, one of the units will try to carry the entire load and the other will shed its entire load. As explained in the MGDL Loss of Communications Strategy (Section 5.6) only units that are in the Majority MGDL group are placed in Failsafe Isochronous Load Sharing mode. Therefore, two or more generator sets in the same Majority MGDL group operating may operate in Failsafe Isochronous Load Sharing mode and will share load equally with each other.

5.8.4 Failsafe Adaptive Droop

In general, generator sets operating in droop mode decrease speed/frequency (voltage) proportionally to load. That is, as the load increases the speed/frequency (voltage) decreases. With the standard droop implementation control scheme a generator set will always produce the same power output at a particular speed/frequency (voltage). However, Failsafe Adaptive Droop units operate such that the last known power output at the time of loss of communications remains constant to avoid instability and any sudden load transfer. Over time, however, the power output level is migrated to a more desired level with each successive load swing. This controlled migration results in a more even distribution of loading between droop units and isochronous units. The process by which this migration is accomplished in Failsafe Adaptive Droop is shown in Figure 33 and described below.

At the time of communications loss, a failsafe adaptive droop unit will run at an operating point defined as nominal frequency at the last known % kW (kVAr) of that individual generator set. From this operating point, a droop characteristic made up of two (2) droop slopes is defined:

- Load Decrease Slope - From nominal actual frequency (voltage) at the last known kW (kVAr) to nominal actual frequency + (z/2)*frequency at 0% kW (kVAr).

- Load Increase Slope - From nominal actual frequency (voltage) at last known kW (kVAr) to nominal actual frequency – (z/2)* frequency at 100 % kW (kVAr).

The droop unit's frequency (voltage) tracks up the Load Decrease Slope and down the Load Increase Slope as droop unit % kW (kVAr) varies. The Load Decrease Slope and Load Increase Slope are re-calculated at each movement up and down. Therefore as the droop unit's load varies the Load Decrease Slope and Load Increase Slope converge to a standard droop slope with 50% load at nominal frequency (voltage). A droop unit's kVAr and voltage droop operation is analogous to the kW and frequency operation described above. For reactive (kVAr) loading z% droop is fixed to 6% and for real (kW) loading z% droop is fixed to 3%.

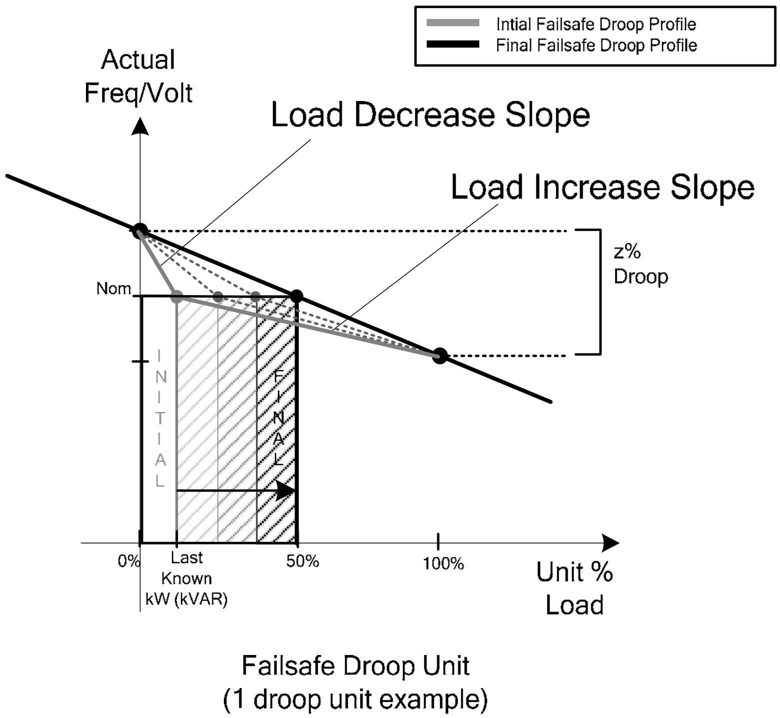


Figure 33: Failsafe Adaptive Droop Slopes

NOTE: If failsafe adaptive droop units' %kW drops below 0%kW or rises above 100% kW, the standard z% droop is implemented.

5.8.5 Failsafe Adaptive Droop and Failsafe Isochronous Load Sharing Example

Figure 34 provides an example of the failsafe adaptive droop control scheme. For illustration purposes three (3) failsafe droop units are considered with each having different loading levels at the time of communications loss. From this initial operating point, each droop unit has two (2) droop slopes defined. As shown in Figure 34, changes in the bus voltage/frequency as a result of any Failsafe Isochronous units move the three failsafe droop units up or down their respective load increase or load decrease droop slopes. Figure 35, Figure 36, and Figure 37 in this example demonstrate how each unit's droop curves adapt over time as the system load changes.

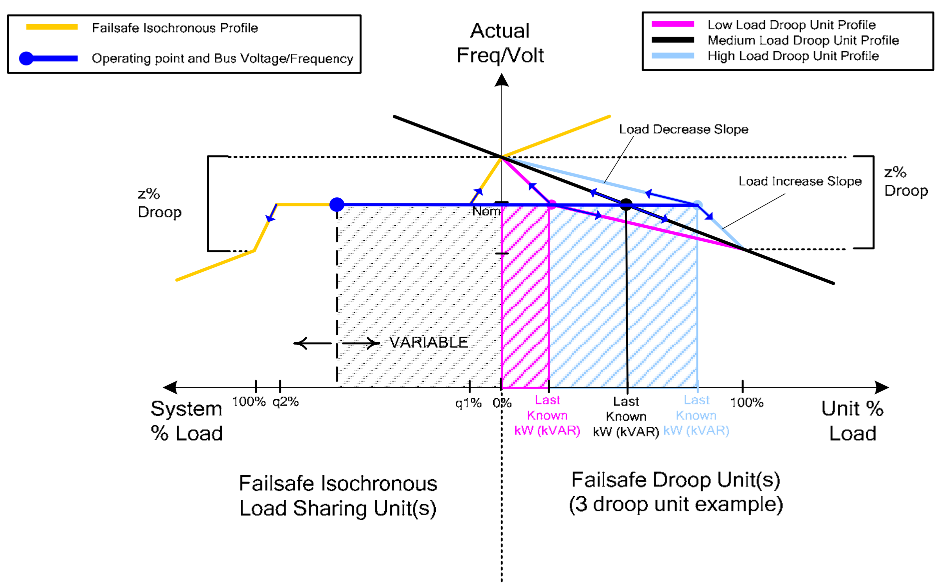


Figure 34: Failsafe Adaptive Droop Loading at Time of Communication Loss

In the load range shown in Figure 34, the Failsafe Isochronous Load Sharing units supply the majority of the load when system load is between q1% and q2%. However, as system load decreases below q1% (Figure 35),

- Isochronous units exhibit resistance to unloading in this region.
- As the Isochronous units unload less freely, the bus frequency/voltage increases; failsafe adaptive droop units track upward on their respective Load Decrease Slopes to begin to unload.
- During this time, the Load Increase Slopes are re-calculated creating a new droop trajectory back towards 100% load. The droop unit's follow this new trajectory the next time system load increases.

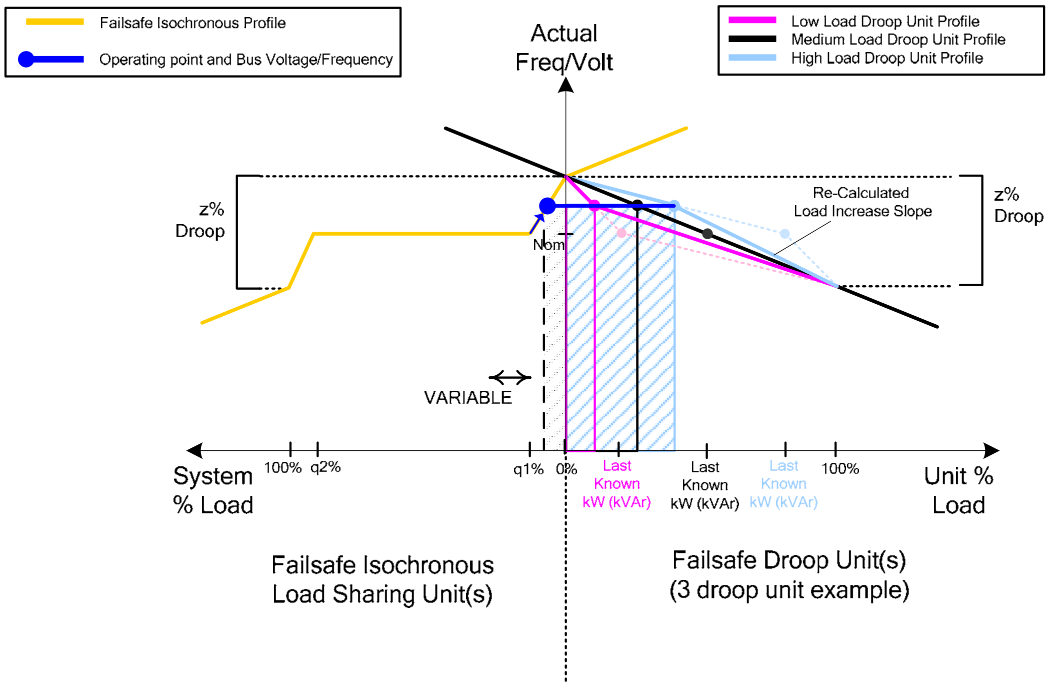


Figure 35: Failsafe Adaptive Droop Operation at Lower System Load Range

Similarly, as system load increases above q2% (Figure 36),

- Isochronous units exhibit resistance to overloading in this region.
- As the isochronous units resist taking on load, bus frequency/voltage decreases; failsafe adaptive droop units track downward on their respective Load Increase Slopes to take on more load.
- During this time the Load Decrease Slopes are re-calculated creating a new droop trajectory back towards 0% load. The droop unit's follow this new trajectory the next time system load decreases.

Notice in Figure 36 that due to the failsafe adaptive droop characteristic, the droop units are closer to a matched load then the initial (last known) kW/kVAr level at the time of communications loss (Figure 34).

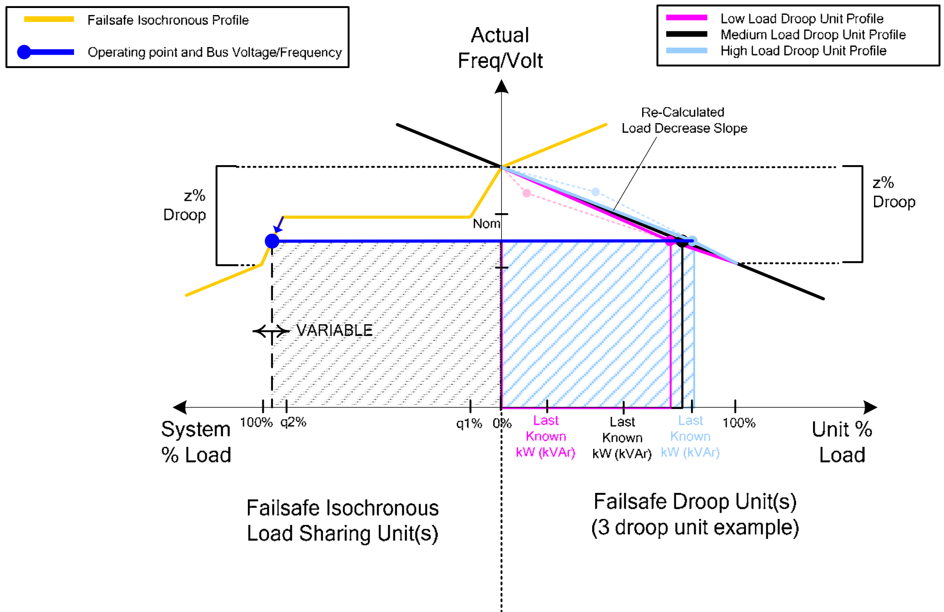


Figure 36: Failsafe Adaptive Droop Operation at Higher System Load Range

Over time as system load swings dictate, the recalculation of the Load Increase Slope and Load Decrease Slope result in all units migrating to the same 50% loading point at nominal frequency on a standard droop curve (Figure 37). In practice, load variations may cause transients in bus frequency/voltage that result in the migration of the droop units to the 50% loading point without system loading in the q1 or q2 ranges. This is not a concern since droop units migrating to matching load in a controlled way is a preferred operating point.

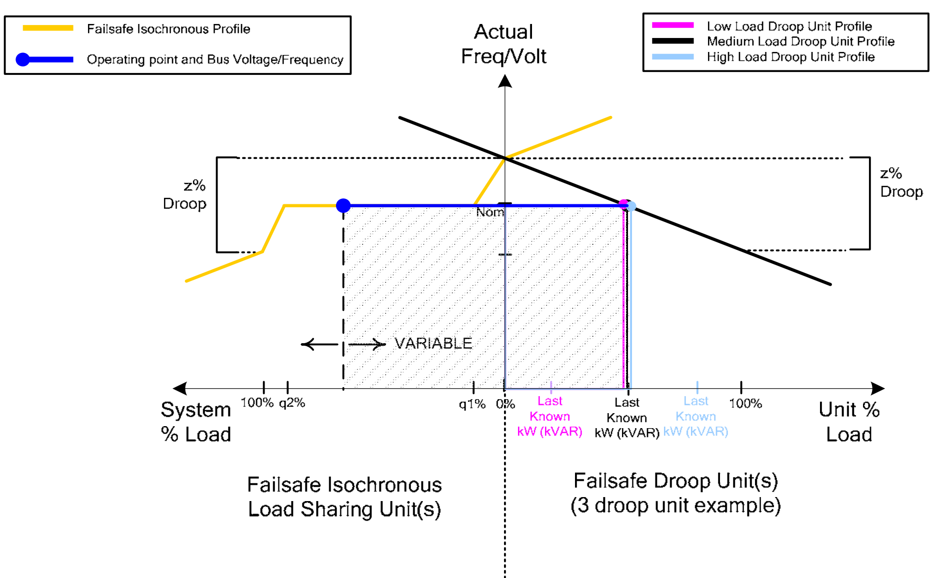


Figure 37: Failsafe Adaptive Droop with Matched Load

In general, if all generator sets in a droop system have the same droop setting, they will each share load proportionally. A benefit of Failsafe Adaptive Droop is that even though the percent load on each droop unit is initially disproportionate (Figure 34) to maintain stability, over time as system load changes, the adaptive droop results in all droop units sharing load proportionally with the same droop settings (Figure 37).

Failsafe Adaptive Droop and Failsafe Isochronous Load Sharing modes are meant for failsafe operation only and are NOT meant for normal operation over long periods of time. While a generator system operating in failsafe mode may provide system load adequately, normal MGDL load sharing is a more robust and stable operating mode. If failsafe modes are activated, the MGDL generator system requires investigation. Proper troubleshooting steps should be taken to return the generator system back to normal operation as soon as possible.

MGDL Load Sharing is designed to transition to and from failsafe modes as seamlessly as possible. However, changes to load sharing gains and system loading have a significant impact on the ability to transition and/or recover without disturbance. Stability is not guaranteed when transitioning to/from Failsafe Adaptive Droop and Failsafe Isochronous Load Sharing from/to normal MGDL load sharing.

6 MGDL Paralleling Tuning Guide

Each generator system has different load share gain tuning needs. This section is intended to aid in properly tuning the system as well as:

- Provide an overview of the Real and Reactive Load Sharing control loops in the EMCP 4.4
- Identify setpoints used for adjusting/tuning Real and Reactive Load Sharing
- Provide basic guidelines for setting up and tuning Real and Reactive Load Sharing

6.1 BACKGROUND

Load sharing is the process of sharing the real power (kW) and reactive power (kVAr) between generator sets while maintaining proper bus frequency and voltage.

6.2 GENERAL CONSIDERATIONS

The controlling factor for kW and frequency is the same. Both are based upon the torque (or power) being provided by the engine. Increasing the power from the engine through the desired speed setting will either increase the kW being provided, which must be consumed, or the bus frequency will increase. The kVAr and voltage are based on the excitation of the generator. Increasing the generator excitation through the desired voltage setting will provide additional kVArs which must be consumed, or the bus voltage will increase. For these reasons, the tuning of Load Sharing is more difficult since single control points (desired speed, desired voltage) drive multiple output parameters (bus frequency and kW, bus voltage and kVAr). An overview of the real and reactive load sharing control loops is presented in Figure 38:

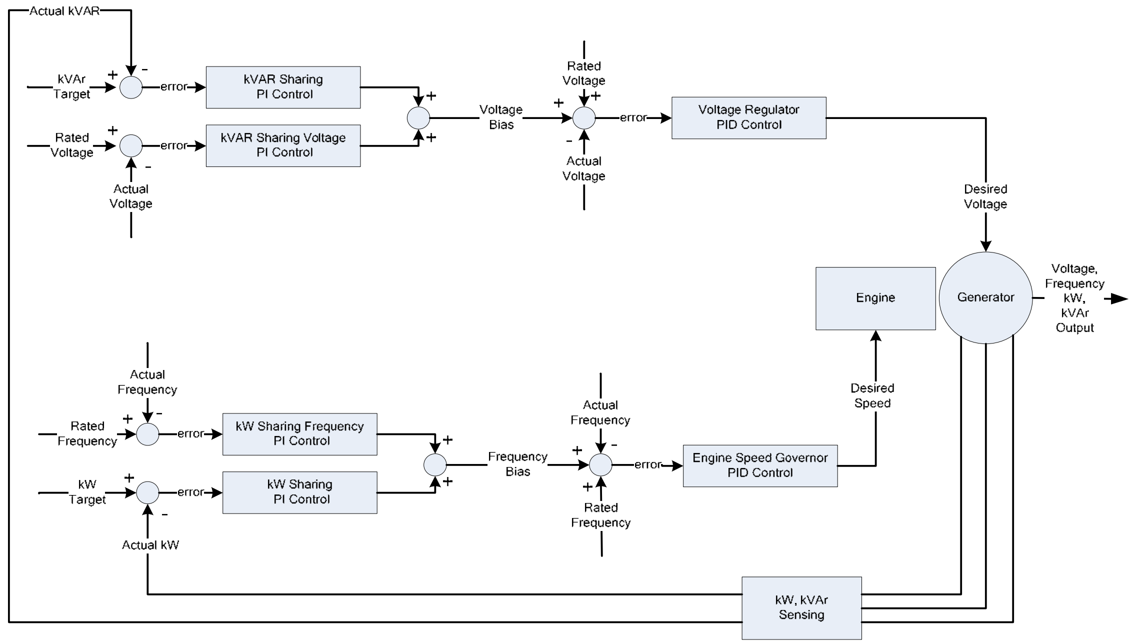


Figure 38: Real and Reactive Load Sharing Control Loop Overview

As shown in Figure 38, a number of PID controls are involved in regulating the real and reactive load sharing output of a generator set. Each control is tuned individually using respective set of PID (or PI) gain parameters. The overview of the real and reactive load sharing control loop with these PID (or PI) gain parameters included is shown in

Figure **39** for reference.

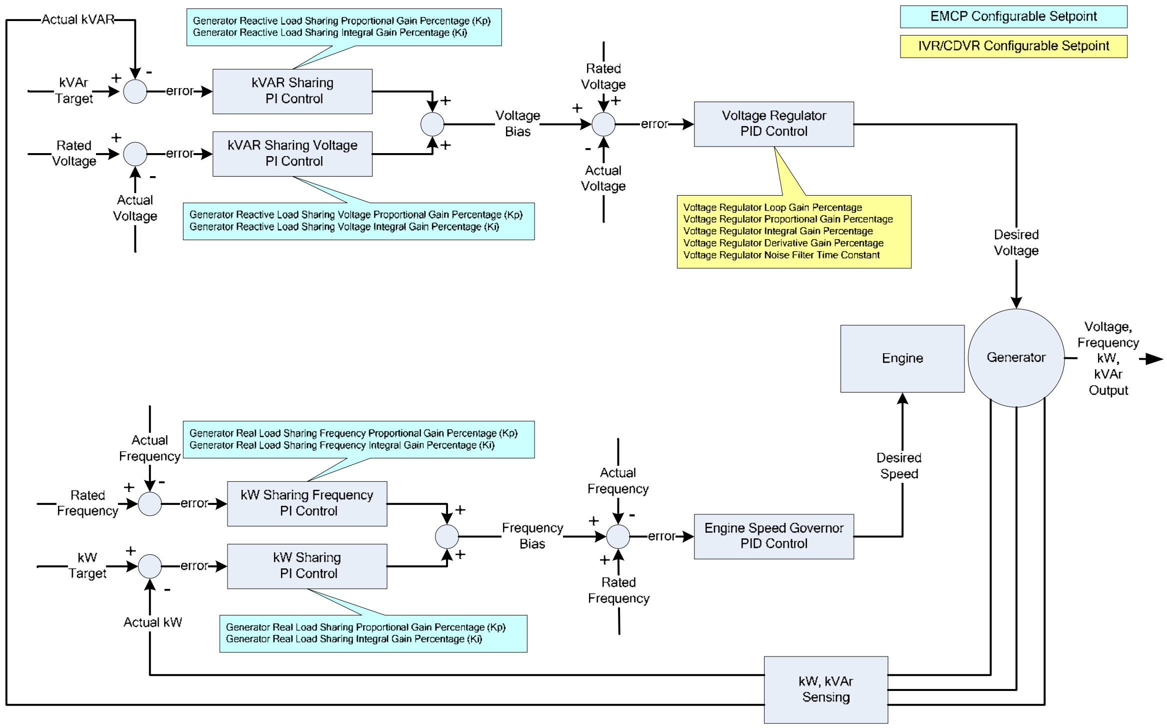


Figure 39: Real and Reactive Load Sharing Control Loop Overview with PID Gain Setpoints

6.3 STRATEGY

Since each of these controls has multiple controlling factors, a means of approaching the tuning of load sharing is required. One item to be considered is that full concentration on any one portion of load sharing is not possible since these different control loops interact with each other. For example, any instability in the voltage/kVAr sharing affects the frequency/kW since the power consumed by the load is usually affected by the voltage. For this reason, multiple items must be considered simultaneously.

6.4 GUIDELINES

Be sure to be familiar with navigation of the EMCP screens and setpoints before attempting to develop a set of gains. Read through and become familiar with how to view the load status information along with information on the electrical output of the generator set. Since load sharing affects multiple units in the system, it is easy for the system to become unstable. All protective relay settings such as reverse kW and reverse kVAr should be reviewed and possibly tightened for commissioning in order to protect the generator set. It is recommended to use a resistive and reactive load bank to tune generator load sharing.

While it is possible to tune the real power sharing with just a resistive load bank, tuning of both parameters require kW and kVAr control. If customer load is going to be used for tuning, care must be taken to ensure that the voltage and frequency variations will not cause damage to the load.

The process of load sharing tuning is an iterative procedure. It is NOT possible to arrive at optimum settings for one PID gains before tuning the other gains. In addition, it is NOT possible to tune one generator set without tuning the other generator sets with which it is load sharing. If the generator sets are equivalent power ratings, tuning is easier since the setpoints can be copied from one unit to the next. The use of multiple people or use of ET on 1 unit with the laptop near the second unit will help in modifying the setpoints of multiple units.

In order to keep the frequency (voltage) gains from overpowering kW (kVAr) gains, the frequency and voltage gains are automatically turned off in the software control when the generators are close to nominal frequency and voltage. This may cause a slight ripple in frequency and voltage while it oscillates around the nominal frequency or voltage.

Regardless of the number of units at a site, it is recommended to first develop initial gains only using 2 units. These gains may need to be adjusted as part of an iterative process when additional units are added, but it is easier to slightly adjust gains once a stable set has been arrived at. The units may ship with starting point gains. If they do, start with these gains and adjust them as needed. If there are no usable gains to start with, perform the following steps to develop initial gains:

1. Tune Voltage Regulator PID and Engine Governor (if available) controls for stability in single genset operation. If stability cannot be achieved while operating as a single genset, do not move on to load sharing tuning. Consult engine or voltage regulator tuning procedures for troubleshooting single genset tuning. These gains will needs to be decreased as additional control loops are added. If using an electronic voltage regulator, the loop gains can simply be reduced by 30% or more.
2. Zero out the Frequency and Voltage Sharing gains (Kp and Ki). This will allow the units to concentrate on sharing kVAr and kW, regardless of the voltage or frequency of the system. If different generator sets are being used, these may not be able to be zeroed out since the governor or voltage regulator may influence frequency (speed) or voltage.

3. Start with a very small integral gain or even zero, but have a medium size proportional gain for kW and kVAr sharing gains. Pay close attention to load sharing levels of the system. While working with the proportional gain, do NOT expect the units to share equally, but some sharing should occur.
4. Increase the integral gain to improve the equality of load sharing. Keep in mind a slightly slower response to transients reduces the chance of instability as parts of the system change due to ambient conditions, loading conditions, fuel quality, etc.
5. Once kW and kVAr sharing gains exist that allow reasonable (+/-10%) sharing to occur, start adjusting the Voltage and Frequency gains from zero in order to correct the bus voltage and bus frequency to the nominal values. These gains will be processed simultaneously with the kW and kVAr loop, and may drive changes in the system. While adjusting these Voltage and Frequency gains, the system should be monitored for response to load changes, adding and removing generator sets, etc. Make sure to watch the response as a single unit load sharing with itself, along with the second unit on the bus.

Figure 39 identifies the PID control setpoints involved in each of the 5 steps for developing initial gains described above.

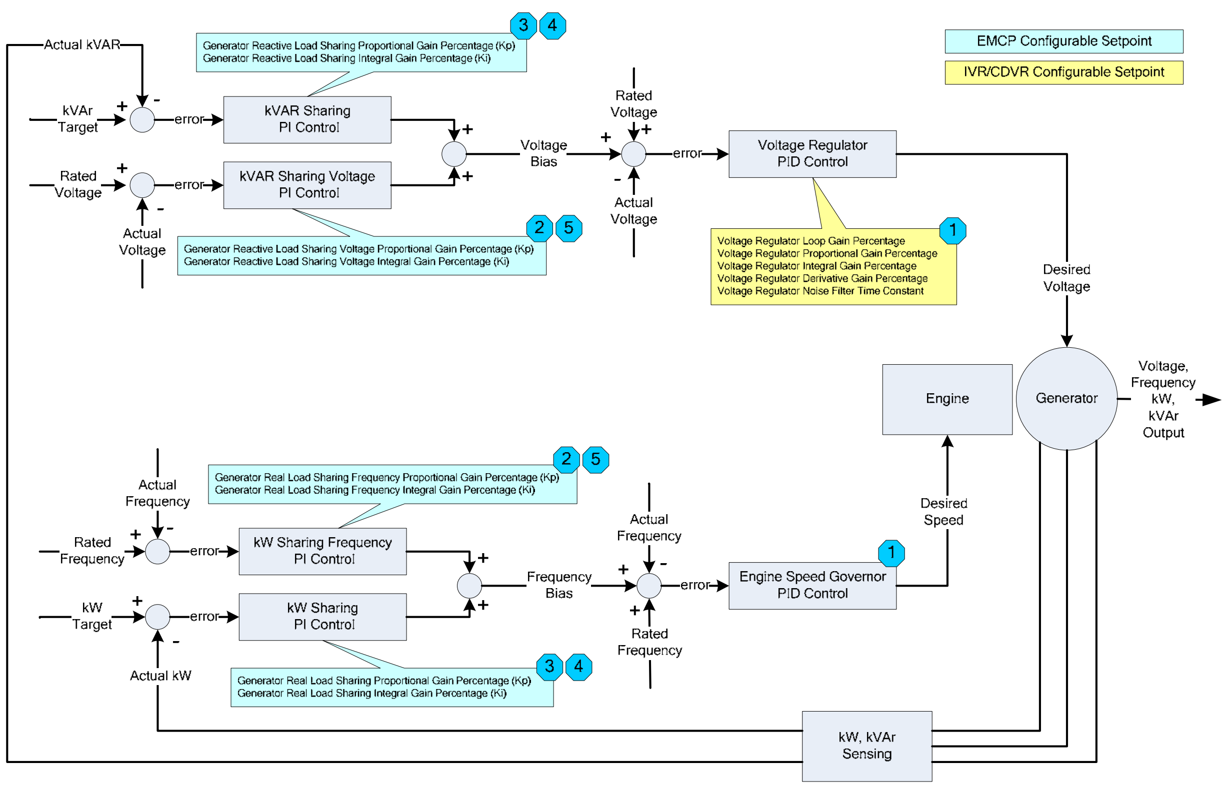


Figure 40: Real and Reactive Load Sharing Control Loop Tuning Steps

There is not a single set of optimal gains that apply to all generator systems, but only an iterative process to develop acceptable gains. Any changes in engine governor software settings or voltage regulator software settings will have an effect on acceptable gains. If instability problems exist, consider lowering the gains of the governor or voltage regulator for improved system performance. The optimum settings of a single unit against a load are NOT the optimum settings for a unit as part of a paralleled system.

7 MGDL Display Screens

The EMCP 4.4 MGDL display screens provide information on the individual unit's paralleling operations. The display screens also provide the ability to monitor key information from ANY EMCP 4.4 controllers communicating on the MGDL network. The EMCP 4.4 MGDL display screens also provide additional control and configurability that is NOT available through ET. Each MGDL display screen is described in more detail below.

7.1 MGDL SYSTEM OVERVIEW SCREENS

The MGDL System Overview and MGDL Unit Details screens can be accessed directly through the EMCP 4.4 display. To access the MGDL Overview and MGDL Unit Details through the display, navigate to the following sub-menus:

MAIN MENU
→ VIEW
→ PARALLELING
→ MGDL OVERVIEW

The MGDL System Overview screen displays key information for all MGDL units from a single EMCP 4.4 controller's display. The MGDL System Overview screen information is described in
Figure 41 through Figure 44.

NOTE: These screens are hidden from display until *Multiple Genset Control Data Link Unit Number* (setpoint) is configured to a non-zero value.

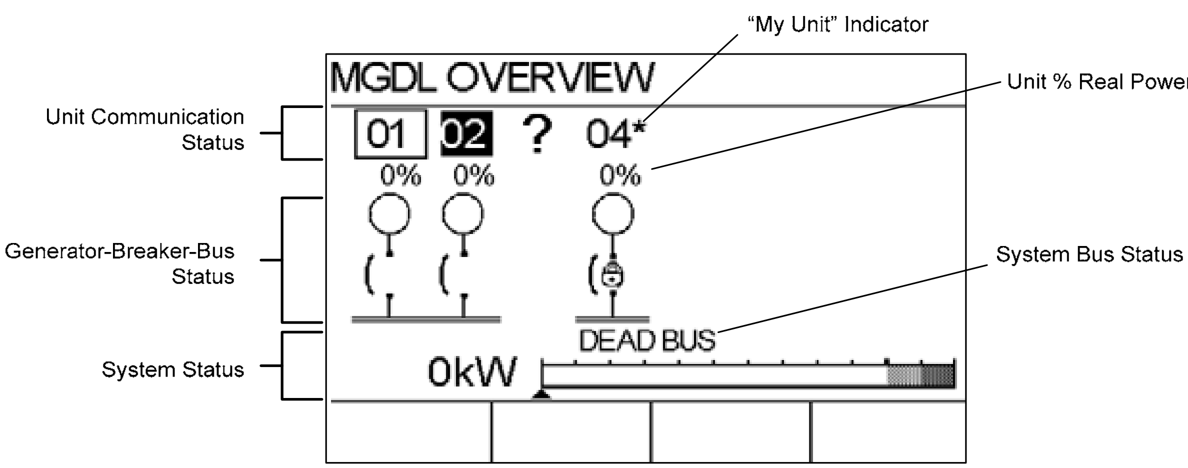


Figure 41: MGDL Overview screen with less than 8 MGDL units

The unit communication status information of all MGDL units is provided in the top section of the MGDL Overview screen.

- The unit number of any MGDL unit that is broadcasting information on the network will automatically appear in a solid block text.
- A unit number that is reverse videoed 02 indicates immature communications. The immature communications indicator is active for the first 60 seconds after a unit begins broadcasting on the MGDL network.
- A unit number is replaced with a question mark if communications have been lost with that unit. Scrolling to and selecting the question mark on the MGDL Overview screen displays a message indicating the unit number of the lost unit (Figure 46).
- To avoid confusion and improve troubleshooting, an asterisk next to a unit number indicates “my unit” and refers to the unit number assigned to the controller whose display is being viewed.

The percent of rated real power of each individual MGDL unit is displayed just below the unit number identification. This provides an indication of the real power loading of each MGDL unit at a given point in time.

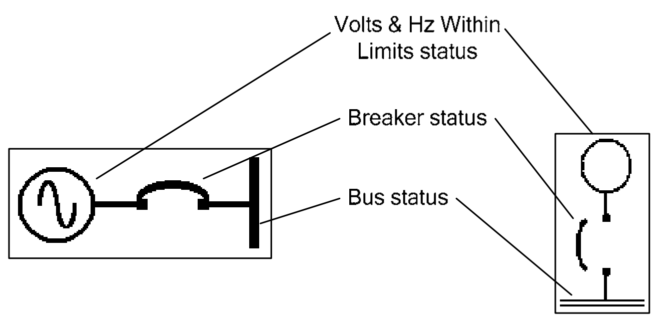


Figure 42: Generator-Breaker-Bus Status Symbol

The generator-breaker-bus status symbol (Figure 42) provides an indication of the generator operating state and consists of three separate indicators:

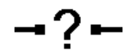
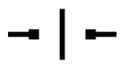
1) Generator Volts/Hz Within Limits Status
2) Generator Breaker Status
3) Bus Voltage Status

If communications are lost, the generator-breaker-bus symbol disappears since the information is unknown.

The Generator Volts/Hz Within Limits Status provides an indication to the generator sets readiness. The generator circle is populated with a sinusoidal wave symbol when the generator voltage and generator frequency are greater than 90% of their rated values. The generator circle is left blank when either generator voltage or generator frequency are less than or equal to 90% of their rated values.

The Generator Breaker Status provides an indication of the generator breaker state. Table 5 shows the possible generator breaker states and corresponding symbols on display.

Table 5: Generator Breaker Status Symbols

	Open	Closed	Locked Out	Unknown
U.S.				
International				

The generator breaker status symbol can be switched between US and International symbols under the EMCP display preferences.

The Bus Voltage Status detected by each MGDL unit is indicated by the bottom row of the generator-breaker-bus symbol. The unit bus bar symbol is filled in to indicate a live bus is detected and is left empty to indicate a dead bus is detected by the individual unit.

The System Bus Status indication considers the dead bus detection of all MGDL units on the network. The system bus status reads LIVE BUS when any MGDL unit detects a live bus and reads DEAD BUS when all MGDL units detect a dead bus.

The System kW value is the total real power provided by all MGDL units on the network. The System % kW is the real power provided by all the MGDL units on the network as a percentage of all the rated power of all the MGDL units on the network regardless of their operating state.

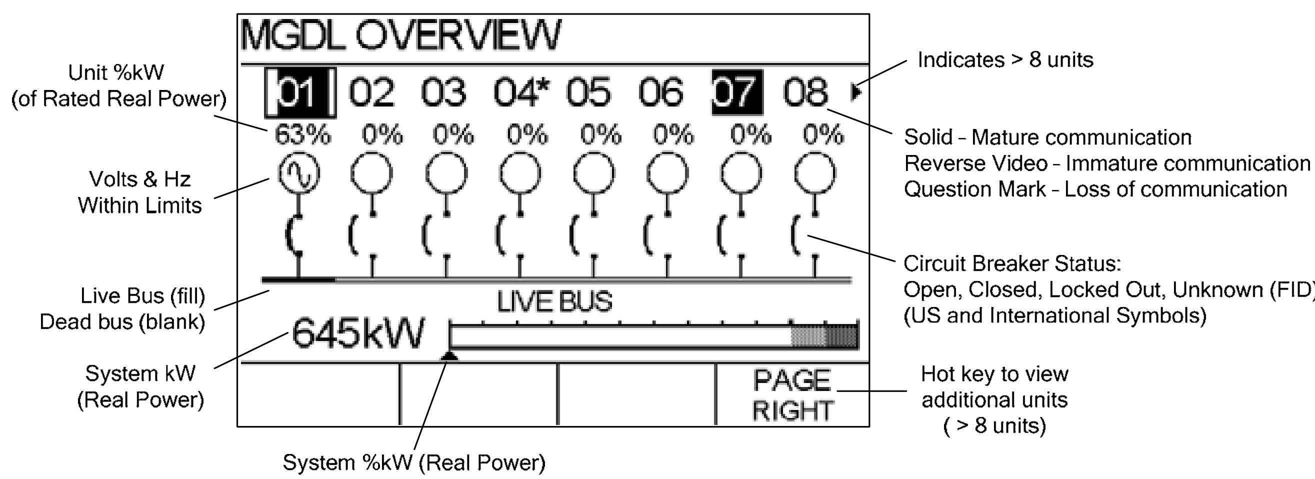


Figure 43: MGDL Overview screen with greater than 8 MGDL units (Screen 1 of 2)

When more than 8 units are connected to the MGDL network an arrow appears indicating an additional MGDL Overview screen is available. Pressing the PAGE RIGHT (F4 hot key) navigates to the second MGDL Overview screen (Figure 44).

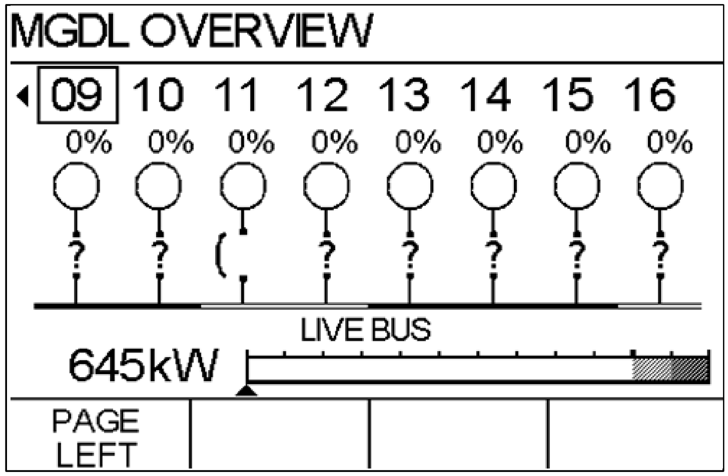


Figure 44: MGDL Overview screen with greater than 8 MGDL units (Screen 2 of 2)

Scrolling left and right on the MGDL Overview screen with the left and right arrow keys allows the user to select a particular MGDL unit. Pressing the OK key provides more detailed information (Figure 45) on the operation of the selected MGDL unit.

MGDL Unit Details

The MGDL Unit Details screen displays detailed information of the selected MGDL unit from a single EMCP 4.4 controller's display. The MGDL Unit Details screen information is described in Figure 45 and Figure 46.

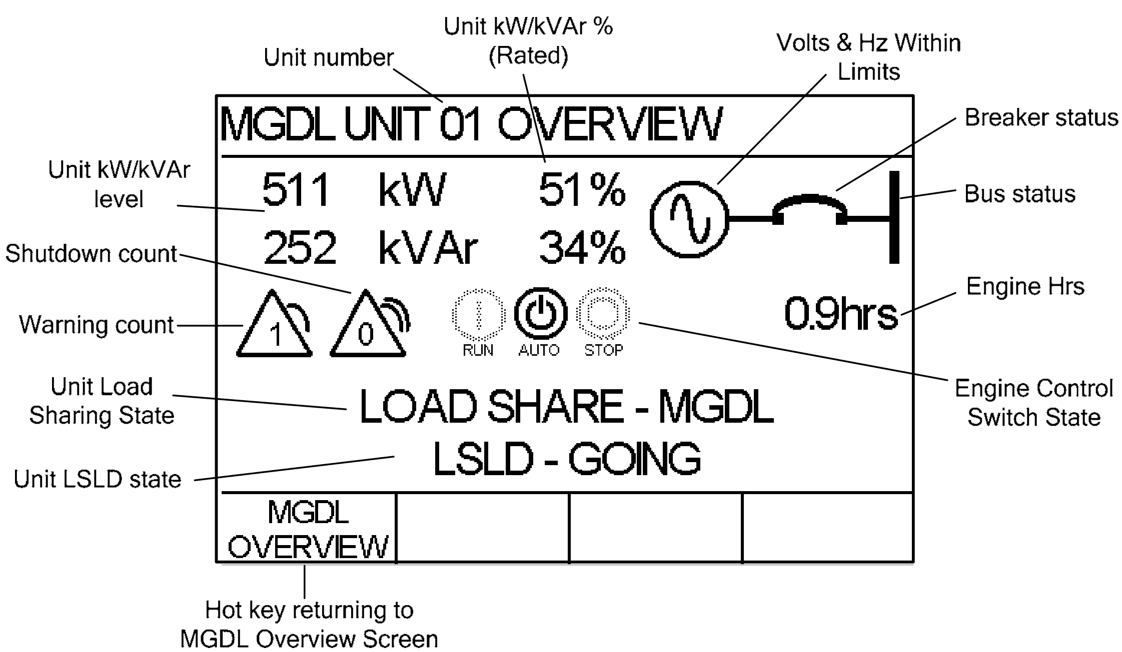


Figure 45: MGDL Unit Details Screen

The unit number of the MGDL unit details being viewed is listed in the title bar of the MGDL Unit Details Screen.

The actual kW and kVAr totals as well as % kW and % kVAr of the unit is listed in the top left of this screen.

The generator-breaker-bus status (described in Figure 42) is also replicated on this screen from the MGDL Overview screen.

In the middle of the screen, the number of active warnings and active shutdowns on the MGDL unit are displayed. If the number of warnings or shutdowns is greater than 9, the number is replaced by a “+” symbol.

The engine control switch symbols (RUN, AUTO, and STOP) visible on the EMCP fascia are replicated on this screen representing the current operating state of the MGDL unit’s engine control switch. As the engine control switch is changed from the unit’s RUN, AUTO, and STOP keys, the symbol is updated on display.

The total operating hours of the unit is listed to the right of the engine control switch status.

The unit’s load sharing and LSLD state is listed on the final two rows of this screen. See Table 6 and Table 9 for a complete list of the possible load sharing and LSLD states.

If communications are lost with a unit, the unit details are not available and the unit details screen is replaced with a message indicating a loss of communications as shown in Figure 46.

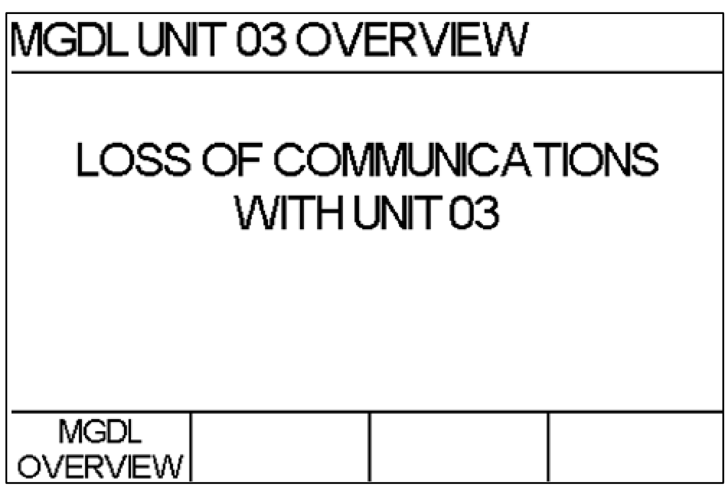


Figure 46: MGDL Unit Details Screen of Unit with Loss of Communications

7.2 MGDL CONTROL SCREEN

The EMCP 4.4 maintains a list of expected controls on the MGDL network and actual controls on the MGDL network. Under normal operation the expected controls equal actual controls. However, in the case of network topology updates or loss of communications, expected controls may NOT equal actual controls. The ability to view and reset the number of expected controls to the number of actual controls for ALL units on the MGDL network is provided through the MGDL Control screen.

NOTE: RESET EXPECTED is a system-wide reset where resetting the expected number of MGDL units from "my unit" sends a system-wide command to ALL units on the MGDL network to reset expected number of MGDL units.

Further details and implications of resetting expected controls on the MGDL network are provided in MGDL Network Configuration (Expected Units) Reset Section 5.7 and Troubleshooting section of this manual Section 8.

To access the MGDL Control screens through the EMCP display, navigate to the following sub-menus:

MAIN MENU
→ CONTROL
→ PARALLELING
→ MGDL CONTROL

NOTE: Pressing the CONTROL key  on the face of the EMCP 4.4 provides a shortcut to the control menu.

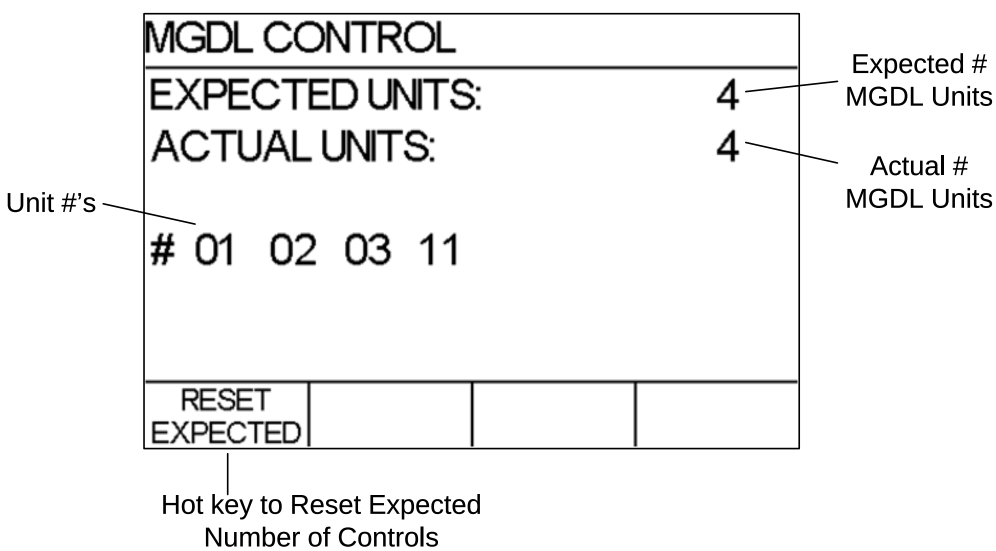


Figure 47: MGDL Control Screen for Viewing/Resetting Expected Number of Units on the MGDL Network

Pressing the RESET EXPECTED (F1 hot key) populates an additional verification screen that requires an OK button press to reset the expected number of MGDL units.

7.3 MGDL SYNCHRONIZING SCREENS

The MGDL Synchronizing screens can be accessed directly through the EMCP display. To access the MGDL Synchronizing view screens through the EMCP display, navigate to the following sub-menus:

MAIN MENU
→ VIEW
→ PARALLELING
→ SYNC OVERVIEW

The MGDL Sync Overview screen displays important synchronizing information of the individual EMCP 4.4 controller. The MGDL Sync Overview screen information is described in Figure 48.

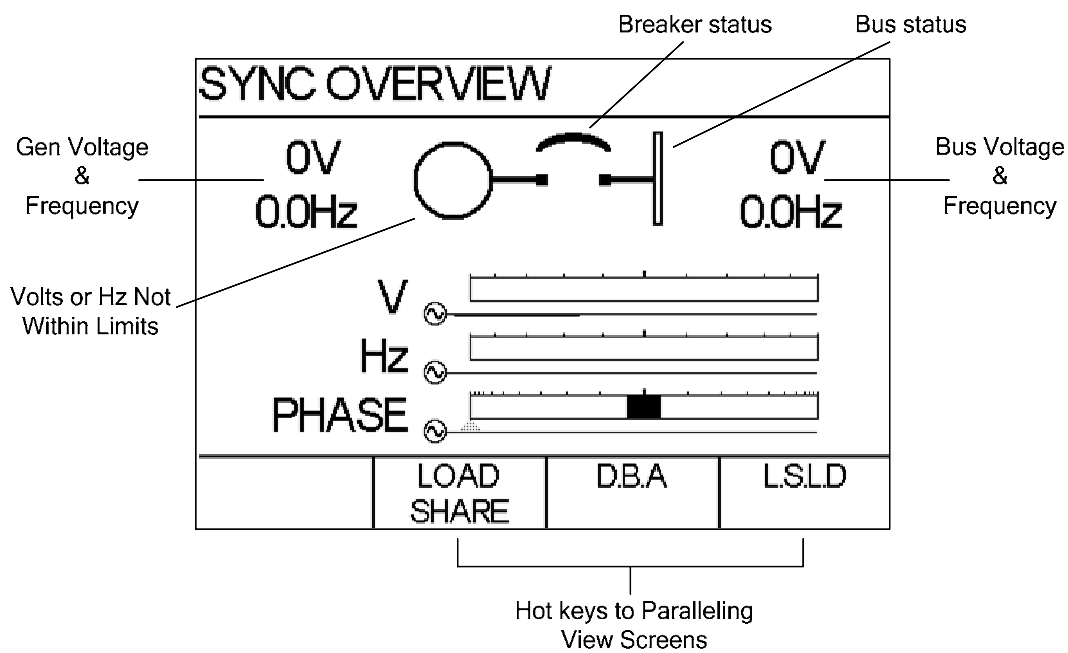


Figure 48: MGDL Sync Overview Screen

Both generator voltage and frequency and bus voltage and frequency are displayed at the top of the screen.

The generator-breaker-bus status (described in Figure 42) is also replicated on this screen from the MGDL Overview screen.

Hot keys are provided for quick access to the other MGDL paralleling view screens (LOAD SHARE (F2 hot key), D.B.A (F3 hot key), and L.S.L.D (F4 hot key)).

To access the MGDL Synchronizing control screens through the EMCP display, navigate to the following sub-menus:

MAIN MENU
→ CONTROL
→ PARALLELING
→ SYNC OVERVIEW
→ SYNC MODE SWITCH

NOTE: Pressing the CONTROL key  on the face of the EMCP 4.4 provides a shortcut to the control menu.

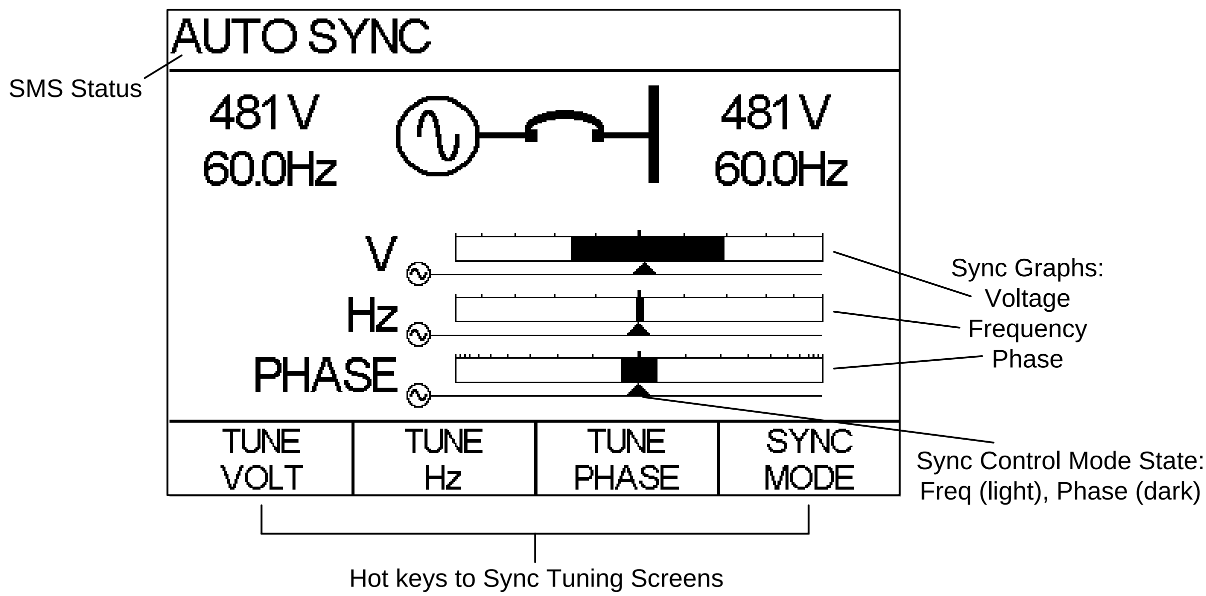


Figure 49: MGDL Sync Control Screen

The Sync Graphs: voltage, frequency, and phase are displayed on this screen. These graphs update while synchronization is occurring.

The sync control mode state changes for frequency correction and phase correction.

Hot keys are provided for quick access to Sync Control screens to tune voltage, frequency and phase as well as select the Sync mode (TUNE VOLT (F1 hot key), TUNE HZ (F2 hot key), TUNE PHASE (F3 hot key), and SYNC MODE (F4 hot key)).

The sync mode switch (SMS) state is shown in the title bar and can be configured from the MGDL Sync Control Screen or from the path below:

MAIN MENU
→ CONTROL
→ PARALLELING
→ SYNC MODE SWITCH

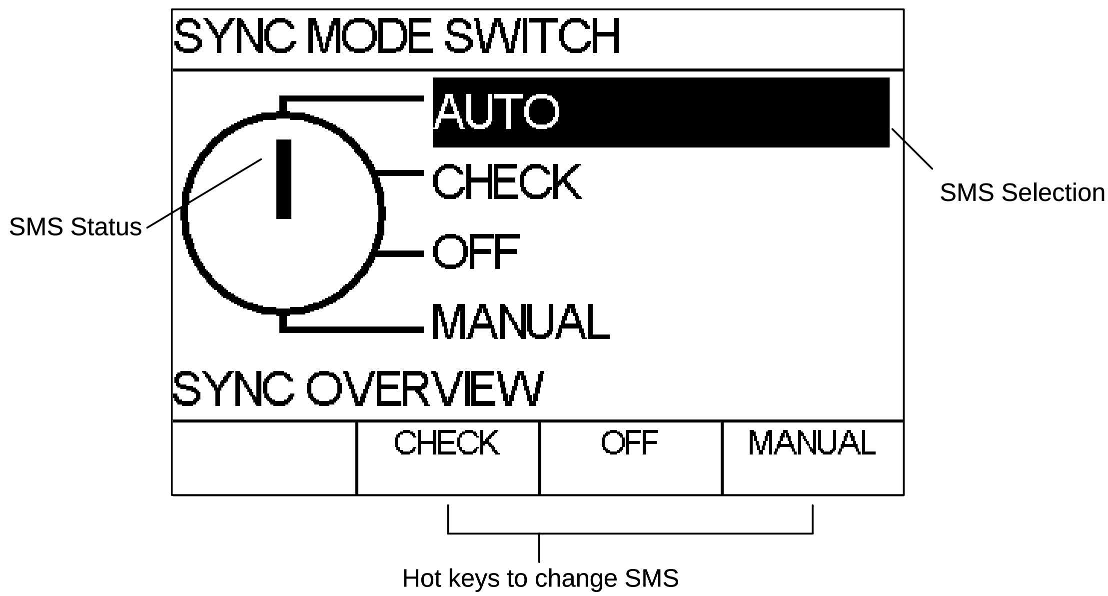


Figure 50: MGDL Sync Mode Switch

The SMS can be changed via the hot keys or by using the arrows on the EMCP fascia.

7.4 MGDL LOAD SHARING SCREENS

The MGDL Load Sharing screens can be accessed directly through the EMCP 4.4 display. To access the MGDL Load Sharing view screens through the display, navigate to the following sub-menus:

MAIN MENU
→ VIEW
→ PARALLELING
→ LOAD SHARE

The MGDL Load Sharing screen displays important load sharing information of the individual EMCP 4.4 controller. The MGDL Load Sharing screen information is described in Figure 51.

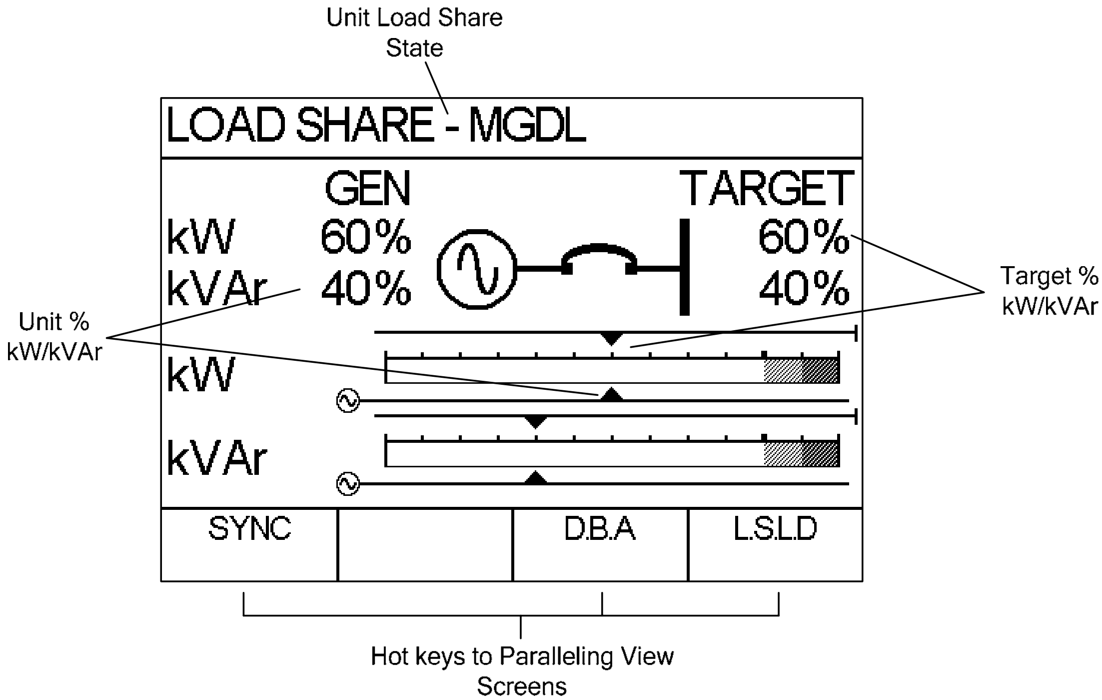


Figure 51: MGDL Load Share View Screen

The Unit Load Share State in the title bar of this screen reflects the generator load control operating mode as seen by the rest of the system. This state takes into account the configured load sharing mode, engine and breaker status, and soft load/unload status. The possible load sharing states are listed in Table 6.

Table 6: MGDL Load Share Operating State

Unit Load Share State	Description
DISABLED	Unit is configured to have load sharing disabled.
INACTIVE	Unit is not actively load sharing.
SOFT LOAD	Unit is increasing load in a controlled manner before attempting to close its generator breaker.
SOFT UNLOAD	Unit is decreasing load in a controlled manner before attempting to open its generator breaker.
FAILSAFE DROOP	Unit has exited normal load sharing due to a failure in the MGDL network and is controlling load according to a failsafe droop curve.
FAILSAFE ISOCH	Unit has exited normal load sharing due to a failure in the MGDL network and is controlling load according to a failsafe isochronous load sharing curve.
BASE LOAD	Unit is controlling load to a desired base load level (typically in parallel to utility/mains). (This features is only available with complex software.)
ANALOG	Unit is actively load sharing via analog (hardwired) load sharing lines.

MGDL	Unit is actively load sharing via multiple genset data link.

The generator-breaker-bus status (described in Figure 42) is also replicated on this screen from the MGDL Overview screen.

This screen also provides the actual kW/kVAr provided with respect to the target kW/kVAr. These values are provided numerically as the percentage of rated as well as visually on the Load Share Graph. During normal load sharing the actual kW/kVAr should regulate to the target kW/kVAr.

MGDL Load Sharing Control screen is similar to the view screen except it provides easy access to load sharing tuning parameters via the F1 and F2 hot keys (shown in Figure 52). To access the MGDL Load Sharing control screens through the EMCP display, navigate to the following sub-menus:

MAIN MENU
→ CONTROL
→ PARALLELING
→ LOAD SHARE

NOTE: Pressing the CONTROL key  on the face of the EMCP 4.4 provides a shortcut to the control menu.

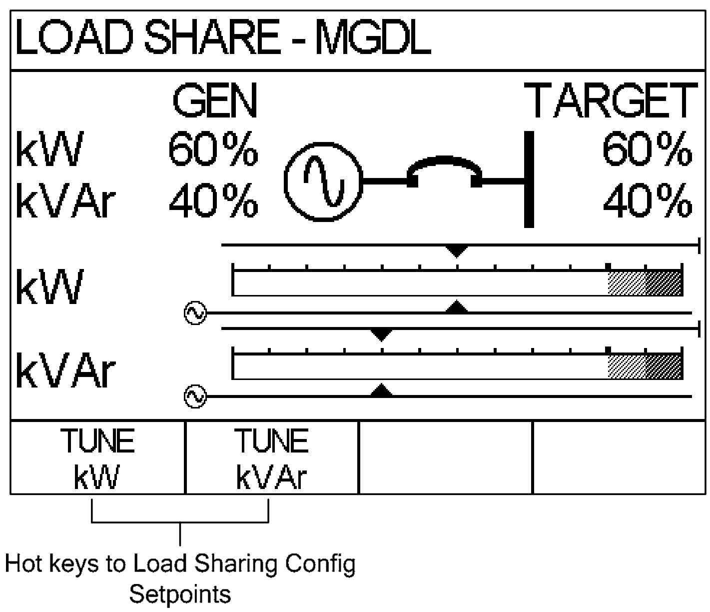


Figure 52: MGDL Load Share Control Screen

7.5 MGDL DEAD BUS ARBITRATION SCREENS

The MGDL Dead Bus Arbitration screens can be accessed directly through the EMCP 4.4 display. To access the MGDL Dead Bus Arbitration view screens through the display, navigate to the following sub-menus:

MAIN MENU
→ VIEW
→ PARALLELING
→ DEAD BUS ARBITRATION

The MGDL Dead Bus Arbitration screen displays important dead bus arbitration information of the individual EMCP 4.4 controller as well as the overall MGDL system. The MGDL Dead Bus Arbitration screen information is described in Figure 53.

NOTE: These screens are hidden from display until the *Dead Bus Close Input Configuration* (setpoint) is configured to “Ethernet (MGDL)”.

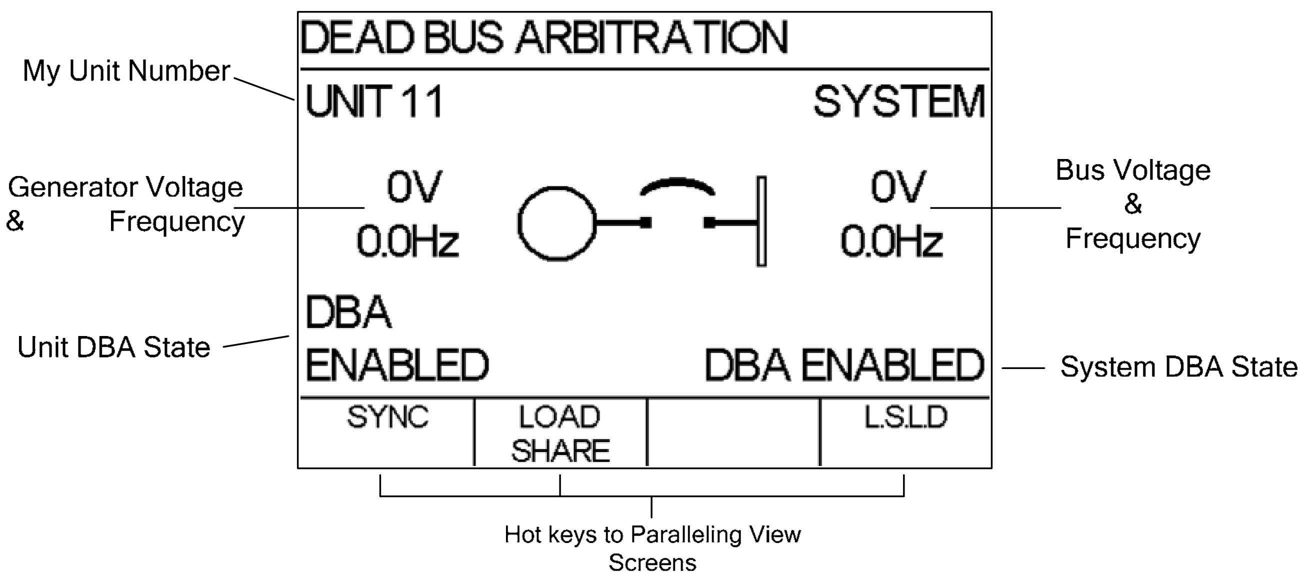


Figure 53: MGDL Dead Bus Arbitration View Screen

The Unit DBA State reflects the state of the unit’s DBA operating mode as seen by the rest of the system. These states take into account the configured DBA mode, progress towards dead bus closing, and generator breaker status. The possible Unit DBA states are listed in Table 7.

Table 7: MGDL Unit Dead Bus Arbitration Operating State

Unit DBA State	Description
DBA DISABLED	Unit is configured to have DBA disabled.
DBA ENABLED	Unit is configured to have DBA enabled (either Hardwired or Ethernet (MGDL)).
REQUESTING	Unit is ready to dead bus close and is requesting permission from other MGDL units to dead bus close.
CAPTURING	Unit is ready to dead bus close and has captured authority to dead bus close but is waiting for all other MGDL units to grant permission to dead bus close.
CLOSE GRANTED	Unit has been granted permission from other MGDL units to dead bus close and has issued a close breaker command, but has not yet detected a breaker closure.
BREAKER CLOSED	Breaker closure has been detected and the unit is on the bus.
FAILURE WAIT	Unit failed to dead bus close and is waiting before re-requesting permission to dead bus close. The unit releases authority to dead bus close to other units.
MAX FAILURES	A maximum number of dead bus close failures (5) has occurred. A Dead Bus Arbitration Failure Shutdown (SPN-FMI: 2530-1) accompanies this state.
LIVE BUS	A live bus is detected and dead bus arbitration is no longer required.

The System DBA State reflects the state of DBA at an overall system level. This state takes into account the individual DBA state of all units on the MGDL network. The possible System DBA states are listed in Table 8.

Table 8: MGDL System Dead Bus Arbitration Operating State

System DBA State	Description
DBA DISABLED	All DBA units are in the DBA DISABLED state then the system is DBA DISABLED.
DBA ENABLED	Any DBA unit is in the DBA ENABLED state then the system is DBA ENABLED.
REQUESTING	Any single DBA unit is in the REQUESTING state then the system is REQUESTING.
UNIT XX CAPTURING	Any DBA unit is in the CAPTURING or CLOSE GRANTED state then the system is CAPTURING and the capturing unit number is identified.
LIVE BUS	Any DBA unit detects a live bus and dead bus arbitration is no longer required.

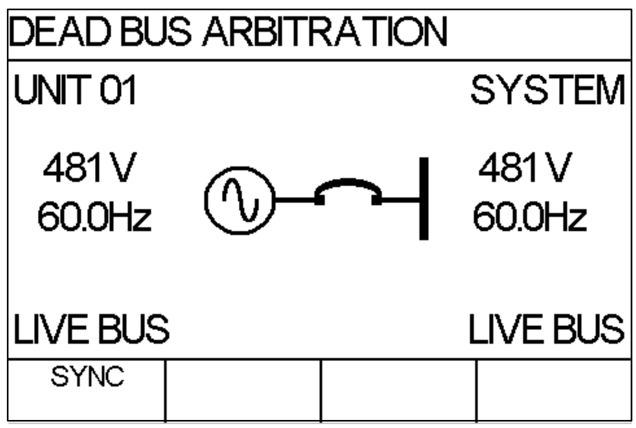
The generator-breaker-bus status (described in Figure 42) is also replicated on this screen from the MGDL Overview screen.

This screen also provides the generator voltage and frequency measurements as well as bus voltage and frequency measurements.

MGDL Dead Bus Arbitration control screen is similar to the view screen (Figure 54) except it provides easy access to the synchronizing control screen (F1 hot key). To access the MGDL Dead Bus Arbitration control screens through the EMCP display, navigate to the following sub-menus:

MAIN MENU
→ CONTROL
→ PARALLELING
→ DEAD BUS ARBITRATION

NOTE: Pressing the CONTROL key  on the face of the EMCP 4.4 provides a shortcut to the control menu.



Hot key to Sync Control Screen

Figure 54: MGDL Dead Bus Arbitration Control Screen

7.6 MGDL LOAD SENSE LOAD DEMAND SCREENS

The MGDL Load Sense Load Demand screens can be accessed directly through the EMCP 4.4 display. To access the MGDL Load Sense Load Demand view screens through the display, navigate to the following sub-menus:

MAIN MENU
→ VIEW
→ PARALLELING
→ LOAD SENSE LOAD DEMAND

The MGDL Load Sense Load Demand view screen displays load sense load demand information of the individual EMCP 4.4 controller as well as the overall MGDL system. The MGDL Load Sense Load Demand view screen information is described in Figure 55.

NOTE: These screens are hidden from display until the LSLD Input Configuration setpoint is configured to “Ethernet (MGDL)”.

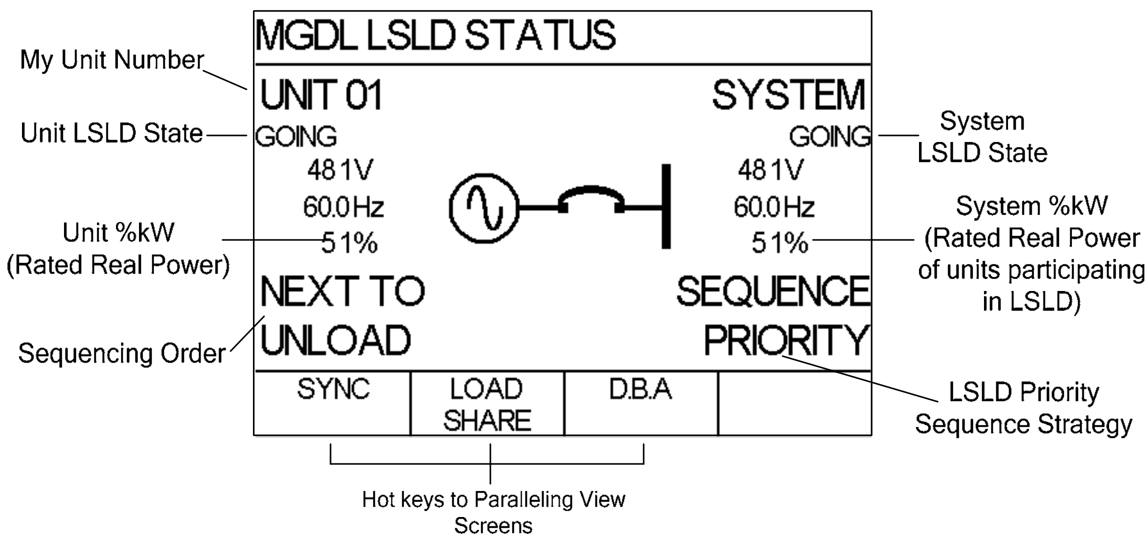


Figure 55: MGDL Load Sense Load Demand View Screen

The Unit LSLD State reflects the state of the unit's LSLD operating mode as seen by the rest of the system. These states take into account the configured LSLD mode, generator breaker status, and soft load/unload status. The possible Unit LSLD states are listed in Table 9.

Table 9: LSLD Unit Operating State

Unit LSLD State	Description
Unit operating under LSLD Control	
GOING	Unit is running with the generator breaker closed and soft loading complete under LSLD control. This unit could sequence off as required based on load demand.
SETTLING	Unit is running with the generator breaker closed and soft loading complete with the LSLD Enable Delay Timer active. No units will sequence off until the LSLD Enable Delay (Settling) Timer has expired.
UNLOADING	Unit is stopping and soft unloading under LSLD control.
LOADING	Unit is starting, synchronizing, and soft loading under LSLD control.
AVAILABLE	Unit is stopped with the generator breaker open under LSLD control and is available to come on the bus.
Unit unable to participate under LSLD Control	
GOING LSLD OFF	Unit is running and the generator breaker is closed, but the unit is unable to participate in LSLD control due to failure to meet certain conditions (such as by the result of manually starting and synchronizing or a failure to open breaker condition).
UNAVAILABLE	Unit is stopping or stopped and the generator breaker is open, but the unit is unable to participate in LSLD control due to certain conditions (such as by the result of pressing the STOP key or an active shutdown).

The System LSLD State reflects the state of LSLD at an overall system level. This state takes into account the individual LSLD state of all units on the MGDL network. The possible System LSLD states are listed in Table 10.

Table 10: LSLD System Operating State

System LSLD State	Description
GOING	All LSLD units are in the GOING state then the system is GOING.
SETTLING	Any LSLD unit is in the SETTLING state then the system is SETTLING.
UNLOADING	Any LSLD unit is in the UNLOADING state then the system is UNLOADING.
LOADING	Any LSLD unit is in the LOADING state then the system is LOADING.
AVAILABLE	Any LSLD unit is in the AVAILABLE state then the system is AVAILABLE implying that the system is not operating at full capacity.
GOING LSLD OFF	At least one LSLD unit is in the GOING LSLD OFF state and all units are either GOING LSLD OFF or UNAVAILABLE.
UNAVAILABLE	All LSLD units are in the UNAVAILABLE state then the system is UNVAILALBLE.

The generator-breaker-bus status (described in Figure 42) is also replicated on this screen from the MGDL Overview screen.

This screen also provides the generator voltage, frequency and percent real power measurements as well as bus voltage, frequency and system percent real power measurements.

The individual unit's order for sequencing on or off the bus under LSLD is indicated by the "NEXT TO LOAD" or "NEXT TO UNLOAD" status in the bottom left corner of this screen. If the unit is going under LSLD and it is prioritized such that it is 1st unit to unload, this status reads "NEXT TO UNLOAD." If the unit is prioritized such that it is 2nd unit to unload, this status reads "NEXT TO UNLOAD + 1."

Similarly, if the unit is available for loading under LSLD and it is prioritized such that it is the 1st unit to load this status reads "NEXT TO LOAD." If the unit is prioritized such that it is the 2nd unit to load this status reads "NEXT TO LOAD + 1."

The currently active LSLD sequence strategy as configured in the LSLD setpoints is listed in the bottom right corner of this screen.

MGDL Load Sense Load Demand control screen (Figure 56) is similar to the view screen except it provides easy access to the LSLD configuration setpoints as well as access to the LSLD Priority Assignment screen. To access the MGDL Load Sense Load Demand control screens through the EMCP 4.4 display, navigate to the following sub-menus:

MAIN MENU
→ CONTROL
→ PARALLELING
→ LOAD SENSE LOAD DEMAND

NOTE: Pressing the CONTROL key  on the face of the EMCP 4.4 provides a shortcut to the control menu.

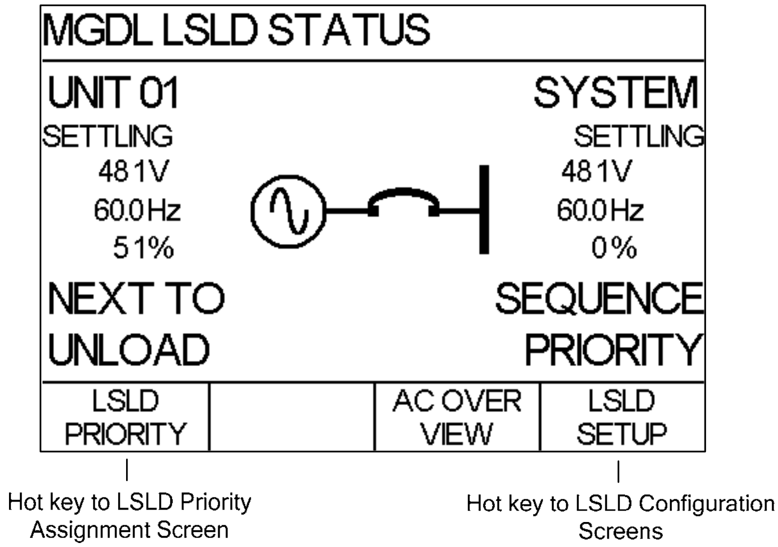


Figure 56: MGDL Load Sense Load Demand Control Screen

The MGDL LSLD Priority Assignment screen displays the LSLD priority assigned to each controller in the MGDL network. This priority is only utilized when operating in the "PRIORITY NUMBER" Sequence Strategy. The LSLD Priority can also be edited from this screen by selecting the "EDIT" F1 hot key. When editing is complete, save the changes by pressing the "ASSIGN ALL PRIORITY" F1 hot key. The LSLD Priority Assignment screens are shown in Figure 57 and

Figure 58.

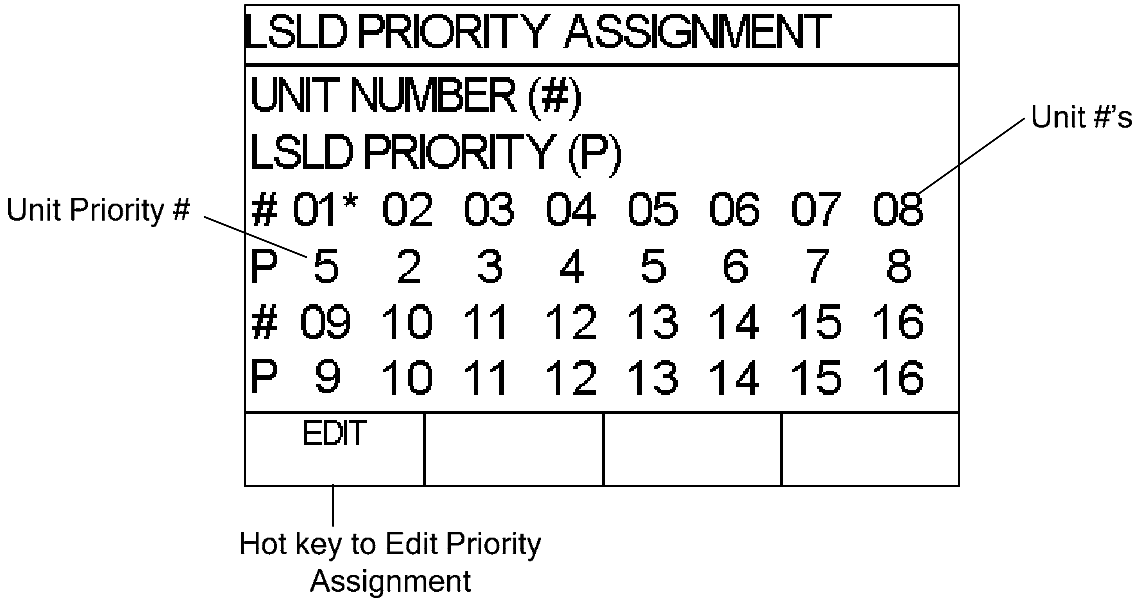


Figure 57: MGDL LSLD Priority Assignment View Screen

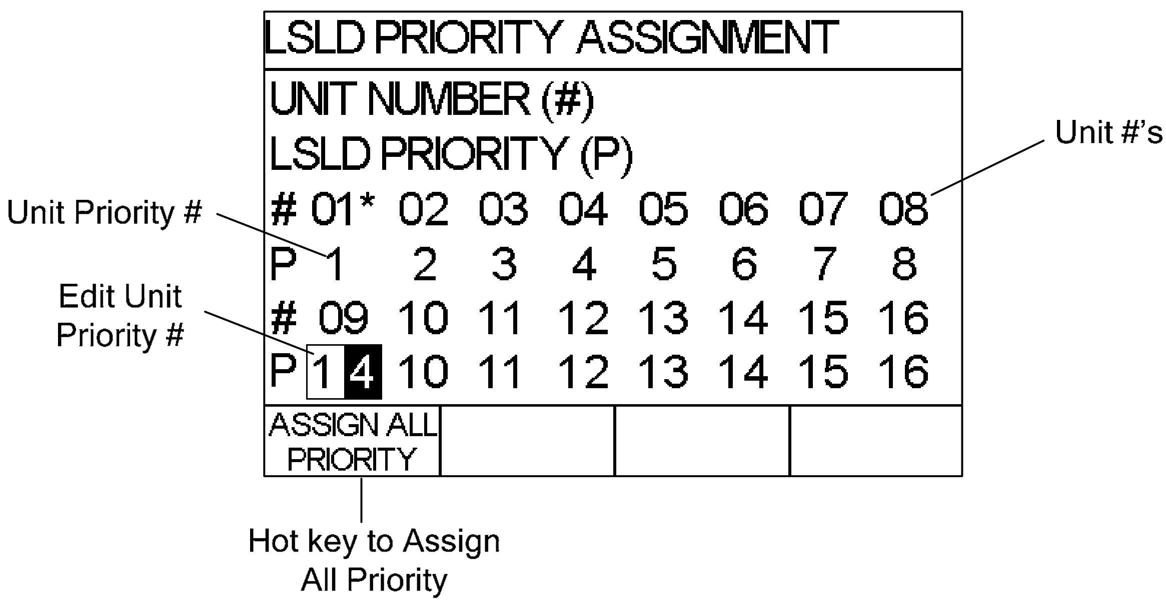


Figure 58: MGDL LSLD Priority Assignment Edit Screen

7.7 MGDL NETWORK STATUS SCREENS

The MGDL Network Status screens can be accessed directly through the EMCP 4.4 display. To access the MGDL Network Status screens through the display, navigate to the following sub-menus:

MAIN MENU
→ VIEW
→ NETWORK STATUS
→ MULTIPLE GENSET DATA LINK

NOTE: This screen is hidden from display until *Multiple Genset Control Data Link Unit Number* (setpoint) is configured to a non-zero value.

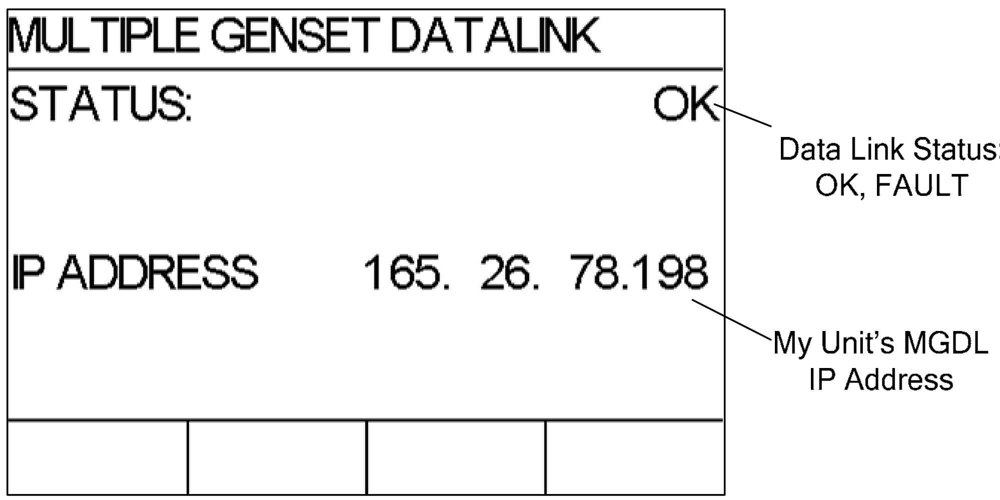


Figure 59: MGDL Network Status Screen

The MGDL Network Status screen provides an indication of the status of the MGDL network. If the MGDL network status displays "FAULT", there is a problem with the MGDL network and the event log should be consulted for troubleshooting. Otherwise, the MGDL network status displays "OK".

The MGDL network IP address listed on the MGDL Network Status screen is specific to the MGDL network node and is NOT related to the TCP/IP network IP address. The MGDL network IP address is dynamically assigned at power-up and is NOT configurable by the user. The MGDL network IP address may change based on network topology and is provided on this screen for reference purposes only.

7.8 MGDL STATUS EVENT LOG SCREENS

The Status Event Log screens can be accessed directly through the EMCP 4.4 display. To access the Status Event Log screens through the display, navigate to the following sub-menus:

MAIN MENU
→ VIEW
→ EVENT LOGS
→ STATUS EVENTS

NOTE: Pressing the EVENT LOG key  on the face of the EMCP 4.4 provides a shortcut to the event logs menu.

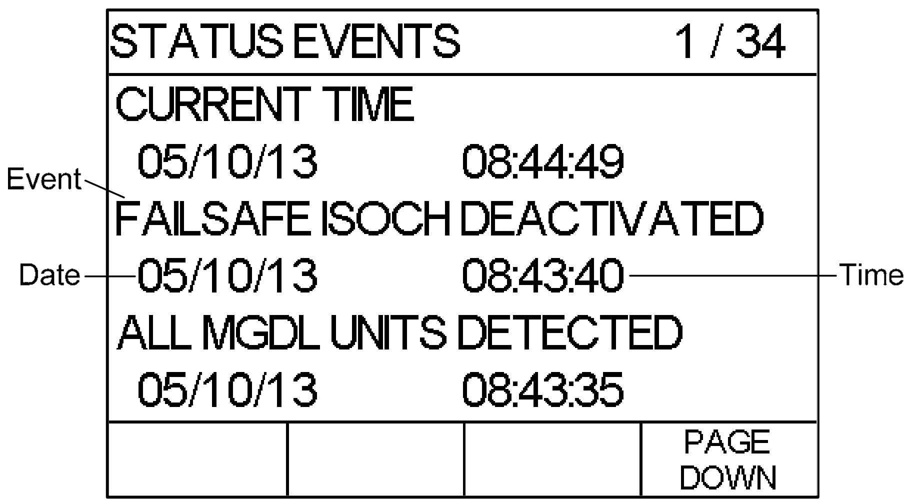


Figure 60: Status Events Screen

The status event log is meant to provide a record of recent generator set events or conditions with time stamps to assist in troubleshooting. Many status events exist and are triggered for the EMCP 4.4. Only the MGDL network related status events and their trigger conditions are listed in Table 11:

Table 11: MGDL-related Status Events

STATUS EVENT	TRIGGER CONDITIONS
NO MGDL UNITS DETECTED	Expected number of controls is non-zero, actual number of controls is one. The unit detects only itself and no other MGDL units on the network.
MGDL UNIT(S) NOT DETECTED	Expected number of controls is non-zero, actual number of controls is non-zero and not equal to expected number of controls. The unit no longer detects one or more MGDL units on the network.
ALL MGDL UNITS DETECTED	Expected number of controls equals actual number of controls. The unit detects all expected MGDL units on the network.
DBA CAUTION MODE ACTIVATED	Unit is attempting to dead bus close while operating under a failure mode caused by a loss of communications or MGDL protocol mismatch.
FAILSAFE DROOP ACTIVATED	Loss of communications or MGDL protocol mismatch has occurred and the unit is attempting to load share while grouped in the Proceed with Caution failsafe group.
FAILSAFE DROOP DEACTIVATED	Unit is no longer in the Proceed with Caution failsafe group because of either loss of communications recovery or exiting of load sharing.
FAILSAFE ISOCH ACTIVATED	Loss of communications has occurred and the unit is attempting to load share while grouped in the Proceed as Normal failsafe group.
FAILSAFE ISOCH DEACTIVATED	Unit is no longer in the Proceed as Normal failsafe group because of either loss of communications recovery or exiting of load sharing.

7.9 MGDL GENSET EVENT LOG SCREEN

The Genset Event Log screens can be accessed directly through the EMCP 4.4 display. To access the Genset Event Log screens through the display, navigate to the following sub-menus:

MAIN MENU
→ VIEW
→ EVENT LOGS
→ GENSET EVENTS

NOTE: Pressing the EVENT LOG key 

on the face of the EMCP 4.4 provides a shortcut to the event logs menu.

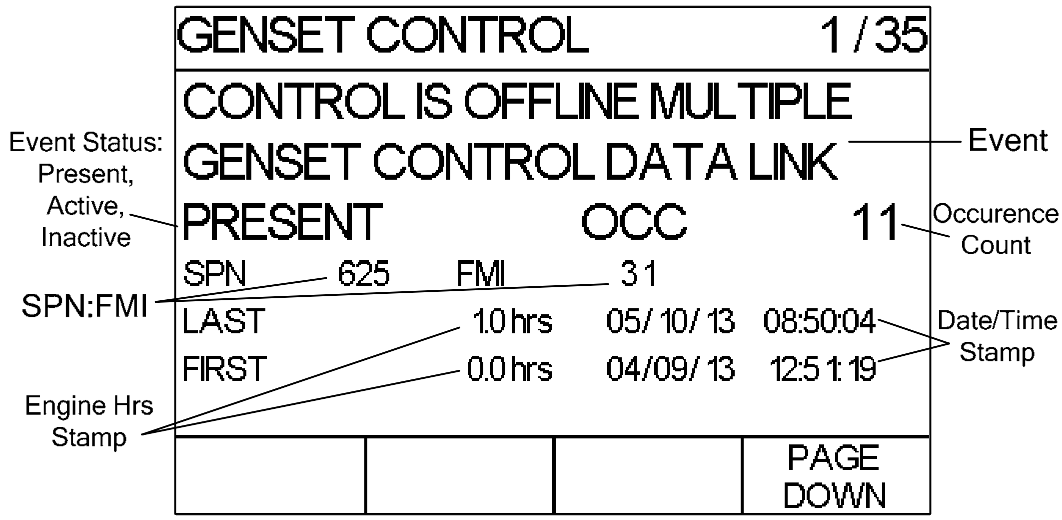


Figure 61: Genset Event Log Entry

The genset event log is meant to provide a detailed log of current and past generator set events including information such as event status, SPN: FMI, occurrence count, and date/time stamps of the last and first time that particular event occurred to assist in troubleshooting. The MGDL-related genset events are explained further as well as troubleshooting assistance in Section 8.

8 Troubleshooting

The EMCP 4.4 is designed to provide diagnostics or events to alert the operator to problems with the MGDL network configuration or operation of paralleled generator sets over the MGDL network. Some of the most common MGDL-related events are listed and described here along with general troubleshooting steps. All of these MGDL-related events appear in the EMCP (genset control) event log when triggered. For further details on troubleshooting EMCP events refer to the EMCP 4.3/4.4 Systems Operation and Troubleshooting and Adjusting (SOTA) Guide – UENR1210.

8.1 MGDL CONFIGURATION ERROR EVENT (SPN-FMI: 625-14)

The MULTIPLE GENSET CONTROL DATA LINK CONFIGURATION ERROR DIAGNOSTIC (SPN-FMI: 625-14) is used to identify when a mis-configuration of the MGDL network is present. This event response is a fixed shutdown and is not configurable. This shutdown event must be cleared before an MGDL unit will operate and is used to confirm that the EMCP 4.4 is configured appropriately.

For operating in full HARDWIRED paralleling mode, configure the EMCP 4.4 based on Table 12.

Table 12: EMCP 4.4 Hardwired Paralleling Configuration

EMCP 4.4 Setpoint	Setpoint Value
Multiple Genset Control Data Link Unit Number	ZERO
Breaker Close to Dead Bus Input Configuration	HARDWIRED INPUT
Generator Real Load Sharing Input Configuration	0 TO 10 V or 0 TO 3 V
Generator Reactive Load Sharing Input Configuration	0 TO 10 V
Load Sense Load Demand Input Configuration	HARDWIRED INPUT

For operating in full MGDL paralleling mode, configure the EMCP 4.4 based on Table 13.

Table 13: EMCP 4.4 MGDL Paralleling Configuration

EMCP 4.4 Setpoint	Setpoint Value
Multiple Genset Control Data Link Unit Number	NON-ZERO
Breaker Close to Dead Bus Input Configuration	ETHERNET (MGDL)
Generator Real Load Sharing Input Configuration	ETHERNET (MGDL)
Generator Reactive Load Sharing Input Configuration	ETHERNET (MGDL)
Load Sense Load Demand Input Configuration	ETHERNET (MGDL)

If Load Sense Load Demand or Dead Bus Arbitration features are not desired, they may be configured to "DISABLED". The EMCP 4.4 must be configured either for HARDWIRED paralleling operation or MGDL paralleling operation. No mixture of HARDWIRED and MGDL modes is permitted. If a configuration mixture of these two modes is detected the MULTIPLE GENSET CONTROL DATA LINK CONFIGURATION ERROR DIAGNOSTIC (SPN-FMI: 625-14) is triggered. With that in mind, the MULTIPLE GENSET CONTROL DATA LINK CONFIGURATION ERROR DIAGNOSTIC trigger conditions are summarized in Table 14.

Table 14: MGDL Configuration Error Conditions

EMCP 4.4 Setpoint	Setpoint Value				
Multiple Genset Control Data Link Unit Number	Zero (0)	Non-zero (1 to 64)	-- (don't care)	Non-zero (1 to 64)	Zero (0)
Breaker Close to Dead Bus Input Configuration	ANY configured to Ethernet (MGDL)	ANY configured to Hardwired Input	ANY mixture of Ethernet (MGDL) AND Hardwired Input	ALL configured to Ethernet (MGDL) or Disabled	ALL configured to Hardwired Input or Disabled
Generator Real Load Sharing Input Configuration					
Generator Reactive Load Sharing Input Configuration					
Load Sense Load Demand Input Configuration					
MGDL Configuration Error Event (SPN-FMI: 625-14)	⚠	⚠	⚠	✓	✓

NOTE: The MULTIPLE GENSET CONTROL DATA LINK CONFIGURATION ERROR DIAGNOSTIC can also be triggered as a result of two other conditions:

- If the EMCP 4.4 detects duplicate MGDL unit numbers on the MGDL network the two units with the same unit number will shutdown with this event.
- The MGDL feature is NOT intended to operate with single phase generator set applications. Therefore, the MULTIPLE GENSET CONTROL DATA LINK CONFIGURATION ERROR DIAGNOSTIC will be triggered if the EMCP 4.4 is configured for MGDL and any one of the following single phase Generator AC Connection Configurations:
  - Single Phase (2-Wire L1-L2) Connection
  - Single Phase (3-Wire L1-N-L2) Connection
  - Single Phase (2-Wire L2-L3) Connection
  - Single Phase (3-Wire L2-N-L3) Connection

Troubleshooting steps:

If the MULTIPLE GENSET CONTROL DATA LINK CONFIGURATION ERROR DIAGNOSTIC is PRESENT in the Genset Events Log on EMCP 4.4 display:

1. Review all setpoints listed in Table 14 to verify there is no mixture of HARDWIRED and MGDL setpoint configurations.

2. Review the Generator Connection Configuration setpoint to verify the generator set is not configured for single phase operation.

3. If all setpoints are configured appropriately for one of the modes, then verify there are not multiple units on the MGDL network configured to the same unit number.

4. If multiple units are configured for the same MGDL Unit Number, re-assign unique unit numbers to those units.

5. Event will transition to ACTIVE once the MGDL configuration is correct, event can now be reset.

It is common for the MULTIPLE GENSET CONTROL DATA LINK CONFIGURATION ERROR DIAGNOSTIC to be triggered during commissioning while individual paralleling features (DBA, LSLD, Load Sharing) are being configured for the first time. Once MGDL and paralleling configuration is complete the event should be capable of being reset.

8.2 MGDL CONTROL IS OFFLINE EVENT (SPN-FMI: 625-31)

The CONTROL IS OFFLINE MULTIPLE GENSET CONTROL DATA LINK DIAGNOSTIC (SPN-FMI: 625-31) is used to identify when a unit that is expected to be on the MGDL network is no longer communicating. The event response for this event is a warning by default, but is configurable via the *Control is Offline Multiple Genset Control Data Link Diagnostic Response Configuration* (setpoint) and is described in Section 4.5.1

This event is triggered as a result of no MGDL messages being received from one or more of expected controls online over a specified period of time. This can occur as a result of conditions such as broken or unplugged Ethernet cables, mis-configuration, power loss to Ethernet router/switch/hub devices, or power loss to ECMP 4.4. The EMCP 4.4 strategy for handling loss of communications is detailed in Section 5.6.

Troubleshooting steps:

If the CONTROL IS OFFLINE MULTIPLE GENSET CONTROL DATA LINK DIAGNOSTIC is PRESENT in the Genset Events Log on EMCP 4.4 display:

1. Navigate to the MGDL System Overview Screen described in Section 7.1. Identify any question mark symbols (?) that are displayed. A unit number is replaced with a question mark symbol (?) if the MGDL unit has lost communications. Scrolling to and selecting the question mark (?) on the MGDL Overview screen displays a message indicating the unit number of the lost node (Figure 46).
    a. A single lost node may indicate a broken wire or mis-configuration. Refer to step 2.
    b. Multiple lost nodes may indicate several broken wires or a possible power loss to Ethernet router/switch/hub devices. Refer to step 3.

2. On the MGDL System Overview Screen, use the “my unit” indicator (*) to determine this controller’s perspective of the MGDL network. If the MGDL System Overview Screen displays only one question mark (?) then there is only one other EMCP 4.4 that has lost communications.

    a. Check the STATUS EVENTS log for “MGDL Unit(s) Not Detected” status event, this triggers if some, but not all units are lost.

    b. Check if the unit with a loss of communications has lost power to the EMCP 4.4.

    c. Check if the unit with a loss of communications has the Ethernet cable unplugged from the Ethernet router/switch/hub device that it was connected to.

    d. Check if the unit with a loss of communications has lost power to the Ethernet router/switch/hub device that it was connected to.

    e. Check if the unit with a loss of communications has a broken Ethernet wire. On the EMCP 4.4 120-pin J1 connector, verify wiring to pin 87, 88, 97, and 98. These are the Ethernet connections and could cause loss of communications, if broken or poorly connected. These connections are explained further in Table 1.

    f. Check if the unit with a loss of communications is properly configured for MGDL operation. Refer to Section 8.1.

3. On the MGDL System Overview Screen, use the “my unit” indicator (*) to determine this controller’s perspective of the MGDL network. If the MGDL System Overview Screen displays multiple question marks (?) then there are multiple other EMCP 4.4 controllers that have lost communications.

    a. Check the STATUS EVENTS log for “No MGDL Units Detected” status event, this triggers if ALL units are lost.

i. Check if this unit's Ethernet cable is unplugged from the Ethernet router/switch/hub device that it was connected to.

ii. Check if this unit's has lost power to the Ethernet router/switch/hub device it was connected to.

b. Check if this unit has a broken Ethernet wire. On the EMCP 4.4 120-pin J1 connector, verify wiring to pin 87, 88, 97, and 98. These are the Ethernet connections and could cause loss of communications, if broken or poorly connected. These connections are explained further in Table 1.

c. Check the STATUS EVENTS log for "MGDL Unit(s) Not Detected" status event, this triggers if some, but not all units are lost.

i. Check if the units with a loss of communications have the Ethernet cable unplugged from the Ethernet router/switch/hub device that it was connected to.

ii. Check if the units with a loss of communications have lost power to the EMCP 4.4.

iii. Check if the units with a loss of communications have lost power to the Ethernet router/switch/hub device they were connected to.

d. Check if the units with a loss of communications have a broken Ethernet wire. On the EMCP 4.4 120-pin J1 connector, verify wiring to pin 87, 88, 97, and 98. These are the Ethernet connections and could cause loss of communications if broken or poorly connected. These connections are explained further in Table 1.

4. Once proper troubleshooting steps have been completed and MGDL communications are re-established:

a. CONTROL IS OFFLINE MULTIPLE GENSET CONTROL DATA LINK DIAGNOSTIC should transition from PRESENT to INACTIVE in the Genset Events Log on EMCP 4.4 display.

b. "All MGDL Units Detected" status event should appear in the Status Events Log.

If it is desired to intentionally disconnect unit(s) from the network for maintenance or permanently removing from the site then "RESET EXPECTED" should be considered. This will keep the system from operating in a failsafe mode during these situations, but must be done with understanding of the effect on the generator system. Refer to Section 5.7 for an explanation of the "RESET EXPECTED" operation as well as implications that could result from this action.

8.3 MGDL COMMUNICATIONS FAILURE EVENT (SPN-FMI: 625-19)

The MULTIPLE GENSET CONTROL DATA LINK COMMUNICATION FAILURE DIAGNOSTIC (SPN-FMI: 625-19) is used to identify when EMCP 4.4 receives unexpected data over the data link. The event response for this event is a hard shutdown by default, but is configurable via the *Multiple Genset Control Data Link Communication Failure Diagnostic Response Configuration* (setpoint) and is described in Section 4.5.1.

If the EMCP 4.4 receives an unexpected data packet over the data link the MULTIPLE GENSET CONTROL DATA LINK COMMUNICATION FAILURE DIAGNOSTIC will be displayed in the Genset Events Log and the unit will shutdown. This event may be triggered due to mismatched software versions installed on the EMCP 4.4s in your network topology. While this event is present, the unit can no longer participate in Load Sense Load Demand.

Troubleshooting steps:

If the MULTIPLE GENSET CONTROL DATA LINK COMMUNICATION FAILURE DIAGNOSTIC is PRESENT in the Genset Events Log on EMCP 4.4 display:

1. Check the software version installed on the EMCP 4.4. To access this information through the EMCP 4.4 display, navigate to the following sub-menus:

   MAIN MENU
   → SOFTWARE INFO

   a. If mismatched software versions are installed on the network a SOFTWARE VERSION (PROTOCOL) MISMATCH (SPN-FMI: 243-31) event may also be present in the Genset Events Log. This event as well as further troubleshooting is explained in Section 8.4.

8.4 SOFTWARE VERSION (PROTOCOL) MISMATCH EVENT (SPN-FMI: 234-31)

The SOFTWARE VERSION MISMATCH (SPN-FMI: 234-31) event is used to identify when mis-matched EMCP 4.4 MGDL communication software is detected between units on the MGDL network. Units attempting to operate with mis-matched software may have mis-matched MGDL communication protocols and have the potential for unsafe operating conditions. Therefore this scenario should be identified and avoided. Each EMCP 4.4 contains logic to ensure that all units on the MGDL network have matched MGDL communication protocols.

If any mis-match in the MGDL communication protocol is detected the SOFTWARE VERSION MISMATCH warning event (SPN-FMI: 234-31) is triggered and the unit enters the Proceed with Caution failsafe modes. The event response to this event is a fixed warning and is not configurable. The unit will remain in failsafe mode and the warning event will remain active until the software mismatch is no longer detected.

Troubleshooting steps:

If the SOFTWARE VERSION MISMATCH event is PRESENT in the Genset Events Log on EMCP 4.4 display:

1. Check the software version installed on the EMCP 4.4 controllers and identify any mismatches. To access this information through the EMCP 4.4 display, navigate to the following sub-menus:

   MAIN MENU
   → SOFTWARE INFO

2. Resolve any mismatch in software version by updating the software in MGDL units as necessary. As soon as ALL units connected to the MGDL network have the same software version without any protocol violations, the SOFTWARE VERSION MISMATCH (SPN-FMI: 234-31) event should be set to INACTIVE.

NOTE: It is NOT recommended to flash new software on a unit while other units are operating/providing system load through an MGDL network. If necessary, the MGDL system can be operated in failsafe modes while units are being flashed. Even though, a generator system operating in failsafe mode may provide system load adequately, normal MGDL load sharing is a more robust and stable operating mode. Proper steps should be taken to return the generator system back to normal operation as soon as possible.

8.5 DEAD BUS ARBITRATION FAILURE EVENTS (SPN-FMI: 2530-17 & 2530-1)

The Dead Bus Arbitration Failure events are triggered during dead bus arbitration when a failure occurs. Once a unit has obtained the dead bus close grant, it attempts to close to the dead bus immediately. If another unit is requesting, the *Breaker Close to Dead Bus Maximum Time* (setpoint) determines how long after issuing a breaker close a unit can try to close before it is determined to have failed. If the *Breaker Close to Dead Bus Maximum Time* expires with no detection of breaker closed, the DEAD BUS ARBITRATION FAILURE WARNING (SPN 2530-17) event is triggered. The event response is a fixed warning and is not configurable.

If a unit fails to close it must remove the breaker close command and then relinquish the dead bus close grant. If other units are requesting, a failed unit may re-request after delaying and de-activating the DEAD BUS ARBITRATION FAILURE WARNING event. If a unit fails to dead bus close a maximum of five dead bus close attempts, a DEAD BUS ARBITRATION FAILURE SHUTDOWN (SPN-FMI: 2530-1) event is generated. The event response is a fixed hard shutdown and is not configurable.

Troubleshooting steps:

If the DEAD BUS ARBITRATION FAILURE WARNING (SPN 2530-17) event or the DEAD BUS ARBITRATION FAILURE SHUTDOWN (SPN-FMI: 2530-1) event is PRESENT in the Genset Events Log on EMCP 4.4 display:

1. Verify a GEN BREAKER CLOSE COMMAND status event was logged in the Status Event Log with the expected timestamp. Each time the EMCP 4.4 issues a breaker close command the Isolated Dedicated Digital Output B is activated and a GEN BREAKER CLOSE COMMAND status event is logged.

    a. If a GEN BREAKER CLOSE COMMAND was issued from the EMCP 4.4, but a dead bus close did not follow, troubleshoot the generator circuit breaker hardware components such as:

        i. Generator Circuit Breaker relay/fuse failure

        ii. Generator Circuit Breaker closing coil failure

        iii. Generator Circuit Breaker charging system failure

    b. If a GEN BREAKER CLOSE COMMAND was not issued from the EMCP 4.4, investigate conditions that could inhibit a generator breaker closure such as:

        i. An ACTIVE programmable digital input configured for INHIBIT GEN BREAKER CLOSE (refer to the I/O STATUS screen)

        ii. An ACTIVE programmable digital input configured for any system event with an event response configured for BREAKER #1 TRIP (refer to the I/O STATUS screen and GENSET EVENT LOG)

        iii. Any ACTIVE system event with an event response configured for BREAKER #1 TRIP (refer to the GENSET EVENT LOG)

        iv. An ACTIVE generator circuit breaker trip command - Isolated Dedicated Digital Input C (refer to the I/O STATUS screen)

8.6 DEAD BUS INCONSISTENT SENSING EVENT (SPN-FMI: 2530-2)

The DEAD BUS INCONSISTENT SENSING (SPN-FMI: 2530-2) event will be made PRESENT if two or more EMCP 4.4 controllers do not agree on the bus live/dead status. This event will trigger if any EMCP 4.4 detects a DEAD BUS while any other unit communicating detects a LIVE BUS and vice versa. The event response for this event is a warning by default, but is configurable via the *Dead Bus Inconsistent Sensing Warning Event Response Configuration* (setpoint) described in Section 4.5.2. This event will be triggered if the EMCP 4.4 is not connected to the bus due to broken bus wire(s) or a failed bus sensing fuse(s). Disabling of this event is NOT recommended.

Troubleshooting steps:

If the DEAD BUS INCONSISTENT SENSING event is PRESENT in the Genset Events Log on EMCP 4.4 display:

1. Check if there is a poor connection on the back of the EMCP 4.4 or broken bus wire(s). On the back of the EMCP 4.4, pay attention to wires going into pin 11 (Bus V-A), pin 13 (Bus V-B), pin 31 (Bus V-C), and pin 47 (Bus V-N) on the J2 70-pin connector. These are the bus sensing connections and could cause inconsistent sensing if broken or poorly connected.

2. Check bus sensing fuses. There will be one on each phase. Replace if fuse has opened.

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