Service Information System

Product: NO EQUIPMENT SELECTED
Model: NO EQUIPMENT SELECTED
Configuration: NO EQUIPMENT SELECTED

Special Instruction
Integrated Voltage Regulator{4467, 4490}

Media Number -REHS9106-01 **Publication Date -14/03/2014** **Date Updated -14/03/2014**

i05751631

Integrated Voltage Regulator{4467, 4490}

SMCS - 4467; 4490

Electric Power Generation:
- **3512 GEN SET (S/N: ZAF1-UP)**
- **3512B GENSET (S/N: ZAH1-UP; ZAJ1-UP)**
- **3516C GEN SET (S/N: SBK1-UP)**
- **C1.5 GEN SET (S/N: GBD1-UP)**
- **C13 GENSET (S/N: X3M1-UP)**
- **C175-16 GEN SET (S/N: WYB1-UP)**
- **C2.2 GEN SET (S/N: GBE1-UP)**
- **C4.4 GEN SET (S/N: D4B1-UP; GLD1-UP; LC41-UP; LC51-UP)**
- **C6.6 GEN SET (S/N: N6D1-UP; LC61-UP)**
- **C7.1 GEN SET (S/N: ETG1-UP; MRP1-UP)**
- **SR4B (S/N: 5CK1-UP)**
- **XQ375 (S/N: X3F1-UP)**

Engine:
- **3412C (S/N: RTY1-UP)**
- **3412E (S/N: TGC1-UP)**
- **3512 (S/N: YBA1-UP; YAK1-UP; YAX1-UP; JM21-UP)**
- **3512B (S/N: YBB1-UP; YBC1-UP; YAM1-UP; YAN1-UP; YAY1-UP; YAZ1-UP; JM31-UP; JM41-UP)**
- **3512C (S/N: YBD1-UP; SBG1-UP)**
- **3516 (S/N: JCG1-UP; YAL1-UP; ZBL1-UP; YAS1-UP; YBS1-UP; JCW1-UP)**
- **3516B (S/N: JDE1-UP; JCH1-UP; JCN1-UP; YAP1-UP; ZBP1-UP; PDR1-UP; YAR1-UP; ZBR1-UP; YAT1-UP; YBT1-UP; YAW1-UP; YBW1-UP; JCY1-UP)**
- **3516C (S/N: SKC1-UP; JDH1-UP; JDJ1-UP; SBJ1-UP; SCJ1-UP; SFJ1-UP; SCK1-UP; SEK1-UP; SFK1-UP)**
- **C175-16 (S/N: WYC1-UP)**
- **C175-20 (S/N: BXR1-UP)**
- **G3406 (S/N: KAR1-UP)**
- **G3412 (S/N: GNA1-UP; KAP1-UP)**
- **G3512E (S/N: GFL1-UP; GFM1-UP)**
- **G3516H (S/N: GLM1-UP; GLN1-UP)**

Generator Set:
- **C15 GEN SET (S/N: T4A1-UP; L8B1-UP; C5E1-UP; C5H1-UP; X5M1-UP; NAP1-UP)**
- **C18 GEN SET (S/N: L8D1-UP; N1D1-UP; EKW1-UP; NAW1-UP)**
- **C27 GEN SET (S/N: DWB1-UP; N1B1-UP; GDS1-UP; T4Z1-UP)**
- **C32 GEN SET (S/N: K7C1-UP; JSJ1-UP; JAZ1-UP)**
- **C9 GEN SET (S/N: C9E1-UP; NBP1-UP; NGP1-UP)**

Power Module:
- **PM3512 (S/N: N1G1-UP)**
- **PM3516 (S/N: N1M1-UP; NBR1-UP)**
- **PMG3516 (S/N: JKK1-UP)**

Introduction

The Integrated Voltage Regulator (IVR) is a substitute for a traditional voltage regulator configuration. The traditional voltage regulator configuration consists of a dedicated controller such as a Cat Digital Voltage Regulator (CDVR) or a VR6. The IVR is integrated into the EMCP 4.1 and EMCP 4.2 controllers.

Important Safety Information

Work safely. 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 in order to perform these functions properly.

Safety precautions and warnings are provided in this instruction and on the product. If these hazard warnings are not heeded, bodily injury or death could occur to you or to other persons. Caterpillar cannot anticipate every possible circumstance that might involve a potential hazard.

Therefore, the warnings in this publication and the warnings that are on the product are not all inclusive. Tools, procedures, work methods, or operating techniques that are used but not recommended by Caterpillar, could be unsafe. Ensure that tools, procedures, work methods, or operating techniques are safe for you and for other people to use.

Ensure that the product will not be damaged or made unsafe by the operation, lubrication, maintenance, or the repair procedures that are used.

Integrated Voltage Regulator (IVR) General Information

The EMCP 4 internal controller regulates generator output voltage. The voltage is regulated by sending a command to the excitation module (EM10/EM15). The excitation module controls generator excitation and therefore generator output voltage.

The IVR feature is available with revised EMCP 4.1 and EMCP 4.2 controllers with software version 4.3PROD and above. The capability does not exist in original EMCP 4.1 and EMCP 4.2 controllers, regardless of software version.

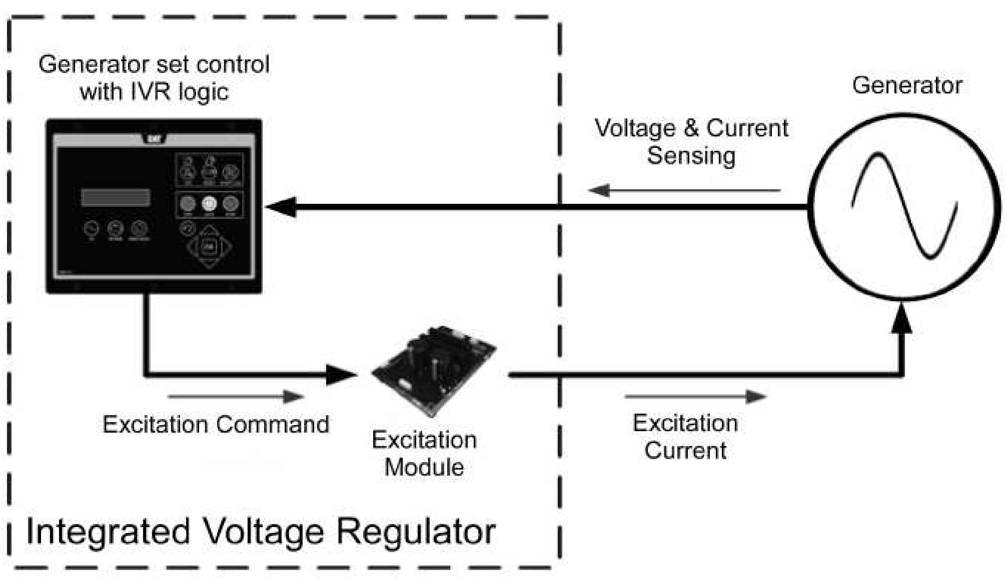

Illustration 1 g03486261

EMCP Integrated Voltage Regulator (IVR) system

IVR Features for EMCP 4.1 and EMCP 4.2

The following functionality is available when an EMCP 4.1 or EMCP 4.2 possesses IVR logic and is used with an excitation module (EM):

- Automatic Voltage Regulation (AVR)
- Programmable stability settings
- Soft start control with an adjustable time setting in AVR control mode
- Dual slope, under frequency (Volts/Hz) regulation that can be configured
- Three-phase or single-phase generator voltage (RMS) sensing/regulation in AVR mode
- Set point configuration adjustment from the EMCP display or Cat® Electronic Technician (Cat ET) Service Tool
- Voltage output adjustment via display, analog input, digital input, or SCADA (Modbus)
- IVR operating status and voltage bias overview screens to provide an enhanced level of user interface

- Integrated voltage regulator event monitoring
- Power factor regulation (PF) (EMCP 4.2 only)
- Reactive droop compensation (EMCP 4.2 only)
- Line drop compensation (EMCP 4.2 only)

Hardware Installation

EMCP IVR Connections

To regulate the generator terminal voltage, the EMCP communicates the desired excitation command to the excitation module via a pulse width modulation PWM signal. A twisted pair shielded cable must be used for the communication link. Table 1 details the connections to be made between the EMCP and excitation module.

Table 1

EMCP 4.1 and EMCP 4.2 Connections to Excitation Module			
EMCP 4.1, EMCP 4.2 70-Pin Connector		**Excitation Module 3-Pin Connector**	
Digital Output #2 / IVR CS+	68	CS+	P3-2
Battery negative splice	60 or 65	CS-	P3-3
Battery negative splice	60 or 65	Shield	P3-1

IVR Excitation Module

The IVR consists of an EMCP 4 that is interfaced with an excitation module.

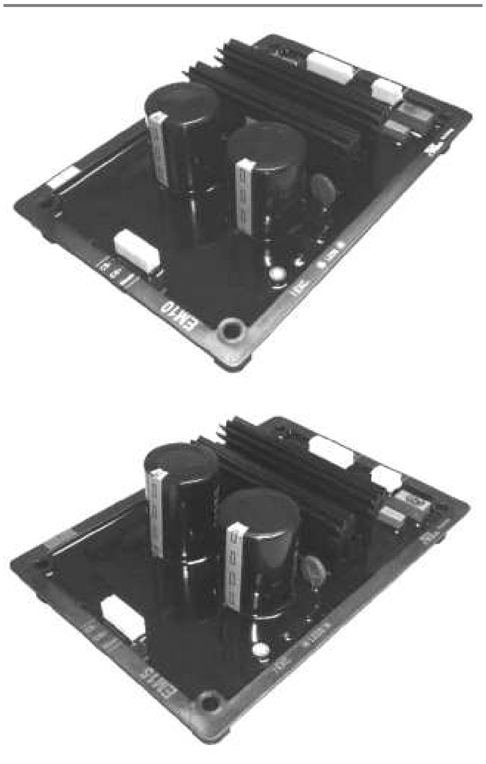

Illustration 2 g03487518

EM10 and EM15 excitation modules

Table 2 provides information on the technical specification of the EM10 and EM15 modules. Selection of the appropriate module must be determined by the following:

- Nominal and maximum generator excitation current at full load (standby, 0.8 PF)
- The maximum AC voltage input

Table 2

EM10 and EM15 Technical Specifications		
	EM10	**EM15**
Compatible Generator Excitation Types	Permanent Magnet (PM) Self-Excitation (SE) Internal Excitation (IE/AREP) (1)	
Nominal Field Current Output	6 A	7 A
Maximum (forcing) Field Current Output	10 A	15 A
Maximum AC Voltage Input	180 Vrms	240 Vrms
Exciter Field Resistance (recommended)	6 to 16 ohms	

(1) Internal Excitation (IE is also referred to as "Auxiliary Regulation Excitation Principle" (AREP).

Details for nominal field current are available on the generator data sheet. For self-excited (shunt) generators, users must understand the connections between the generator winding and the excitation module to understand the maximum AC voltage input. Caterpillar recommends that an intermediate, half-phase to neutral connection be used for self-excited generators.

IVR Excitation Module (EM) Physical Layout

The recommended location for the excitation module is in the generator set control panel or the generator terminal box. The EM should be installed in "landscape" orientation in order to achieve optimum cooling from the module heat sink. The module must be mounted using four M6 x 30 mm mounting bolts. Torque the mounting bolts to 5 ± 1 N·m (3.7 ± 0.7 lb ft). An M6 washer with an external diameter of 12 mm (0.5 inch) must be used with the mounting bolts to protect the module. Refer to Illustration 3 for the dimensions of the EM10 module.

Note: The EM15 has the same dimensions.

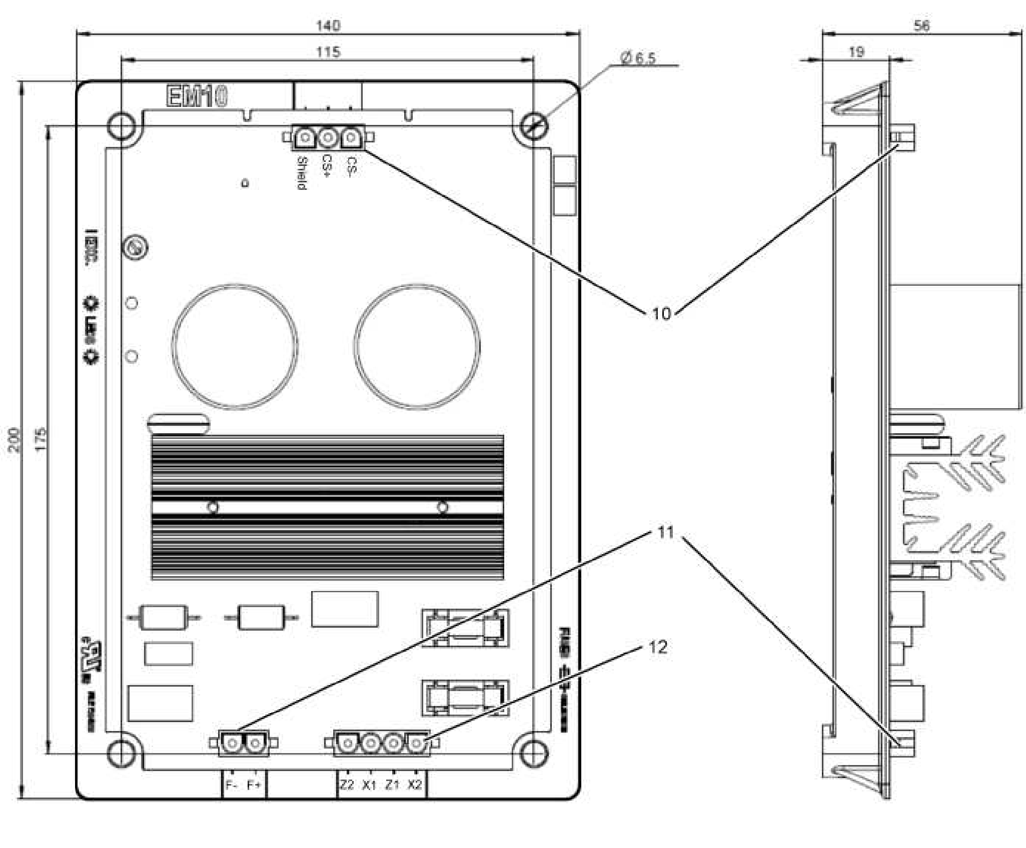

Illustration 3 g03487546

EM10 Excitation module (dimensions are in millimeters)

(10) Connector P3

(11) Connector P2

(12) Connector P4

IVR Excitation Module Connections

The EM10 and EM15 excitation modules have three plug type multiple-pin connectors. The connectors are labeled P2, P3, and P4 as shown in Illustration 3. Table 3 describes the signal and function of each connector pin.

Table 3

Excitation Module Connections		
Terminal	**Label**	**Signal/Function**
P2-1	F+	Exciter Field Positive
P2-2	F-	Exciter Field Negative
P3-1	Shield	Excitation Command Control Signal Shield
P3-2	CS+	Excitation Command Control Signal Positive
P3-3	CS-	Excitation Command Control Signal Negative
P4-1	X2	Excitation Power Supply Input X2
P4-2	Z1	Excitation Power Supply Input Z1
P4-3	X1	Excitation Power Supply Input X1
P4-4	Z2	Excitation Power Supply Input Z2

Note: The X2 and Z1 connections are internally linked within the excitation module. The link provides a point of common connection for the auxiliary windings where an AREP or IE excitation supply is available. Also, the X2 and Z1 connections may be linked externally to the excitation module. Only three connections (X1, X2, and Z2) are needed for the EM. Refer to Systems Operation/Test and Adjust/Troubleshooting, UENR1209, "Integrated Voltage Regulator Connections" for excitation module wiring connections. The wiring diagrams are for self-excitation (shunt), auxiliary windings (AREP/IE), and permanent magnet (PM) configurations.

IVR Excitation Module Over-Excitation Protection

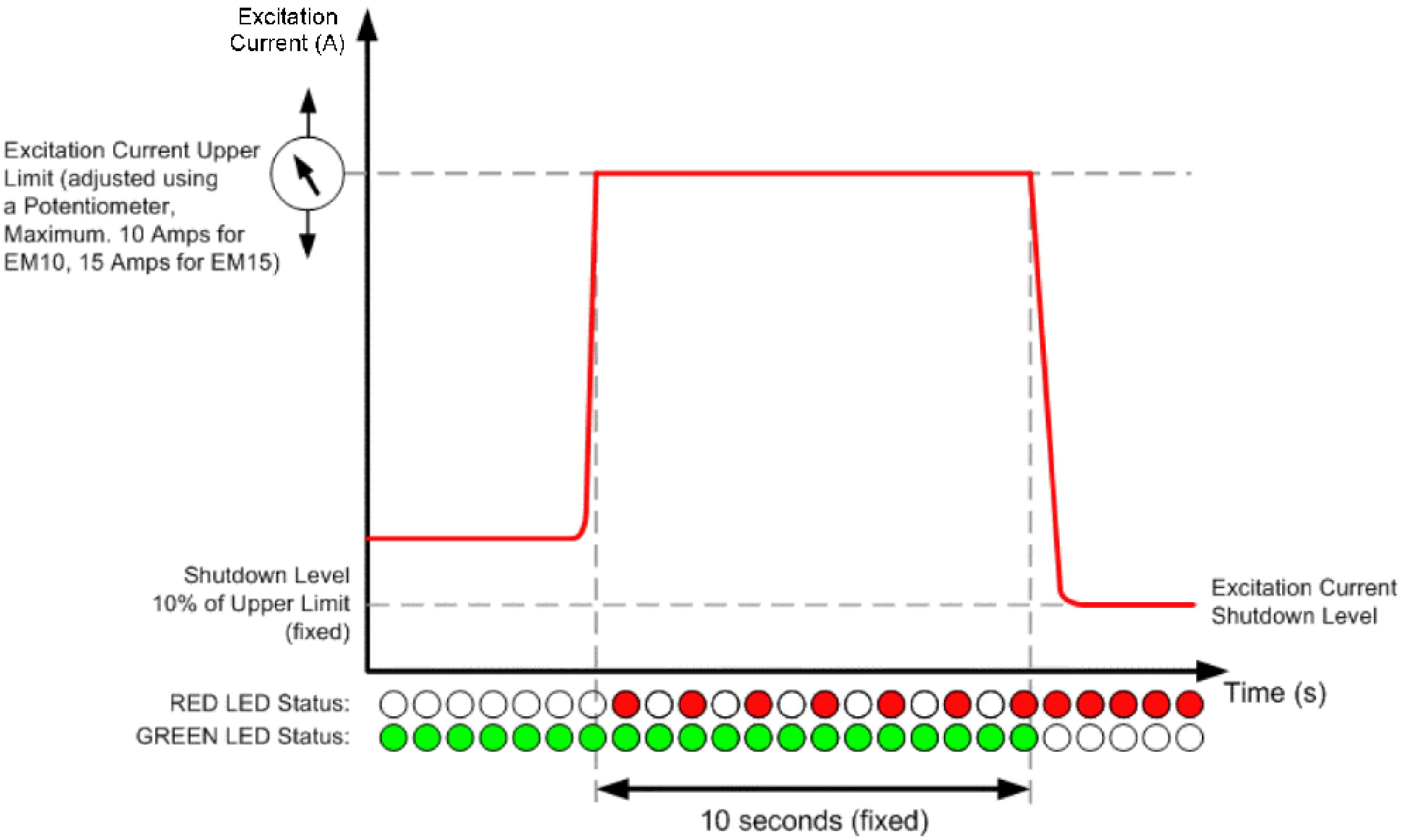

Illustration 4 g03487620

The excitation module has a built-in over-excitation protection strategy. The strategy is designed to protect the generator from thermal damage. The protection strategy is shown in illustration 4.

Under normal conditions the excitation current will remain well below the upper limit and the green LED on the excitation module will be lit continuously.

In the event of a fault condition such as a short-circuit on the generator terminals, the excitation current will increase rapidly. The process is referred to as "field forcing". The excitation module will limit the forcing current to the defined upper limit for a fixed period of 10 seconds.

When the excitation module is actively limiting the field current, a red LED will flash indicating a fault condition. After the fixed delay time has expired, the excitation module will "limit" the excitation current to a safer level. A safer level is 10% of the upper limit.

When the excitation module has shut down the excitation current, the red LED is lit continuously and the green LED is not lit. The red LED will be lit only while voltage is being supplied to the excitation module. The power supply must be removed from the excitation module to reset the excitation current limiting the excitation current. Power is removed by shutting down the generator set.

The excitation limit potentiometer on the excitation module has 270 degrees of rotation. The potentiometer is used to configure the excitation current upper limit as shown in Illustration 5. The potentiometer must be set for maximum forcing current, and not nominal excitation current.

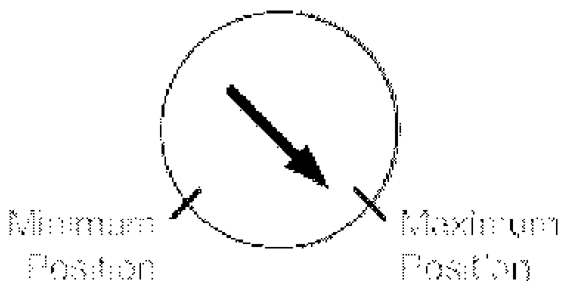

Illustration 5 g03487816

Excitation limit potentiometer

Table 4

Excitation Limit Potentiometer Settings		
	EM10	**EM15**
Minimum Position	4 A	6 A
Maximum Position	10 A	15 A

IVR Excitation Module Fusing

The EM10 has internal fusing, therefore installation of external fuses for the excitation power supply inputs are not necessary. The EM15 requires external fusing to be installed on inputs X1 and Z2. The recommended fuse for Underwriters Laboratory (UL) listed generator sets is a Bussman KTK-10. For non-UL listed generator sets, an alternative fuse can be used. The alternate fuse is Bussman AGC-10RX. Refer to the Systems Operation, Testing and Adjusting, UENR1209, "Integrated Voltage Regulator Connections" sections for wiring diagrams. The wiring diagram shows the location of external fusing for the EM15.

IVR Software Configuration

The IVR parameters can be accessed using either the Cat ET Service Tool, or directly through the EMCP display. Some set points are locked using Cat ET Service Tool only or at security level 3. The set points that are locked, cannot be changed from the EMCP display. The set points that are locked will require a level 3 password. Cat ET Service Tool version 2012C or later is needed to access and adjust the IVR parameters. To access the IVR set points using Cat ET Service Tool, connect to the EMCP generator set control. Click on the "Configuration Tool" button or as an alternative press "F5" to enter the configuration menu. Select "Integrated Voltage Regulator" from the menu on the left. Set voltage regulator control source configuration equal to "generator set control" to display the following default settings.

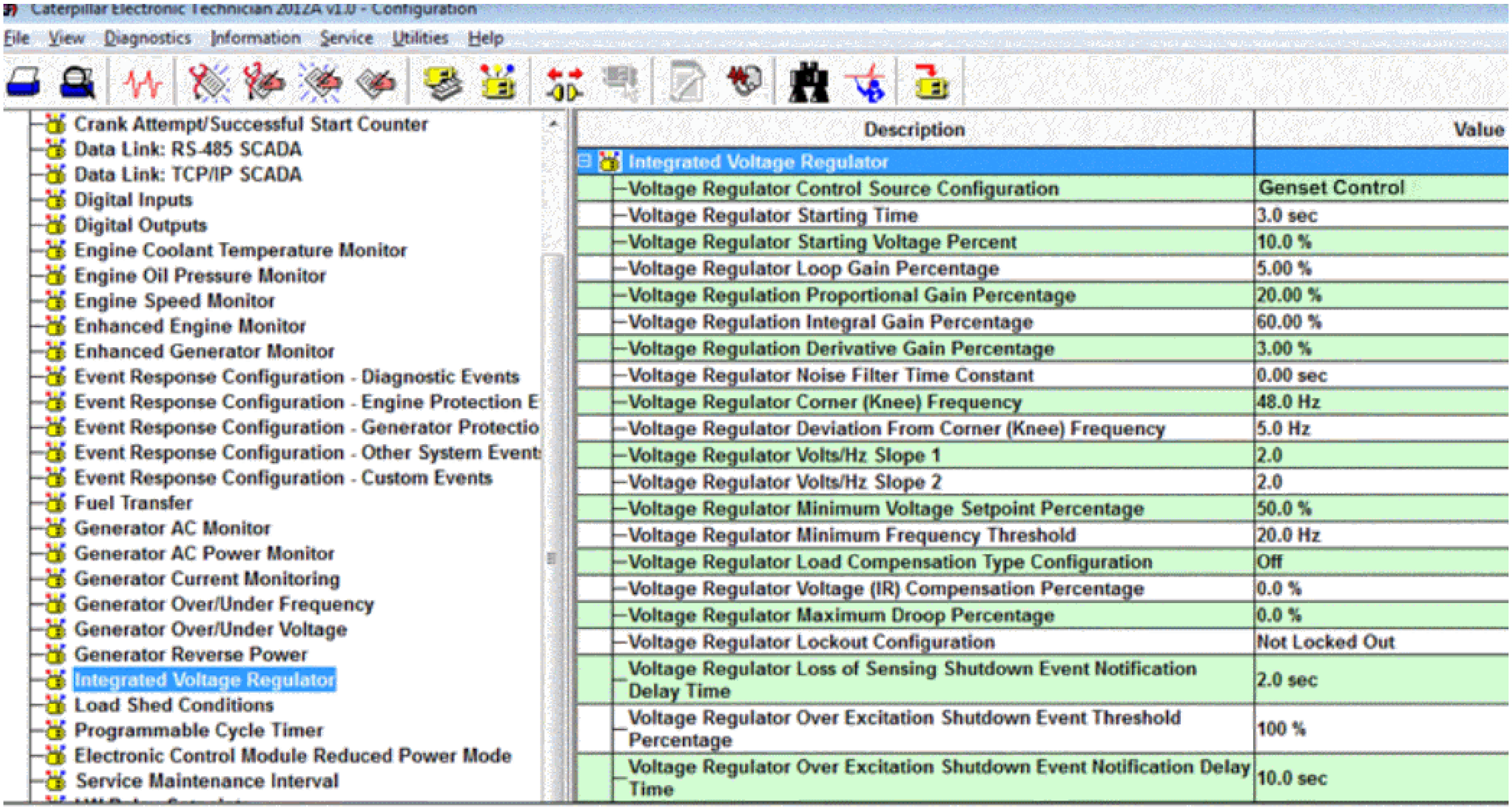

Illustration 6 g03487941

Use the following steps to access IVR set points with the EMCP.

1. Begin at the "Main Menu".
2. Use the arrow buttons to select "CONFIGURE". Press the "OK" key.
3. Use the arrow buttons to select "All Set Points". Press the "OK" key.
4. Use the arrow buttons to select "Voltage Regulator". Press the "OK" key.

If replacing a Cat Digital Voltage Regulator (CDVR) with an IVR, the parameters can be programmed the same as the CDVR. Use Cat ET Service Tool scaling in order to achieve similar performance.

The parameters can be programmed to the default values with a low loop gain. The values can start in the region of 1.0% to 5.0% for the following installations:

- New IVR installation
- Replacing a R450 voltage regulator
- Replacing a VR6 voltage regulator

Note: Default parameters should provide stable voltage control for most generator sets. However some optimization and tuning may be required to achieve the desired performance. The following sections provide further detail on each individual set point, including range, resolution and default values.

Voltage Regulator Control Source Configuration

Table 5

Voltage Regulator Control Source Configuration			
Name	**Options**	**Default Value**	**Access**
Voltage regulator control source configuration	0 = External Control 1 = generator set control	0 (External Control)	only by usingCat ET Service Tool

The voltage regulator control source configuration parameter is used to enable or disable the IVR feature.

If the configuration is set to "External", the IVR feature of the EMCP is disabled. The generator set can run with an external voltage regulator such as a CDVR, R450, or a VR6.

If the configuration is set to "Generator Set Control", the IVR feature of the EMCP is enabled. The generator set will run using an excitation module.

Note: The voltage regulator control source configuration parameter will only change state if the generator set is stopped. The stop button must be pressed and engine speed must be zero rpm. The voltage regulator control source configuration can only be changed using Cat ET Service Tool. That is, the EMCP display cannot be used to adjust the "Voltage Regulator Control Source Configuration" parameter.

The voltage regulator control source configuration must be correctly programmed **BEFORE** starting the generator set.

There is a risk of nuisance triggering of IVR-related warning and shutdown events if both of the following exist:

- An external voltage regulator is used
- The voltage regulator control source configuration is set to "Generator Set Control"

There is a risk that the pulse width modulated (PWM) output (DO#2) may float high if both of the following exist:

- The "Excitation Module is Installed"
- The voltage regulator control source configuration is set to "External"

The output change would cause the excitation module to force the excitation current to the upper limit. The current increase can damage the generator set and/or load.

Starting Profile

Table 6

Starting Profile						
Name	**Min**	**Max**	**Resolution**	**Units**	**Default Value**	**Access**
Voltage Regulator Starting Voltage Percent	0.0	90.0	0.1	%	10.0	Cat ET Service Tool or EMCP display
Voltage Regulator Starting Time	0.0	60.0	0.1	seconds	3.0	

The starting profile set points defined above are used to determine the slope of the voltage ramp when starting the generator set. If the voltage regulator starting voltage percent is zero, the voltage regulator starting time defines the time to reach the rated voltage set point. The time to reach the rated voltage set point is from the point that the frequency exceeds the voltage regulator minimum frequency threshold. Refer to Illustration 7 for an example of a starting profile with both of the following parameters:

- The voltage regulator starting voltage percentage set to 0%
- The voltage regulator starting time set to 5 seconds

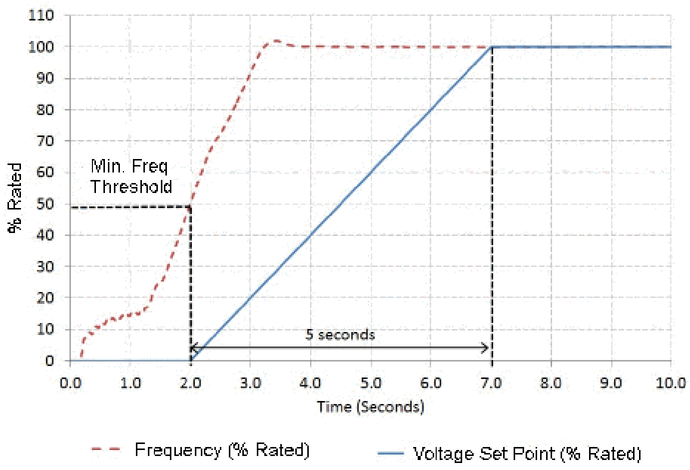

Illustration 7 g03487977

Starting profile with voltage regulator starting voltage set to 0% and voltage regulator starting time set to 5 seconds.

The voltage regulator starting time defines the time to get to the rated voltage set point from the voltage regulator starting voltage percent. If the Volts/Hz slope results in a lower set point than the starting profile, the minimum voltage set point will be followed.

Refer to Illustration 8 as an example starting profile. The example shows the voltage regulator starting voltage percentage set to 10% and voltage regulator starting time set to 3 seconds.

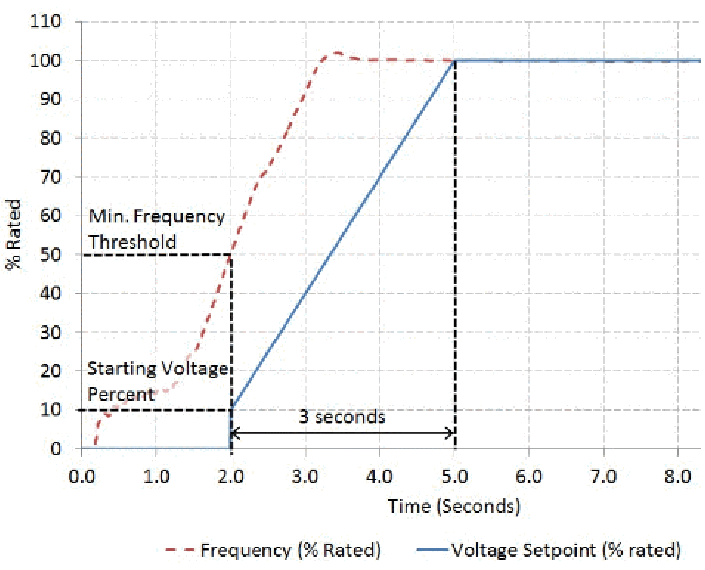

Illustration 8 g03487981

Starting Profile - starting voltage set to 10% and starting time set to 3 seconds

Refer to Illustration 9 as another example starting profile. However, Illustration 9 shows the starting voltage percentage set to 90% and starting time set to 3 seconds.

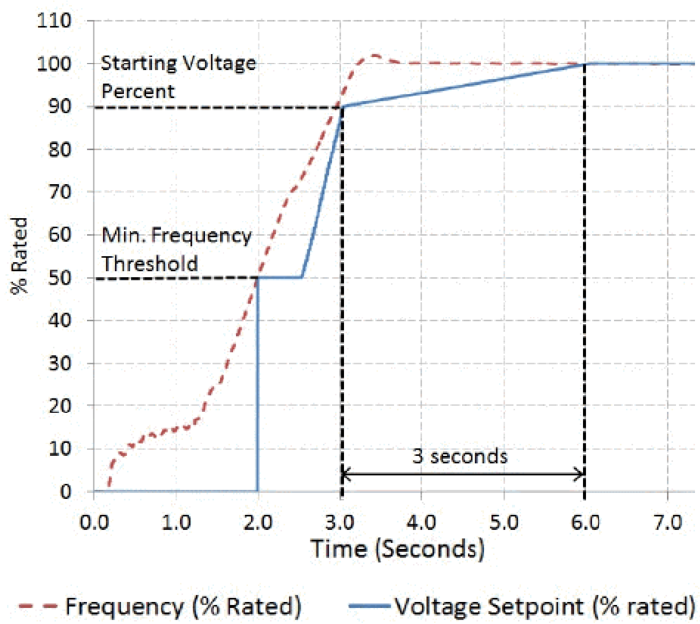

Illustration 9 g03487982

Starting Profile - Starting Voltage set to 90% and starting time set to 3 seconds

If the voltage regulator starting time is set to zero, or the engine has a slow starting ramp, the IVR will follow the programmed Volts/Hz slopes. The voltage set point during starting is the minimum of the starting profile set point and the under-frequency roll-off (loading) profile set point.

The excitation command output from the EMCP is limited to a maximum value of 20% during starting. The limit is used to avoid a large voltage overshoot during starting. The limit is needed particularly on generators with shunt or AREP excitation systems.

The limit for excitation command output from the EMCP prevents integral windup within the "Proportional Integral Derivative" (PID) controller. The limit is needed during starting where there is insufficient residual voltage at the generator output to build excitation. Once the frequency exceeds the voltage regulator corner (knee) frequency threshold and the nominal voltage set point has been reached, the IVR will follow the under-frequency roll-off (loading) profile. The starting profile will not be initiated again until the frequency drops below the voltage regulator minimum frequency threshold.

IVR PID Gain Set Points

Table 7

IVR PID Gain Set Points						
Name	**Min**	**Max**	**Resolution**	**Units**	**Default Value**	**Access**
Voltage Regulator Loop Gain Percentage	0.00	100.00	0.01	%	5.00	Cat ET Service Tool or EMCP display
Voltage Regulator Proportional Gain Percentage	0.00	100.00	0.01	%	20.00	Cat ET Service Tool Only (Level 3 Password)
Voltage Regulator Integral Gain Percentage	0.00	100.00	0.01	%	60.00	
Voltage Regulator Derivative Gain Percentage	0.00	100.00	0.01	%	3.00	
Voltage Regulator Noise Filter Time Constant	0.00	1.00	0.01	Seconds	0.00	

The PID gain set points can be tuned to achieve the desired voltage response. Adjusting the PID gain set points depends on the application and generator set configuration. The default parameters have been selected to provide stable voltage control on most generators, however some optimization may be required. If the voltage regulation appears unstable, there may be a need to reduce the voltage regulator loop gain percentage to achieve stability. As a guideline, decreasing in steps of 0.5 to 1.0% is sufficient to observe a noticeable improvement. If the voltage response appears sluggish, increase the voltage regulator loop gain percentage to achieve the desired response. Increasing in steps of 0.5 to 1.0%

is sufficient to observe a noticeable improvement.

Under-Frequency Roll-Off (Loading) Profile

Table 8

Under-Frequency Roll-Off (Loading) Profile						
Name	**Min**	**Max**	**Resolution**	**Units**	**Default Value**	**Access**
Voltage Regulator Corner (knee) Frequency	45.0	65.0	0.1	Hz	48.0	Cat ET Service Tool or EMCP display
Voltage Regulator Deviation From Corner (knee) Frequency	0.0	10.0	0.1	Hz	5.0	
Voltage Regulator Volts/Hz Slope 1	0.0	10.0	0.1	Volts/Hz	2.0	
Voltage Regulator Volts/Hz Slope 2	0.0	10.0	0.1	Volts/Hz	2.0	
Voltage Regulator Minimum Voltage (set point) Percentage	30	100	1	%	50	
Voltage Regulator Minimum Frequency Threshold	20	40	1	Hz	20	

The voltage regulator knee frequency must be configured for your specific package requirements. The knee frequency for 50 Hz operation will usually be between 48.0 and 49.8 Hz. For 60 Hz operation, the parameter must be set between 58.0 to 59.8 Hz.

Refer to Illustration 10 for an example under-frequency roll-off (loading) profile.

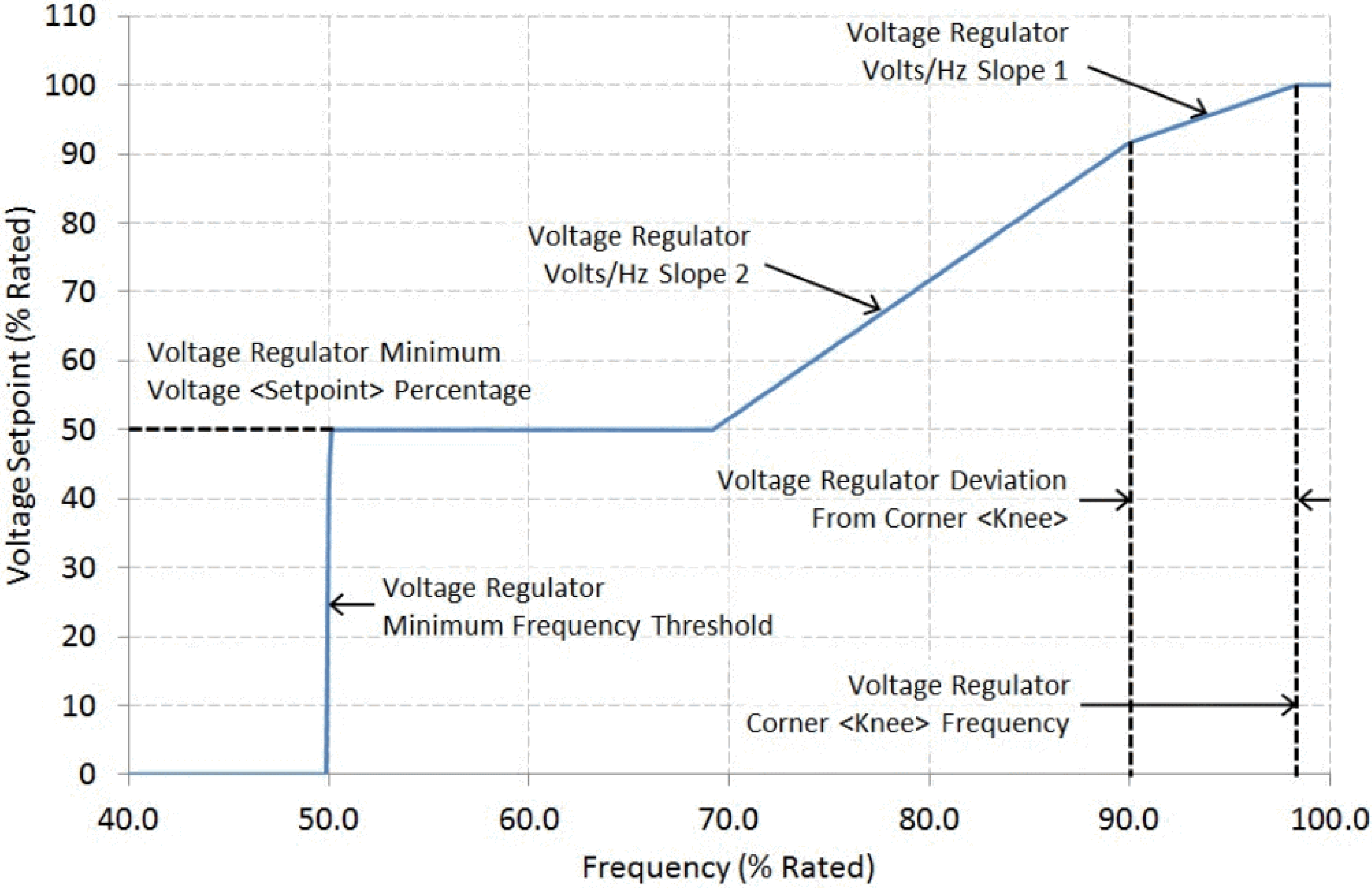

Illustration 10 g03487998

Under-frequency (loading) profile slope1 = 1.0 V/Hz, slope2 = 2.0 V/Hz

Voltage Regulator Load Compensation Type Configuration

Table 9

Voltage Regulator Load Compensation Type Configuration			
Name	Options	Default Value	Access
Regulator Load Compensation Type Configuration Voltage	0 = OFF 1 = IR Compensation 2 = Voltage Droop	0	Cat ET Service Tool or EMCP Display

The load compensation features of line loss (IR) compensation and voltage droop are explained in the following sections.

Note: IR compensation and voltage droop are mutually exclusive features designed for different applications. The IR compensation and voltage droop features are different compensation types and cannot be enabled at the same time.

Line Loss (IR) Compensation

Table 10

Line Loss (IR) Compensation

Name	Min	Max	Resolution	Units	Default Value	Access
Voltage Regulator Voltage (IR) Compensation Percentage	0.0	10.0	0.1	%	0.0	Cat ET Service Tool or EMCP display

In some single generator installations with long feeder lines to the load, providing line loss compensation might be advantageous. Line loss compensation is commonly referred to as "IR compensation". Current flowing through a long conductor causes a voltage drop due to the resistance of the wire. Therefore, the voltage at the load end of the conductor will be lower than the voltage at the generator end. The condition is commonly referred to as line loss. In order to improve the power quality, the IVR can compensate for the line loss. As the generator load increases, the IVR will increase the output voltage at the generator terminals in order to compensate for line losses.

The voltage regulator voltage (IR) compensation percentage set point controls the quantity of voltage compensation at the rated kVA load. The set point must be adjusted to yield a constant voltage at the location of the load. the following is an example. If the voltage at the load side of the feeder line has decreased by 5% from rated voltage when the generator is supplying rated kVA load, the voltage regulator (IR) compensation percentage must be set to 5.0%. In the example, the output voltage measured at the generator terminals will increase from 100% to 105% of rated voltage as the generator load increases from 0% to 100% of rated kVA. Refer to Illustration 11.

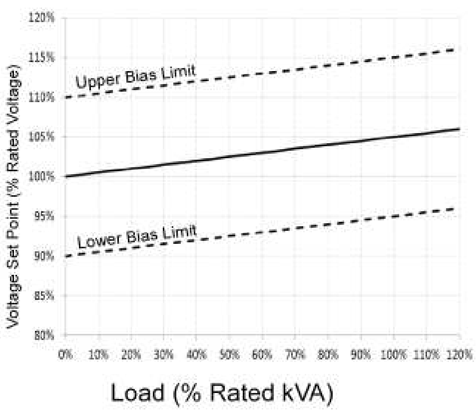

Illustration 11 g03488116

Line loss voltage set point change based on total (kVA) load

If a bias is applied to the voltage set point from an external source, the IR compensation percentage is applied to the nominal set point plus the bias percentage. As an example, if a +10% or -10% bias were applied to the nominal voltage, the voltage set point would increase linearly. Refer to the upper and lower bias limit dashed lines indicated in Illustration 11.

Ensure that the capability of the generator set is not exceeded during operation.

Reactive Droop Compensation

Table 11

Reactive Droop Compensation						
Name	Min	Max	Resolution	Units	Default Value	Access
Voltage Regulator Maximum Droop Percentage	0.0	10.0	0.1	%	0.0	Cat ET Service Tool or EMCP display

When generators operate in parallel, there are two primary objectives.

1. Share the real power requirements of the system electrical load.
2. Share the reactive power requirements of the system electrical load.

The engine governors will control sharing of the real power requirements (kW). The voltage regulators will control sharing of the reactive power requirements (kVAr) of the total system load. When one or more generators are connected in parallel, the voltage measured at the output terminals of each generator will be the same. However, if the voltage set point of one generator is slightly higher than the other generators, that generator will increase excitation in an attempt to raise the system voltage. The attempt to raise the system voltage will also supply lagging reactive current to the other generators connected in the group. The lagging reactive current will circulate between generators, causing excessive heating of the generator windings and an increased risk of thermal damage.

One method of minimizing the effect is to cause an individual generator voltage set point to sag or droop. The sag or droop is in proportion to the reactive power output. For proper reactive load sharing, the regulator must know the rated generator reactive power (kVAr). The kVAr is calculated from the generator set rated kVA, kW, and the desired percentage of output voltage droop when the generator is supplying rated reactive power.

As the reactive power output increases, the IVR will cause the output voltage to droop (reduce the voltage) proportionally. If the measured reactive power output is leading, the output voltage will rise in the same linear fashion. In either case, the action will support better kVAr sharing with other generators.

Note: Ensure that the capability of the generator set is not exceeded during operation.

The voltage regulator maximum droop percentage set point controls how much the generator output voltage will vary for a given amount of reactive power output. If the maximum droop percentage is set to 5.0%, the voltage set point will drop from 100% to 95% of rated voltage as the reactive power output increases from 0% to 100% of rated kVAr (lagging). Refer to Illustration 12.

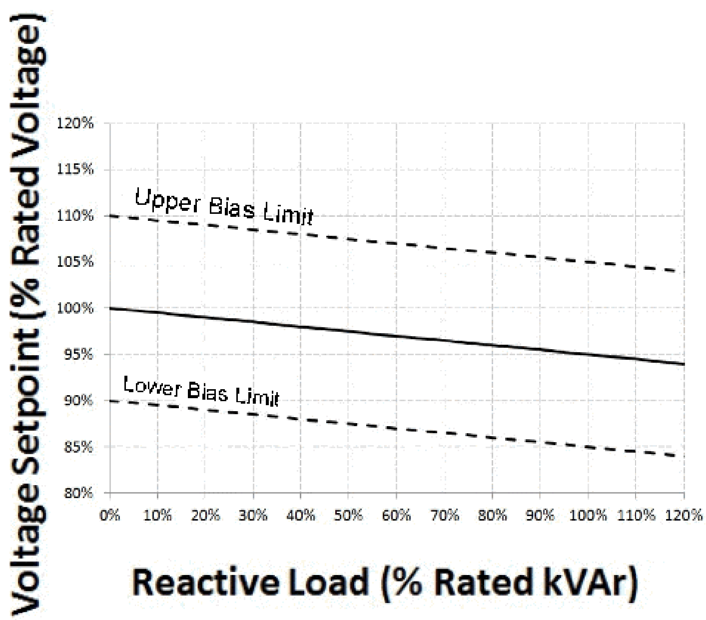

Illustration 12 g03488240

Reactive droop voltage set point change based on reactive (kVAr) load

If a bias is applied to the voltage set point from an external source, the reactive droop percentage is applied to the nominal set point plus the bias percentage. For example, if a +10% or -10% bias were applied to the nominal voltage, the voltage set point would droop. Refer to Illustration 12 that shows the upper and lower bias limit dashed lines.

Ensure that the capability of the generator set is not exceeded during operation.

Voltage Regulator Lockout Configuration

Table 12

Voltage Regulator Lockout Configuration			
Name	**Options**	**Default Value**	**Access**
Voltage Regulator Lockout Configuration	0 = Not Locked Out 1 = Locked Out	0.0	Cat ET Service Tool Only

When voltage regulator lock out configuration is set to "Not Locked Out", the IVR will operate normally. The IVR will also control the generator voltage output to the reference set point.

When voltage regulator lock out configuration is set to "Locked Out", the IVR will be prevented from controlling the generator voltage output. The excitation command output will remain at zero. Excitation is therefore disabled in the scenario. The generator will only produce residual voltage. The voltage regulator lockout configuration set point can only be changed when the generator set is **STOPPED**. That is, after the EMCP stop button has been pressed and engine speed equals zero.

Loss of Sensing Shutdown Event

Table 13

Loss of Sensing Shutdown Event						
Name	**Min**	**Max**	**Resolution**	**Units**	**Default Value**	**Access**
Voltage Regulator Loss Of Sensing Shutdown Event Notification Delay Time	0.0	25.0	0.1	Seconds	2.0	Cat ET Service Tool or EMCP display

The voltage regulator loss of sensing shutdown event notification delay time determines the following:

1. The time delay required before a loss of sensing voltage is recognized.
2. When a loss of sensing shutdown event is generated. (SPN-FMI: 611-0)

Based on average line-to-line voltage monitoring, for single phase configuration, loss of sensing will be triggered under the following condition:

- Average line-to-line voltage is less than 8% of the rated voltage

Based on average line-to-line voltage monitoring, for 3-phase configuration, loss of sensing will be triggered due to any one the following conditions:

- Balanced 3-phase average is less than 8% of the rated voltage
- Imbalance between a line quantity and 3-phase average is greater than 20% of the rated voltage
- Loss of a phase (line-to-neutral voltage is less than 8% of the rated voltage)

The loss of sensing shutdown event is inhibited when:

- A generator short circuit condition is detected (any phase current exceeds 300% of rated)
- During voltage starting profile (operating mode equals soft start)
- For 5 seconds after frequency increases above the voltage regulator minimum frequency threshold set point
- Excitation is disabled (voltage regulator lockout configuration is set to "Locked Out")

Over Excitation Shutdown Event

Table 14

Over Excitation Shutdown Event						
Name	**Min**	**Max**	**Resolution**	**Units**	**Default Value**	**Access**
Voltage Regulator Over Excitation Shutdown Event Threshold	10	100	1	%	100.0	Cat ET Service Tool or EMCP Display
Voltage Regulator Over Excitation Shutdown Event Notification Delay Time	0.1	20.0	0.1	Seconds	10.0	

The over excitation shutdown event threshold configuration determines the percentage of excitation command that will cause an over excitation shutdown event. If the excitation command percentage exceeds the over excitation shutdown event threshold for longer than the over excitation shutdown event notification delay time, an over excitation shutdown event (SPN-FMI: 3381-0) will be generated.

Note: The over excitation shutdown event monitors and triggers an event based on excitation command percentage and does not trigger based on measured excitation current. See the section on excitation module over-excitation protection for a description of the excitation module over-excitation protection feature that is based on measured excitation current.

IVR Voltage Adjustment

Voltage adjustments are categorized into two types, manual biasing and analog biasing. Manual voltage adjustment includes fine-tuning the generator output voltage via digital input, EMCP display, or SCADA (Modbus). Analog voltage adjustment is performed via programmable analog inputs to the EMCP. Analog voltage adjustment provides a voltage control interface for external potentiometers or external control systems, such as switch gear.

The generator maximum voltage bias percentage set point must be configured correctly to be greater than the expected bias range. If this set point is not correctly configured, the required voltage bias may not be possible to achieve. The generator maximum voltage bias percentage parameter is accessed with Cat ET Service Tool. The parameter is accessed through the configuration dialog under "Generator AC Monitor" or can be accessed with the EMCP display. Use the following to navigate to the EMCP sub menu.

1. Press the "MAIN MENU" button on the EMCP.
2. Use the arrow keys to select "CONFIGURE". Press the "OK" key.

3. Use the arrow keys to select "ALL SET POINTS". Press the "OK" key.

4. Use the arrow keys to select "GEN AC MONITOR". Press the "OK" key.

Note: All manual voltage biasing is removed and reset to zero when the engine is stopped. Manual voltage bias levels are not carried over to the next startup after an engine shutdown.

Digital Inputs

Remote voltage adjustment toggle switches may be used to fine-tune the generator output voltage. The process is accomplished by programming an EMCP digital input for raise voltage and lower voltage. Each activation of the digital input raises or lowers the voltage by 0.2% of rated. When the digital input is activated continuously, the voltage bias is raised or lowered by 0.2% of rated approximately every 400ms.

Refer to Systems Operation, Test and Adjust, Troubleshooting, UENR1209, "Digital Input Programming" for further details on programming digital inputs on EMCP 4 controllers.

Voltage / HZ Control (EMCP Display)

The EMCP display can be used to fine-tune the generator output voltage. Each press of the voltage raise or voltage lower key raises or lowers the voltage by 0.2% of rated voltage. When the voltage raise or voltage lower key is pressed and held continuously, the voltage bias is raised or lowered by 0.2% of rated approximately every 400ms.

The "Voltage / Hz" screen can be found on the EMCP display. Use the following steps to navigate to the "Voltage / Hz" screen.

1. Press the "MAIN MENU" button on the EMCP.

2. Use the arrow keys to select "CONTROL". Press the "OK" key.

3. Use the arrow keys to select "VOLTAGE / Hz CONTROL". Press the "OK" key.

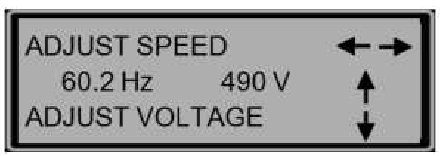

Illustration 13 g03488436

EMCP 4.1 and EMCP 4.2 Volts/Hz control screen

SCADA MODBUS (EMCP 4.2 ONLY)

EMCP 4.2 SCADA data link also provides a means for adjusting voltage remotely. EMCP 4.2 Modbus registers are defined for reading and controlling the target output voltage of the generator. Refer to Application and Installation Guide, LEBE0010, "EMCP 4 SCADA Data Links" for more details on EMCP 4.2 dedicated SCADA data links.

Analog Inputs

Analog voltage adjustment is done via a programmable analog input to the EMCP configured for generator voltage control. Analog inputs provide a voltage control interface for external potentiometers or external control systems, such as switch gear. The following analog input types can be configured on an EMCP 4.1 or EMCP 4.2 to adjust the generator voltage set point.

- Resistive (a range of input maps are available depending on the potentiometer size)
- Voltage 0 to 5 V, 1 to 5 V, 0.5 to 4.5 V

The generator voltage control analog input signal is interpreted and converted by the EMCP into a voltage bias percentage of (nominal) rated voltage. For example, consider an analog input configured for a signal range of -10 V to +10 V and a data range of -10% to 10%. When the analog input signal value equals +2 V, a voltage bias percentage of +2.0 % of rated will be applied to the generator output voltage.

Refer to Systems Operation, Test and Adjust, Troubleshooting, UENR1209, "Analog Input Programming" for further details on programming analog inputs on EMCP 4 controllers.

IVR Display Screens

The integrated voltage regulator overview and voltage bias overview can be accessed directly through the EMCP. Use the following steps to navigate to the IVR overview and voltage bias overview with the EMCP.

1. Press the "MAIN MENU" button on the EMCP.

2. Use the arrow keys to select "VIEW". Press the "OK" key.
3. Use the arrow keys to select "IVR OVERVIEW". Press the "OK" key.
4. Use the arrow keys to access the "VOLTAGE BIAS OVERVIEW" screen.

The IVR overview screen provides IVR operating mode, target voltage, excitation command, and voltage compensation information. The voltage bias overview screen provides information on all active voltage biasing on the generator system.

Note: Excitation command percentage is not a measurement of excitation current, but rather a commanded excitation operating point. A non-zero excitation command percentage may be displayed on the screen during a fault scenario even though zero excitation current output is present.

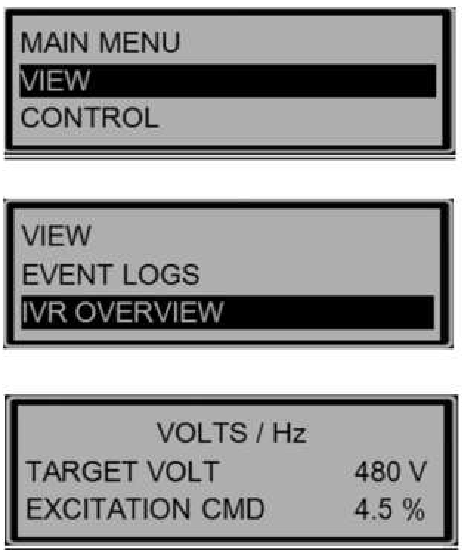

Illustration 14 g03488443

IVR overview

The IVR operating modes for the EMCP 4.1 and the EMCP 4.2 are described below.

VOLTS/Hz - Voltage is regulated according to the under frequency roll off (Volts/Hz) profile.

V/Hz + DROOP - Voltage is regulated according to the under frequency roll off (Volts/Hz) profile.

V/Hz + LINE LOSS - Voltage is regulated according to the under frequency roll off (Volts/Hz) profile in addition to any line loss (IR) compensation bias.

SOFT START - Voltage is ramped during startup from 0 voltage to rated voltage according to the starting profile.

IVR LOCKED OUT - Voltage regulation is locked out and the excitation command is disabled (forced to 0 %). Generator output voltage will not build beyond residual voltage.

PF CONTROL - Voltage regulation is performed in order to control power factor to a desired level (EMCP 4.2 only).

STOPPING - Voltage is ramped down in proportion to engine speed during shutdown.

The voltage bias overview screen displays manual, analog, load compensation, and total voltage bias percentages applied to the generator output.

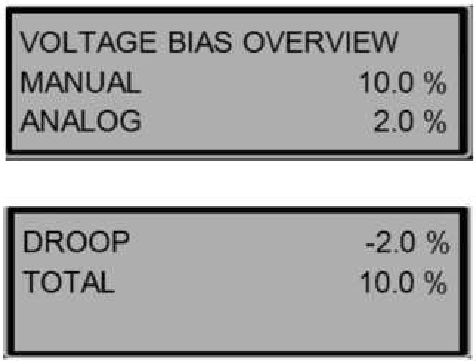

Illustration 15 g03488457

Voltage bias overview

The voltage biasing information is described below.

MANUAL - Summation of any voltage bias applied via programmable digital input, Voltage / Hz Control screen on the EMCP display or SCADA (Modbus) voltage bias.

ANALOG - Any voltage bias applied via a programmable analog input.

DROOP or LINE LOSS - Any voltage bias applied as a result of reactive droop or line loss load compensation, for EMCP 4.2 only.

TOTAL - Total voltage bias applied to the generator system. The total percentage bias is the summation of any manual, analog, or compensation (droop or line loss) biasing in the system.

Note: The total percentage bias that can be applied to the generator system is limited by the maximum generator voltage output bias percentage set point. The set point is configured with the EMCP.