

Specifications Systems Operation Troubleshooting Testing and Adjusting

VR6-B Voltage Regulator

CCB1-Up (Generator Set)
9EP1-Up (Generator Set)
8NS1-Up (Generator Set)
9ES1-Up (Generator Set)
BCW1-Up (Generator Set)
LRW1-Up (Generator Set)
CBX1-Up (Generator Set)
LRX1-Up (Generator Set)
LRY1-Up (Generator Set)
4BZ1-Up (Generator Set)
8AZ1-Up (Generator Set)

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 lubrication, maintenance or repair on this product, until you have read and understood the operation, lubrication, maintenance and repair information.

Safety precautions and warnings are provided in this manual 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. Caterpillar dealers have the most current information available.



When replacement parts are required for this product Caterpillar recommends using Caterpillar 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.

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Testing and Adjusting

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Specifications Section

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Electrical

SMCS Code: 4467

Table 1

Specifications		
Regulator Characteristics	Regulation	Less than $\pm 1\%$ of voltage setpoint from no load to full load
	Response time	Maximum of 4 milliseconds
	Voltage drift	Less than $\pm 1\%$ steady state
	Temperature drift	Less than $\pm 1\%$ for any $40\text{ }^{\circ}\text{C}$ ($104.0\text{ }^{\circ}\text{F}$) change over the operating temperature range
	Sensing voltage	True RMS three-phase sensing is standard. Single phase sensing is available. The variable sensing range is 180 to 264 VAC for 60 Hz. The variable sensing range is 150 to 220 VAC for 50 Hz.
	Stability	The regulator responds to the main component of the sensed voltage and remains stable for total harmonic distortion of the generator output voltage waveform, up to 20%.
Regulation	Volts/Hz characteristic	The characteristic is linearly proportional to frequency. 1 V/Hz characteristic can be selected by placing the jumper between terminals 6A and 8. 2 V/Hz characteristic can be selected by removing the jumper between terminals 6A and 8. These characteristics provide matched engine/generator performance for improved block load performance.
	Knee frequency	The knee frequency is adjustable from 45 Hz to 65 Hz. Refer to the Testing and Adjusting, "Knee Frequency - Adjust" for more information.
Adjustment Characteristics	Voltage adjust range	+10% to -25% of regulator sensing voltage
	Reactive droop adjustment	Adjustable from 0 to 10% at rated input current and 0.8 power factor. Either a 1 Ampere current transformer (CT) or a 5 Amperes CT can be used with a VA<10.
	External Voltage Adjust Rheostat	10 kOhm, 2 Watts
Protection	For Overexcitation	The protection shuts off the generator output when excitation current exceeds normal operating currents for 30 seconds at 90 VDC $\pm 5\%$.
Power Characteristics	Power dissipation	Maximum 50 watts at rated output
	Input	180 to 264 VAC, single-phase or three-phase on 50 Hz or 60 Hz applications 90 to 120 VAC, three-phase, on 100 Hz to 240 Hz permanent magnet (PMG) applications. Maximum of 3125 VA. 240 VAC, single-phase, on 100 Hz to 240 Hz permanent magnet (PMG) applications. Maximum of 3125 VA.
	Output (with a 240 VAC Input)	12 Amperes DC at 65 VDC maximum continuous 25 Amperes DC at 125 VDC forcing for 10 seconds
Temperature Range	Ambient operating	$-40\text{ }^{\circ}\text{C}$ ($-40\text{ }^{\circ}\text{F}$) to $+70\text{ }^{\circ}\text{C}$ ($+158\text{ }^{\circ}\text{F}$).
	Storage	$-40\text{ }^{\circ}\text{C}$ ($-40\text{ }^{\circ}\text{F}$) to $+70\text{ }^{\circ}\text{C}$ ($+158\text{ }^{\circ}\text{F}$).
Physical Specifications	Weight	1.1 kg (2.4 lb).
	Shock	Withstands up to 20 g's.
	Vibration	Withstands 0.5 g's at frequencies between 18 and 2000 Hz in three mutually perpendicular planes.

(continued)

(Table 1, contd)

Specifications		
Conformity	Electromagnetic compatibility	Meets 89/336/EEC Electromagnetic Compatibility Directive. Contains internal EMI suppression filter.
	UL	UL 508 certified
	CSA	Certified per Standard CAN/CSA-C22.2 No. 14-95, CSA File No. LR 23131
	CE	Conforms to the following standards: Radiated Emissions EN50081-2 Radiated Immunity (electric field) EN61000-4-3 (10 V/m) Radiated Immunity (conducted) EN61000-4-6 (10 VRMS) Conducted Emissions EN50081-2 (EN55011, Class A) ESD Immunity EN50082-2 (4 KV contact, 8 KV air) EFT Immunity EN50082-2 (2 KV coupling clamp) Magnetic Immunity EN50082-2 (30ARMS, 50 Hz) Safety EN61010-1

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Dimensions

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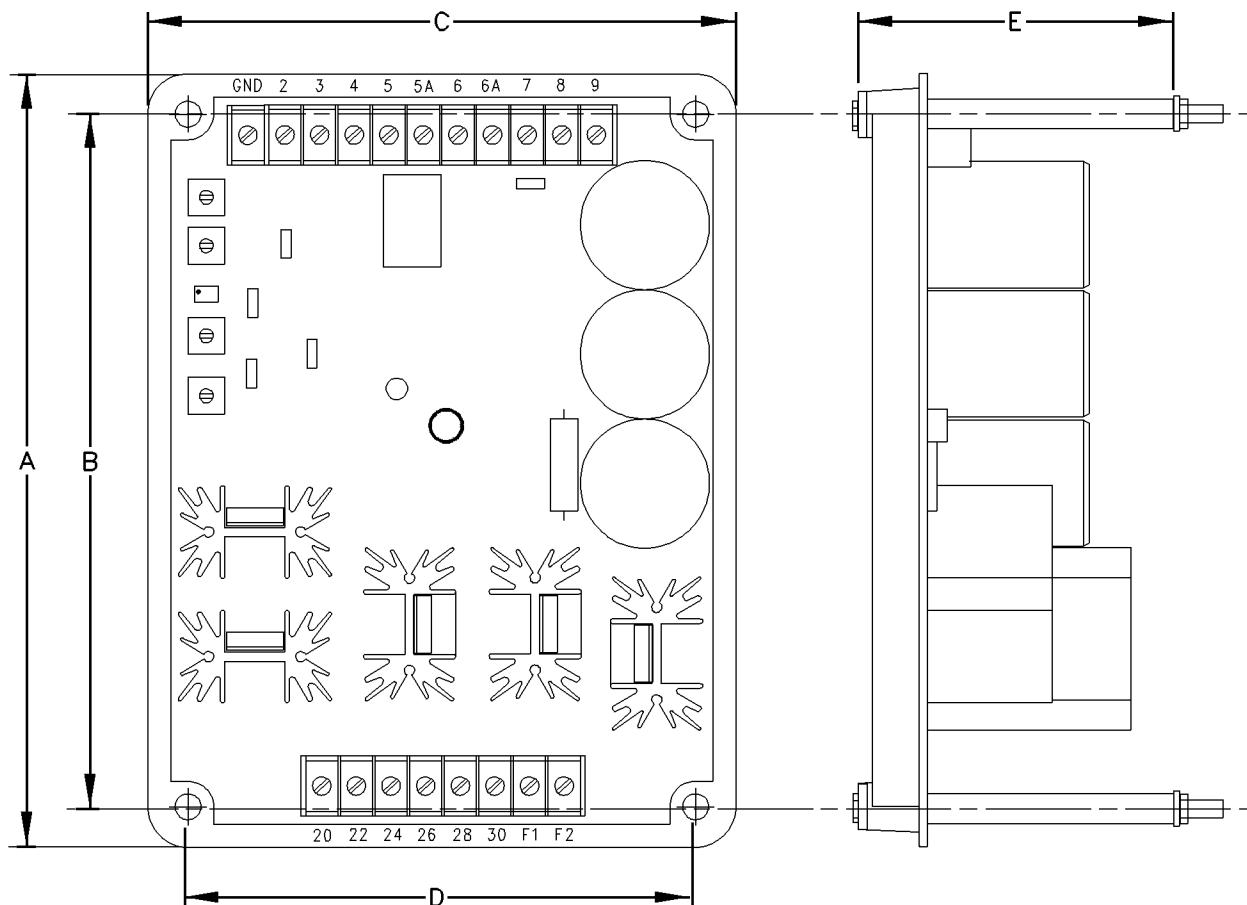


Illustration 1

Dimensions of the VR6 Voltage Regulator

(A) 212.75 mm (8.376 inch)
(B) 190.50 mm (7.500 inch)

(C) 161.95 mm (6.376 inch)
(D) 139.70 mm (5.500 inch)

(E) 87.4 mm (3.441 inch)

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Description of Terminals

Note: When the voltage regulator is used with a permanent magnet generator, ensure that the jumpers are removed between the following terminals: 20 - 28, 22 - 30, and 24 - 26. Ensure that the jumper is installed between terminals 28 and "GND".

Table 2

Number of the Terminal	Description
GND	Ground
2	Auxiliary input from VAR/PF Controller
3	Auxiliary input from VAR/PF Controller
4	This terminal is used in conjunction with terminal 7 for selecting internal voltage adjustment. Place the jumper between terminals 4 and 7 for using internal voltage adjustment. Remote voltage adjustment requires a remote voltage adjust rheostat between terminals 6A and 7.
5	1 Ampere Current Transformer (CT)
5A	5 Ampere Current Transformer (CT)
6	Common for the Current Transformer
6A	Common connection for selectable features
7	This terminal is used in conjunction with terminal 4 for selecting external voltage adjustment. Place the jumper between terminals 4 and 7 for using internal voltage adjustment. Remote voltage adjustment requires a remote voltage adjust rheostat between terminals 6A and 7.
8	Connect terminal 8 to terminal 6A in order to select a 1 V/Hz underfrequency slope.
9	Connect terminal 9 to terminal 6A in order to select three-phase sensing.
20	Sensing input on phase C
22	Sensing input on phase A
24	Sensing input on phase B
26	Three-phase power input
28	Single-phase power input or three-phase power input
30	Single-phase power input or three-phase power input
F1	Positive field lead
F2	Negative field lead

Internal Adjustments

Table 3

Adjustment	Description
"DRP"	Adjustment of the Voltage Droop
"FAC CAL"	This is the factory calibration of the voltage adjustment range. Adjustment by the customer is not required.
"VLT ADJ"	Voltage Adjustment
"UF"	Underfrequency Knee Adjustment
"STB"	Stability Adjustment

Systems Operation Section

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General Information

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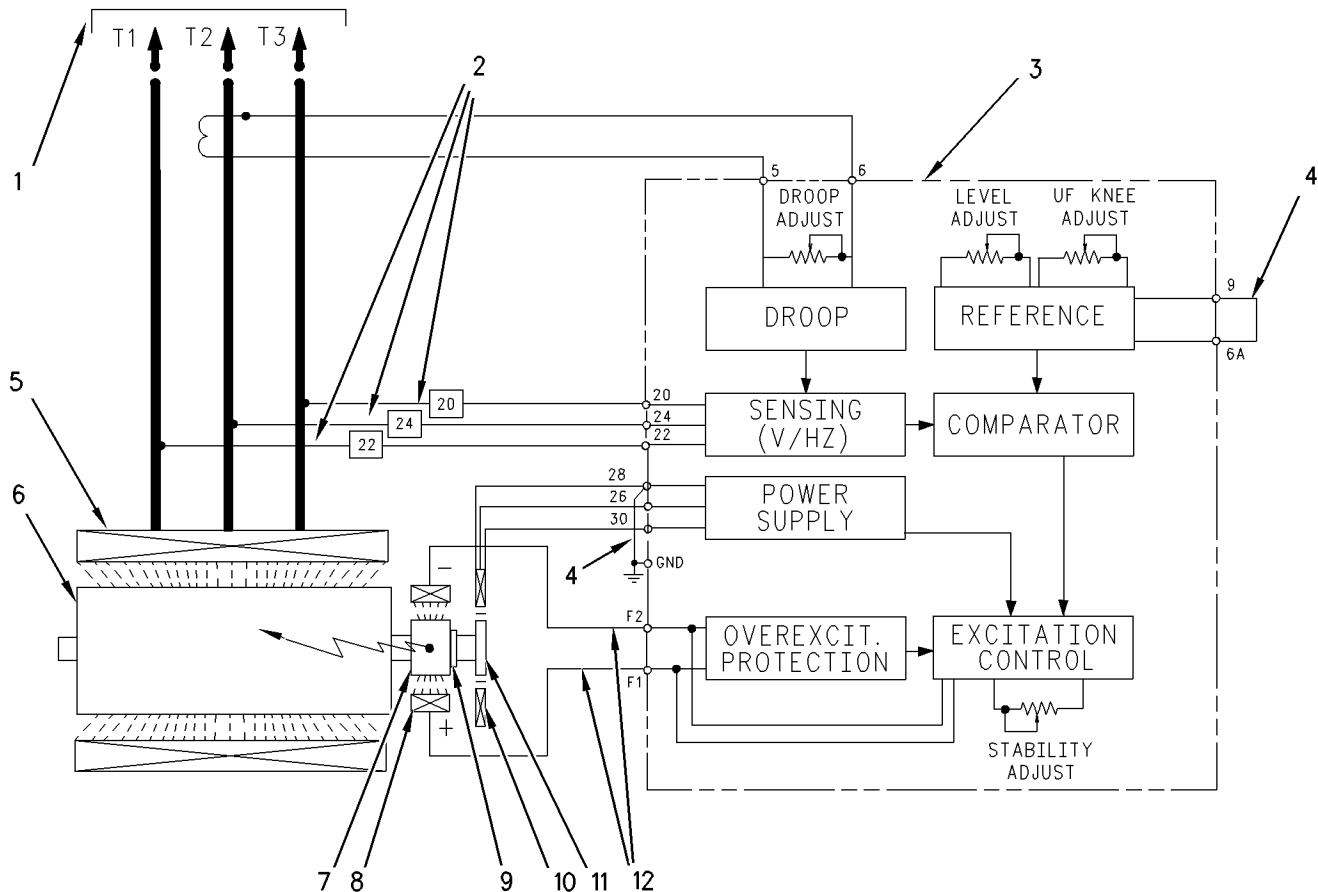


Illustration 2
Typical Block Diagram of SR4B PMPE Generator with VR6 Voltage Regulator

- | | | |
|--|----------------------------|--|
| (1) Generator lines (output voltage) | (5) Main stator | (10) Permanent magnet stator |
| (2) Generator lines (sensing voltage and AC power) | (6) Main rotor | (11) Permanent magnet |
| (3) VR6 voltage regulator | (7) Exciter rotor | (12) Generator lines (DC excitation voltage) |
| (4) Jumper | (8) Exciter stator | |
| | (9) Three-phase rectifiers | |

This manual covers the VR6 voltage regulator which is used on 4/6 and 10/12 lead self-excited generators and permanent magnet generators. The VR6 regulator is typically located in the generator terminal box. The regulator may also be located in the marshalling box.

The VR6 voltage regulator (3) keeps the generator output voltage constant with changing loads. The voltage regulator controls the DC voltage and current that is supplied to the exciter stator (8).

The regulator senses the generator voltage through the generator sensing leads (2). The sensing leads are connected to the following terminals: 20, 22, and 24. The sensed voltage is then compared to a reference voltage. The reference voltage value is set by the voltage adjust rheostat on the regulator. The reference voltage value may also be set by an external voltage adjust rheostat.

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When the regulator senses a decrease in output voltage due to an increase in load, the regulator will increase the DC voltage on wires F1 and F2 (12). This increases the magnetic field in the exciter stator (8). The increased magnetic field in the exciter stator increases the AC voltage and current, which is induced in the exciter rotor (7). This increased three-phase AC voltage from the exciter rotor causes more AC current to flow. The three-phase AC voltage is then rectified to DCV by the three-phase full wave rectifier (9). The increased DC output from the bridge rectifier is carried to the main rotor (6) by conductors, which are routed through a passage in the generator shaft. Increased current through the main rotor increases the magnetic field of the generator. The increased magnetic field induces a larger AC voltage into the main stator (5). Therefore, the three-phase AC voltage (1) increases until the voltage regulator no longer senses a decreased output voltage.

When the voltage regulator senses an increase in output voltage due to a decrease in load, the regulator will decrease the DC voltage to the exciter. A decrease in generator voltage will occur due to similar responses, as described above.

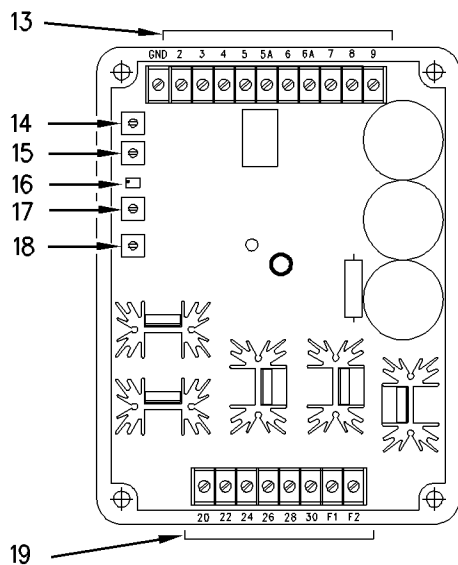


Illustration 3

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The VR6 Voltage Regulator

- (13) Terminal strip for attachments
- (14) Droop adjustment
- (15) Factory calibration of the voltage adjustment range
- (16) Voltage adjustment
- (17) Knee frequency adjustment
- (18) Stability adjustment
- (19) Terminal strip for sensing and power

There are five adjustments on the VR6 voltage regulator:

- Droop adjustment (14)

- Factory calibration of the voltage adjustment range (15)
- Voltage adjustment (16)
- Knee frequency adjustment (17)
- Stability adjustment (18)

The factory calibration of the voltage adjustment range (15) should not be adjusted by the user. For the other adjustments, refer to the Testing and Adjusting Section within this manual.

The excitation circuit can be disabled by removing the power from the VR6.

The VR6 voltage regulator can operate in one of the following modes:

- three-phase sensing
- single-phase sensing

For three-phase sensing, place the jumper between terminals 6A and 9. Sensing leads (2) should be connected to terminals 20, 22 and 24 for three-phase sensing.

For single-phase sensing, the jumper should be removed. Sensing leads (2) should be connected to terminals 20 and 22 for single-phase sensing.

Note: The VR6 voltage regulators are sensitive to A-B-C phase rotation. Connections should be "T1" to 22, "T2" to 24 and "T3" to 20. Incorrect connections can result in high circulating currents during parallel operation.

Note: Rated sensing voltage for the VR6 is 240 VAC for 60 Hz systems and 200 VAC for 50 Hz systems. The sensing voltage can be adjusted +10% or -25%. When the generator has a different operating voltage, the following methods can be used in order to step down the output voltage to the regulator voltage: generator taps, connection of the sensing lead to midpoint generator connections, and power transformers (PT).

On PMPE generators, leads from permanent magnet (11) are connected to terminals 26, 28 and 30. These leads provide power to the regulator. Terminals 26, 28, and 30 are part of the terminal strip for sensing and power (19). On PMPE generators, there is a jumper between terminals 28 and "GND".

On self-excited generators, terminal 20 is jumpered to terminal 28. Terminal 22 is jumpered to terminal 30. Terminal 24 is jumpered to terminal 26. The sensing leads provide the power to the regulator. Terminals 20, 22, 28, and 30 are part of the terminal strip for sensing and power (19).

The terminal strip for attachments (13) accommodates the following optional connections:

- KVAR/PF controller
- External voltage adjust rheostat
- Droop current transformer (CT)
- Selection of the underfrequency slope
- Selection of the sensing phase

The KVAR/PF controller is connected at terminals 2 and 3. Terminals 2 and 3 should be jumpered if the KVAR/PF controller is not used.

If an external voltage adjust rheostat is used, there should be no jumper between terminals 4 and 7. An external voltage adjust rheostat is rated at 10 kOhm and 2 Watt. An external voltage adjust rheostat is connected between terminals 6A and 7. If the internal voltage adjust rheostat is used, place the jumper between terminals 4 and 7.

If a 1 Ampere droop current transformer (CT) is used, the CT secondary should be connected between terminals 5 and 6. If a 5 Ampere droop current transformer (CT) is used, the CT secondary should be connected between terminals 5A and 6.

In order to create a 1 V/Hz underfrequency slope, place the jumper between terminals 6A and 8. Leave these terminals unconnected for a 2 V/Hz underfrequency slope.

Connect terminal 6A to terminal 9 for three-phase sensing. Do not connect these terminals for single-phase sensing.

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Features

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Sensing Voltage

The sensing voltage is the three-phase AC voltage at terminals 20, 22 and 24. The ratio of the sensing voltage to the generator voltage depends on the following conditions:

- The connection point of the sensing leads to the generator leads

- The use of power transformers (PT)

Reference Voltage

The reference voltage is set by the voltage adjust rheostat or by an external voltage adjust rheostat. The reference voltage is the desired voltage on the output of the generator at rated frequency.

Knee Frequency

The knee frequency is adjusted by turning the knee frequency adjustment. Without setting the knee frequency, generator voltage would follow generator frequency proportionally. If the generator frequency is above the adjusted knee frequency, the regulator maintains the generator voltage at the reference voltage.

V/Hz Slope

If the generator frequency drops below rated frequency, the regulator will regulate the voltage to a lower reference voltage. This helps the engine to recover quickly during block loading. The reference voltage is proportional to the generator frequency. There are two slopes that can be selected: 1 V/Hz and 2 V/Hz. The jumper between terminals 6A and 8 creates a 1 V/Hz slope. In this case, a 1 percent change in frequency below the knee frequency adjustment will produce a 1 percent lower reference voltage. In order to select a 2 V/Hz slope, remove the jumper between terminals 6A and 8. In this case, a 1 percent change in frequency below the knee frequency adjustment will produce a 2 percent lower reference voltage.

Droop

When a generator set operates in parallel with another generator set, it is necessary for the output voltages to match in order to prevent circulating currents. Depending on the power factor, the droop raises the reference voltage or the droop lowers the reference voltage. This slight raising of the output voltage or lowering of the output voltage results in the reactive load sharing between gensets that are operating in parallel.

Stability

Because of a time delay from the moment when the regulator senses a change in voltage to the moment when the generator voltage is increased or decreased, the generator voltage can become unstable (or hunt). The time delay varies. This delay depends on time constants for the exciter and the generator. The stability circuit slows the response of the regulator in order to stabilize the voltage. The stability adjustment is used in order to ensure that the regulator responds as quickly as possible, while still keeping the voltage stable.

Overexcitation Protection

The overexcitation protection will shut the regulator off at $90 \text{ VDC} \pm 5\%$. The overexcitation protection takes the output to zero in greater than 30 seconds. The output can be 125 VDC for greater than 10 seconds.

The generator set must be shut down in order for the regulator to reset.

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Remote Voltage Control

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The generator output voltage level can be controlled from a remote location. In order to control the voltage from a remote location, perform the following steps:

1. Connect a 10 kOhm, 2 Watt potentiometer between terminals 6A and 7 on the voltage regulator.
2. Remove the jumper between terminals 4 and 7.

For an acceptable voltage control, the remote mounted potentiometer must be 10 kOhm $\pm 5\%$ with three turns or more and a dielectric strength of 1000 VAC minimum. The terminals of the remote mounted potentiometer are fragile. The wiring, which is connected to remote mounted potentiometer, should not have a diameter larger than 18 gauge. A wire with a larger diameter is not recommended. The wire should be 600 Volt class with 90°C (194.0°F) insulation. When the remote potentiometer is mounted at a long distance (up to 15.24 m (50 ft)) from generator set, a shielded cable may be necessary in order to isolate the signal from noise.

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Manual Voltage Control

SMCS Code: 4467

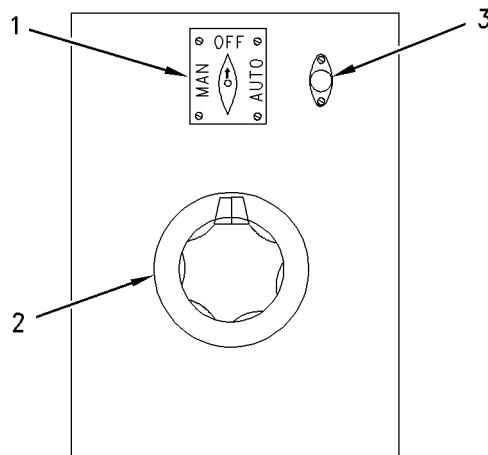


Illustration 4

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Manual Voltage Control Panel (Option)

- (1) Switch (OFF, AUTO, and MAN positions)
(2) Voltage control rheostat
(3) Fuse

The manual voltage control is an option. The manual voltage control can be used to control the generator voltage when there is a failure in the generator regulator assembly. The manual voltage control will manually control the current flow to the exciter stator. The manual voltage control panel has a switch (1) and a voltage control rheostat (2) for the manual operating mode. The switch (1) is used to make the selection between the following positions: AUTO, MAN, and OFF.

In the AUTO position, the VR6 voltage regulator controls the generator voltage.

In the OFF position, the voltage will go to zero.

In the MAN position, the generator voltage is controlled by voltage control rheostat (2).

Note: The manual voltage control panel must not be installed in a location that is subject to engine vibrations or to outside weather.

Note: When the manual voltage control is operating in the manual mode, it is not necessary for the VR6 regulator to be connected to the generator. However, the manual control must remain connected to the sensing lines 20 and 24 of the self-excited generator. The manual control must remain connected to the sensing lines 11 and 13 of the permanent magnet generator. Refer to the Testing and Adjusting, "Wiring Diagrams" for proper connections.

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Voltage Droop Control

SMCS Code: 4467

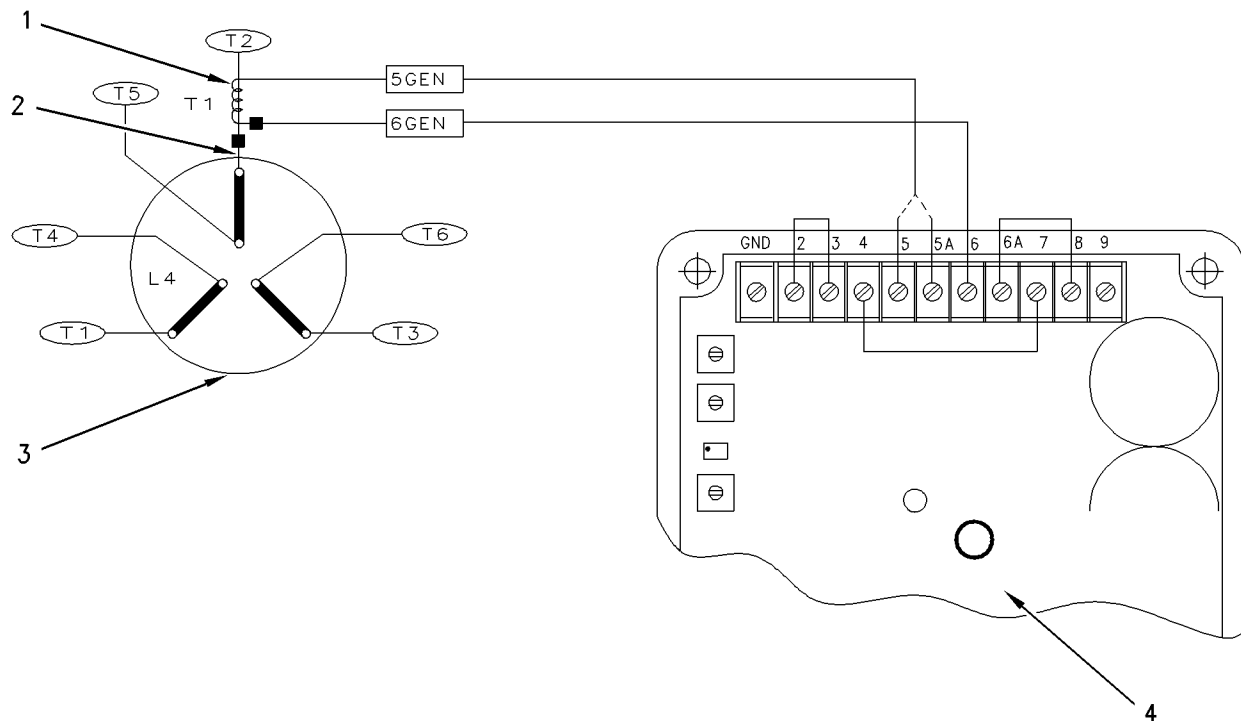


Illustration 5

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Voltage Droop Control (Typical Example)

- (1) Voltage droop transformer T1
- (2) Lead
- (3) Main stator
- (4) VR6 voltage regulator

There are two primary requirements for parallel operation:

- Genset engines should share the real power requirements (kW) of the electrical load.
- Generators should share the reactive power requirements (kVAR) of the electrical load.

The engine governors will control sharing of the real power requirements (kW). The voltage regulator will control sharing of the reactive power requirements (KVAR) of the total system load. Occasionally, one generator output voltage is slightly higher than the other generators. This will supply lagging reactive current flow to the other generators that are connected in the group. The lagging reactive current flow will circulate between generators. This could possibly cause an ampere overloading.

In order to share reactive loads, an individual generator output voltage droops in proportion to the lagging reactive current flow. The reactive current flow is measured with a current transformer (CT). As reactive generator output current increases, the regulator will cause the output voltage to lower proportionally. If the measured reactive current is leading, the output voltage will rise. In either case, this action will tend to reduce the reactive current for better sharing of KVAR with other units.

The following items are required in order to provide the voltage droop function:

- 1 Ampere CT or 5 Ampere CT (1)
- wiring harness

The droop transformer senses load current in lead "T2" (2) of 4/6 lead generators or in lead "T8" of 10/12 lead generators. The droop adjustment adjusts the droop voltage. The transformer may be standard on some generators or an attachment on other generators. The wiring harness may be standard on some generators or an attachment on other generators.

Note: At full rated current (1 Ampere or 5 Ampere), the droop adjustment is up to 10%. As the CT current decreases, the amount of droop adjustment decreases proportionally. It is important to size the CT correctly for the load which will be carried by the generator.

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Cross Current Compensation

SMCS Code: 4467

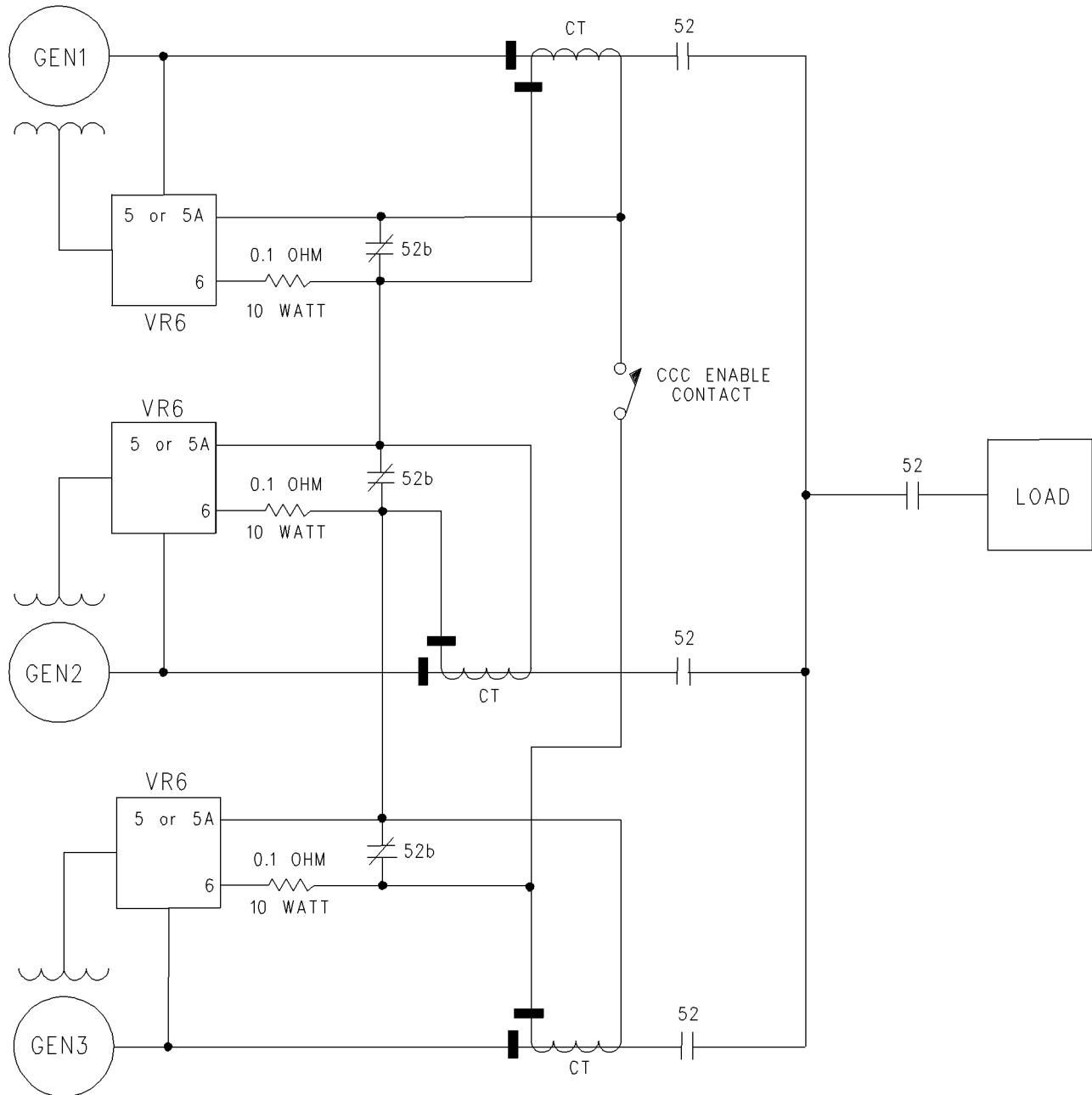


Illustration 6

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Cross current compensation (CCC) is often used to minimize circulating current flow between the generators which are connected in parallel. All generators contribute toward establishing the same output voltage to the load. The operation is similar to the reactive voltage droop mode, except that the secondary circuits of the current transformers of all generators are interconnected in series. Each generator is initially adjusted in order to provide the same output voltage.

When all generators share the same current according to the current transformer (CT) ratio, there will be no significant voltage output on the secondary winding of any current transformer (CT) for the generators. A net difference voltage signal will be created on the burden resistor for that current transformer (CT) if one of the generators carries more current. If the current that is being carried by the generator is lagging relative to the other generators or leading relative to the other generators, a net difference voltage signal will be created on the burden resistor for that current transformer (CT). If that generator is supplying more reactive current than other generators, the polarity and the magnitude of the signal that is returned to the voltage regulator will cause a slight decrease in the voltage that is generated. This will reduce the amount of reactive current. Less reactive current will cause the generator voltage to rise. The voltage that is generated and the output current of each generator is trimmed toward an operating point. All generators will share the same load current at that operating point. This current will be in proportion to the CT ratio. There will be little current or no circulating current between generators.

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Series Boost

SMCS Code: 4467

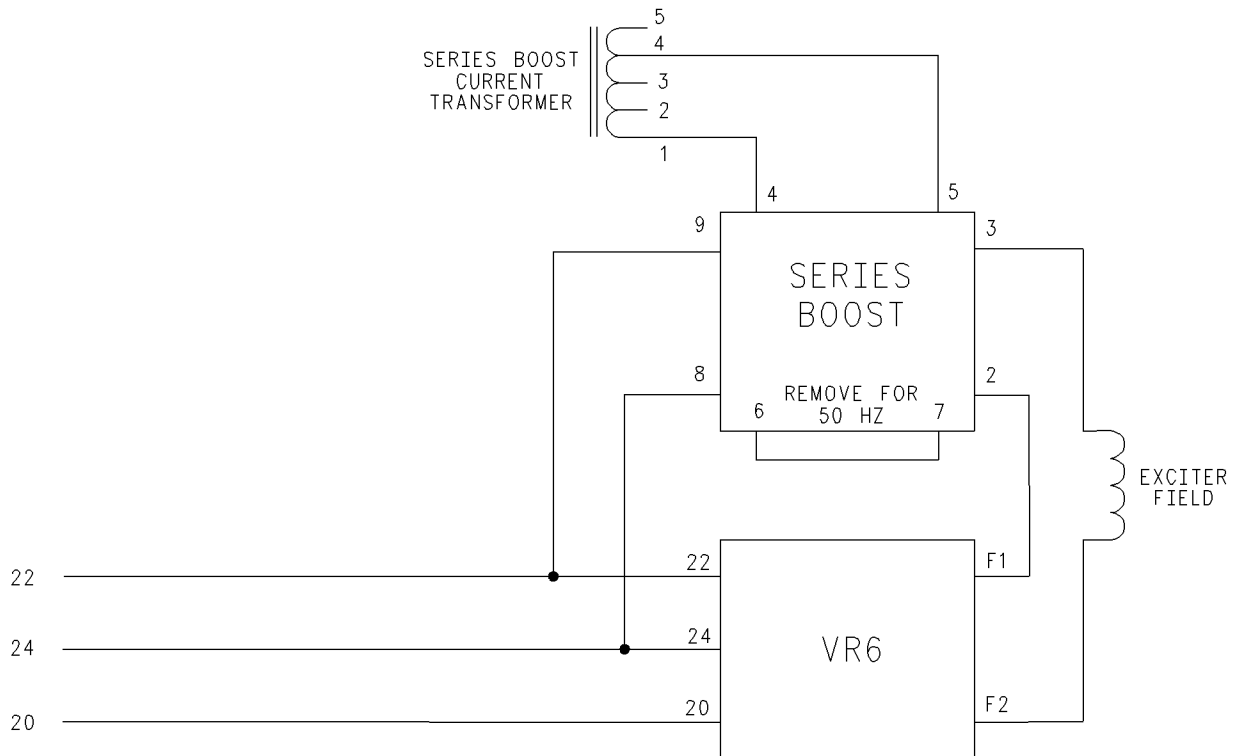


Illustration 7

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Typical Example of a Series Boost Module

A series boost module is an option. Series boost allows the self-excited generators to stay on the line (approximately 10 seconds) when there is a short in the generating circuits or in the load circuits. Therefore, circuit breakers in the load distribution system get a chance to trip in sequence. When circuit breakers trip in sequence, there is less chance for a loss of power to all of the electrical system.

Series boost consists of the series boost module and current transformers (CT).

Voltage sensing and power are applied to the series boost module from the voltage sensing terminals 20, 22, and 24 of the regulator.

When the sensed voltage is within normal limits, an electrical signal is sent to the gate of a triac which is located in the series boost module. This triac short circuits the current transformer. This prevents any series boost during normal operation.

If there is a short circuit in the system that causes the voltage at the regulator sensing terminals to drop to a low value, the control signal to the gate of the triac will be turned off. Current from the current transformer will be rectified. This current will be applied directly to the exciter stator. This field current will be enough to give at least three times full load current into a short circuit. After approximately ten seconds, a timer within the series boost module will again cause a control signal to be applied to the gate of the triac. The triac will short circuit the current transformer. Current flow to the exciter stator will be zero, until the short circuit is corrected.

Note: A PM generator will provide a similar short circuit current characteristic.

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Power Factor Regulation and KVAR Regulation

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When the generator is connected in parallel with an infinite bus (utility), the voltage of the generator is controlled by the infinite bus. The voltage of the generator will change as the infinite bus voltage changes. It is not possible to control the system voltage when the generator is connected to an infinite bus. In this instance, it is necessary for the voltage regulator to regulate the reactive power output which is supplied by the generator. There are two methods for regulating the reactive power output.

- Power Factor Regulation
- KVAR Regulation

Power factor (PF) determines the relationship between true power and apparent power. The true power is also known as an active power. The apparent power is also called a reactive power. The true power (kW) is the power that is produced by the engine. The true power determines the amount of power that is available for the load to do work. The apparent power (kVA) is the total power that is produced by the generator. Power factor can be calculated by using the following formula.

$$PF = KW / KVA,$$

KW – kilowatts

KVAR – Kilo-Volt-Ampere

KVAR stands for Kilo-Volt-Ampere-Reactive, which is the unit of measurement for reactive power.

Note: The generator does NOT control power factor. Power factor is determined by the load.

The voltage regulator can be used with an external device (KVAR/PF controller) in order to control one of the output parameters of the generator such as KVAR or PF. When the voltage regulator is in the power factor mode, the generator produces a constant power factor regardless of the real power output of the generator. In this case, the reactive current will change when the real power output of the generator changes. A 5 Amperes current transformer is necessary for any mode of operation to work.

When the voltage regulator is in the KVAR operating mode, the generator produces a constant value of reactive power (KVAR) regardless of the real power output of the generator. In this case, the power factor of the generator will change when the real power output of the generator changes. A 5 Amperes current transformer is necessary for any mode of operation to work.

Troubleshooting Section

Introduction

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General Information

SMCS Code: 4467

WARNING

Personal injury or death can result from high voltage.

When power generation equipment must be in operation to make tests and/or adjustments, high voltage and current are present.

Improper test equipment can fail and present a high voltage shock hazard to its user.

Make sure the testing equipment is designed for and correctly operated for high voltage and current tests being made.

When servicing or repairing electric power generation equipment:

- Make sure the unit is off-line (disconnected from utility and/or other generators power service) , and either locked out or tagged DO NOT OPERATE.
- Remove all fuses.
- Make sure the generator engine is stopped.
- Make sure all batteries are disconnected.
- Make sure all capacitors are discharged.

Failure to do so could result in personal injury or death. Make sure residual voltage in the rotor, stator and the generator is discharged.

WARNING

When the engine-generator, or any source to which the engine-generator is synchronized to, is operating, voltages up to 600V are present in the control panel.

Do not short these terminal with line voltage to ground with any part of the body or any conductive material. Loss of life or injury could result from electrical shock or injury from molten metal.

WARNING

Do not connect generator to a utility electrical distribution system unless it is isolated from the system. Electrical feedback into the distribution system can occur and could cause personal injury or death.

Open and secure main distribution system switch, or if the connection is permanent, install a double throw transfer switch to prevent electrical feedback. Some generators are specifically approved by a utility to run in parallel with the distribution system and isolation may not be required. Always check with your utility as to the applicable circumstances.

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Service Tools

SMCS Code: 0785

Table 4

Tools Needed		
Part Number	Description	Amount
6V - 7070	Digital Multimeter	1
9U - 7330	Multimeter (Option) for frequency and duty cycle measurements	1
146 - 4080	Digital Multimeter (RS-232)	1
8T - 0900	AC/DC Clamp-On Ammeter	1

Symptom Procedures

i01533715

Low Voltage

SMCS Code: 4467-035

Test Step 1. PERFORM THE INITIAL CHECK

- A.** Turn off the genset.
- B.** Check for loose terminals.
- C.** Check for corroded terminals.
- D.** Check for proper connections between the voltage regulator and the generator.

Expected Result:

All initial checks show no problems.

Results:

- **YES** – There are no loose terminals or corroded terminals. The connections are correct. Proceed to test step 2.
- **NO** – One or more of initial checks shows a problem.

Repair: Tighten loose terminals. Replace corroded terminals. If the connections are incorrect, connect the wiring properly according to the wiring diagram.

STOP.

Test Step 2. CHECK METERS

- A.** Start the genset.
- B.** Run the genset at no load.
- C.** Ensure the accuracy of the voltmeter. If you are reading the voltage from the control panel, check that voltage with a multimeter.

Note: Take the voltage readings on terminals 20, 22 and 24 at the regulator.

Expected Result:

Meters are accurate.

Results:

- **YES** – Meters' readings are accurate. Proceed to test step 3.
- **NO** – The meters' readings do not match.

Repair: Troubleshoot the metering circuit. Verify the schematic for the metering circuit. Verify whether the meters are connected correctly.

STOP.

Test Step 3. CHECK CONNECTIONS OF THE VOLTAGE ADJUST RHEOSTAT

- A.** Turn off the genset.
- B.** Check if there is the jumper between terminals 4 and 7.

Expected Result:

There is a jumper that is placed between terminals 4 and 7.

Results:

- **YES** – If a remote voltage adjust rheostat is NOT used, the jumper is properly installed. Proceed to test step 5.
- **YES** – If a remote voltage adjust rheostat is used, the jumper should be removed from terminals 4 and 7. In this case, the remote voltage adjust rheostat should be connected to terminals 6A and 7. Proceed to test step 4.
- **NO** – There is no jumper between terminals 4 and 7. The regulator may go into the overexcitation shutoff.

Repair: Verify the wiring schematics. Install the jumper in accordance with the wiring schematic.

STOP.

Test Step 4. CHECK THE RESISTANCE OF THE REMOTE VOLTAGE ADJUST RHEOSTAT

- A.** Disconnect the wires from terminals 6A and 7.
- B.** Measure the resistance of the remote voltage adjust rheostat while the rheostat is being adjusted over the operating range.

Expected Result:

The resistance should be between 0 kOhm and 10 ± 0.5 kOhm.

Results:

- **YES** – The resistance increases smoothly within the specified range. Proceed to test step 5.
- **NO** – The resistance is not within the specified value. The resistance jumps to a high value when the rheostat is adjusted.

Repair: Replace the remote voltage adjust rheostat.

STOP.

Test Step 5. CHECK THE SENSING CONNECTIONS

- A.** Check if there is a jumper between terminals 6A and 9.

Note: If you are using three-phase sensing, terminals 6A and 9 should be jumpered. If you are using single-phase sensing, this jumper should be removed.

Expected Result:

The jumper may be installed or the jumper may not be installed, based on the phase sensing selection.

Results:

- **YES** – The jumper is installed between terminals 6A and 9 for three-phase sensing. For single-phase sensing, the jumper is not installed between terminals 6A and 9. Proceed to test step 6.
- **NO** – The jumper is not installed between terminals 6A and 9 for three-phase sensing. The jumper is installed between terminals 6A and 9 for single-phase sensing.

Repair: Connect the jumper in accordance with the phase sensing selection.

STOP.

Test Step 6. CHECK CONNECTIONS FOR THE VAR/PF CONTROLLER

- A.** If the VAR/PF controller is used, verify whether there is no jumper between terminals 2 and 3.
- B.** If the VAR/PF controller is not used, place the jumper between terminals 2 and 3.

Expected Result:

The jumper has been placed accordingly.

Results:

- **YES** – The jumper is installed when the VAR/PF controller is not used. There is no jumper between terminals 2 and 3 when the VAR/PF controller is used. Proceed to test step 7.
- **NO** – The connections are not correct.

Repair: Place the jumper according to the wiring schematic.

STOP.

Test Step 7. CHECK CONNECTIONS FOR THE DROOP CURRENT TRANSFORMER (CT)

- A.** Stop the genset.

- B.** For a 1 Amperes CT, verify that the connections are to terminals 5 and 6.

- C.** For a 5 Amperes CT, verify that the connections are to terminals 5A and 6.

Note: For troubleshooting purposes, it is possible to operate the voltage regulator when the droop CT is disconnected. However, the droop CT secondary wires must be connected together.

- D.** Verify that the polarity connection of the droop CT is connected to terminal 6.

Expected Result:

The connections are correct.

Results:

- **YES** – The connections are correct. If a permanent magnet generator is used, proceed to test step 8. If a self-excited generator is used, proceed to test step 9.
- **NO** – The connections are not correct or the connections are impossible to verify.

Repair: Run an individual genset with a reactive load. If the voltage increases as the reactive load increases, the CT secondary is not connected properly. Stop the genset and reverse the CT lead connections.

STOP.

Test Step 8. CHECK THE VOLTAGE INPUTS ON A PERMANENT MAGNET GENERATOR

- A.** Check the voltages between the following terminals:

- 26 and 28
- 26 and 30
- 28 and 30

Expected Result:

The voltages are between 90 VAC and 120 VAC.

Results:

- **YES** – The voltage is between 90 VAC and 120 VAC. Proceed to test step 10.
- **NO** – The voltage is below 90 VAC.

Repair: There is no power which is coming from the permanent magnet generator to the voltage regulator. Correct the wiring according to schematics. Refer to the Testing and Adjusting, "Wiring Diagrams". If the measured voltages are balanced, but the voltages are between 20 VAC and 89 VAC, replace the PM exciter rotor.

STOP.

Test Step 9. CHECK THE VOLTAGE INPUTS ON A SELF-EXCITED GENERATOR

A. Check the voltages between the following terminals:

- 26 and 28
- 26 and 30
- 28 and 30

B. Measure the sensing voltages between the following terminals:

- 20 and 22
- 20 and 24
- 22 and 24

Expected Result:

The voltages match accordingly. The voltages are between 230 VAC and 250 VAC.

Results:

- **YES** – The voltage between terminals 26 and 28 matches the voltage between terminals 20 and 22. The voltage between terminals 26 and 30 matches the voltage between terminals 20 and 24. The voltage between terminals 28 and 30 matches the voltage between terminals 22 and 24. Proceed to test step 10.
- **NO** – The voltages do not match.

Repair: Check the jumpers between the following terminals: 20-28, 22-30, and 24-26. Place the appropriate jumpers according to the wiring diagram. Refer to the Testing and Adjusting, "Wiring Diagrams".

STOP.

Test Step 10. VERIFY THE SENSING VOLTAGE

A. Make sure that the generator set is off.

B. If the generator uses Power Transformers (PT) to step down the generator output voltage to the sensing voltage, check the sensing voltage range. The sensing voltage range should lie between the following limits:

- 180 V to 264 V on 60 Hz gensets
- 150 V to 220 V on 50 Hz gensets

C. Verify that sensing wires 20, 22, and 24 are connected correctly. Wire 20 should be connected to T3 phase. Wire 22 should be connected to T1 phase. Wire 24 should be connected to T2 phase.

Expected Result:

The sensing voltage is correct. The sensing wires are connected properly.

Results:

- **YES** – The sensing voltage is correct. The connections are correct. Proceed to test step 11.
- **NO** – The sensing voltage is NOT correct and/or the sensing wires are NOT connected properly.

Repair: Install a PT with correct ratios. Connect the sensing wires to correct terminals.

STOP.

Test Step 11. CHECK THE OUTPUT VOLTAGE

- A. Start the genset.
- B. Run the genset at no load.
- C. Read the output voltage from the control panel.

Expected Result:

The generator voltage is lower than the nominal voltage. The generator voltage is steady.

Results:

- **YES** – The generator voltage is still low but steady. Proceed to test step 12.
- **NO** – The generator voltage oscillates. The voltage goes very high. Then, the voltage goes very low.

Repair: Add the load to the genset. If the voltage still oscillates, turn off the genset in order to reset the voltage regulator. Start the genset again and run at no load. Add load to the generator. If the voltage oscillates again, go to the Troubleshooting, “Unstable Voltage”. If the voltage is no longer low, the problem has been fixed.

STOP.

Test Step 12. CHECK THE OPERATING FREQUENCY OF THE GENSET

- A. Measure the generator frequency. Use the frequency meter on the control panel. You may use a multimeter with the frequency measuring function.

Expected Result:

The generator frequency is below 5% of the rated frequency.

Results:

- **YES** – The frequency is below the rated frequency. In this case, the voltage will be lower than the rated voltage.

Repair: Adjust the generator frequency. Reset the knee frequency. Refer to the Testing and Adjusting, “Knee Frequency - Adjust”.

STOP.

- **NO** – The generator frequency is same as the rated frequency. The low voltage problem still exists. Proceed to test step 13.

Test Step 13. CHECK THE REGULATOR

- A. Adjust the operating voltage range by using the voltage adjustment. Refer to the Testing and Adjusting, “Voltage - Adjust”.

Expected Result:

The voltage should be adjustable between 180 and 264 V for 60 Hz operation. The voltage should be adjustable between 150 and 220 V for 50 Hz operation.

Results:

- **YES** – If the voltage regulator performs the adjustment to operating voltage range and the low voltage problem has not been eliminated, troubleshoot the attachments. Refer to the appropriate section within the Troubleshooting Section. **STOP**.
- **NO** – The regulator does not perform the adjustment to operating voltage, as described above.

Repair: Check the generator diodes. Refer to the appropriate Operations and Maintenance Manual for the particular generator. If the problem has not been eliminated, test the voltage regulator. Refer to the Testing and Adjusting, “Voltage Regulator - Test”. If necessary, replace the voltage regulator.

STOP.

i01499554

High Voltage

SMCS Code: 4467-035

Test Step 1. PERFORM THE INITIAL CHECK

- A. Turn off the genset.
- B. Check for loose terminals.
- C. Check for corroded terminals.
- D. Check for proper connections between the voltage regulator and the generator.

Expected Result:

All initial checks show no problems.

Results:

- **YES** – There are no loose terminals or corroded terminals. The connections are correct. Proceed to test step 2.

- **NO** – One or more of initial checks shows a problem.

Repair: Tighten loose terminals. Replace corroded terminals. If the connections are incorrect, connect the wiring properly according to the wiring diagram.

STOP.

Test Step 2. CHECK METERS

- A.** Start the genset.
- B.** Run the genset at no load.
- C.** Ensure the accuracy of the voltmeter. If you are reading the voltage from the control panel, check that voltage with a multimeter.

Note: Take the voltage readings on terminals 20, 22 and 24 at the regulator.

Expected Result:

Meters are accurate.

Results:

- **YES** – Meters' readings are accurate. Proceed to test step 3.
- **NO** – The meters' readings do not match.

Repair: Troubleshoot the metering circuit. Verify the schematic for the metering circuit. Verify whether the meters are connected correctly.

STOP.

Test Step 3. CHECK CONNECTIONS OF THE VOLTAGE ADJUST RHEOSTAT

- A.** Turn off the genset.
- B.** Check if there is the jumper between terminals 4 and 7.

Expected Result:

There is a jumper that is placed between terminals 4 and 7.

Results:

- **YES** – If a remote voltage adjust rheostat is NOT used, the jumper is properly installed. Proceed to test step 5.

- **YES** – If a remote voltage adjust rheostat is used, the jumper should be removed from terminals 4 and 7. In this case, the remote voltage adjust rheostat should be connected to terminals 6A and 7. Proceed to test step 4.

- **NO** – There is no jumper between terminals 4 and 7. The regulator may go into the overexcitation shutoff.

Repair: Verify the wiring schematics. Install the jumper in accordance with the wiring schematic.

STOP.

Test Step 4. CHECK THE RESISTANCE OF THE REMOTE VOLTAGE ADJUST RHEOSTAT

- A.** Disconnect the wires from terminals 6A and 7.
- B.** Measure the resistance of the remote voltage adjust rheostat while the rheostat is being adjusted over the operating range.

Expected Result:

The resistance should be between 0 kOhm and 10 ± 0.5 kOhm.

Results:

- **YES** – The resistance increases smoothly within the specified range. Proceed to test step 5.
- **NO** – The resistance is not within the specified value. The resistance jumps to a high value when the rheostat is adjusted.

Repair: Replace the remote voltage adjust rheostat.

STOP.

Test Step 5. CHECK THE SENSING CONNECTIONS

- A.** Check if there is a jumper between terminals 6A and 9.

Note: If you are using three-phase sensing, terminals 6A and 9 should be jumpered. If you are using single-phase sensing, this jumper should be removed.

Expected Result:

The jumper is installed or the jumper is not installed, based on the phase sensing selection.

Results:

- **YES** – The jumper is installed between terminals 6A and 9 for three-phase sensing. The jumper is not installed between terminals 6A and 9 for single-phase sensing. Proceed to test step 6.
- **NO** – The jumper is not installed between terminals 6A and 9 for three-phase sensing. The jumper is installed between terminals 6A and 9 for single-phase sensing.

Repair: Connect the jumper in accordance with the phase sensing selection.

STOP.

Test Step 6. CHECK CONNECTIONS FOR THE DROOP CURRENT TRANSFORMER (CT)

- A.** Stop the genset.
 - B.** For a 1 Amperes CT, verify that the connections are to terminals 5 and 6.
 - C.** For a 5 Amperes CT, verify that the connections are to terminals 5A and 6.
- Note:** For troubleshooting purposes, it is possible to operate the voltage regulator when the droop CT is disconnected. However, the droop CT secondary wires must be connected together.
- D.** Verify that the polarity connection of the droop CT is connected to terminal 6.

Expected Result:

The connections are correct.

Results:

- **YES** – The connections are correct. Proceed to test step 7.
- **NO** – The connections are not correct or the connections are impossible to verify.

Repair: Run an individual genset with a reactive load. If the voltage increases as the reactive load increases, the CT secondary is not connected properly. Stop the genset and reverse the lead connections.

STOP.

Test Step 7. VERIFY THE SENSING VOLTAGE

- A.** Make sure that the generator set is off.

- B.** If the generator uses Power Transformers (PT) to step down the generator output voltage to the sensing voltage, check the sensing voltage range. The sensing voltage range should lie between the following limits:

- 180 V to 264 V on 60 Hz gensets
- 150 V to 220 V on 50 Hz gensets

- C.** Verify that sensing wires 20, 22, and 24 are connected correctly. Wire 20 should be connected to T3 phase. Wire 22 should be connected to T1 phase. Wire 24 should be connected to T2 phase.

Expected Result:

The sensing voltage is correct. The sensing wires are connected properly.

Results:

- **YES** – The sensing voltage is correct. The connections are correct. Proceed to test step 8.
- **NO** – The sensing voltage is NOT correct and/or the sensing wires are NOT connected properly.

Repair: Install a PT with correct ratios. Connect the sensing wires to correct terminals.

STOP.

Test Step 8. CHECK THE OUTPUT VOLTAGE

- A.** Start the genset.
- B.** Run the genset at no load.
- C.** Read the output voltage from the control panel.

Expected Result:

The generator voltage is higher than the nominal voltage. The generator voltage is steady.

Results:

- **YES** – The generator voltage is still high but steady. Proceed to test step 9.
- **NO** – The generator voltage oscillates. The voltage goes very high. Then, the voltage goes very low.

Repair: Add the load to the genset. If the voltage still oscillates, turn off the genset in order to reset the voltage regulator. Start the genset again and run at no load. Add load to the generator. If the voltage oscillates again, go to the Troubleshooting, "Voltage Regulator". If the voltage is no longer high, the problem has been fixed.

STOP.

Test Step 9. CHECK THE OPERATING FREQUENCY OF THE GENSET

A. Measure the generator frequency. Use the frequency meter on the control panel or a multimeter with frequency measuring function.

Expected Result:

The generator frequency is above 5% of the rated frequency.

Results:

- **YES** – The frequency is above the rated frequency. In this case, the voltage will be higher than the rated voltage.

Repair: Adjust the generator frequency. Reset the knee frequency. Refer to the Testing and Adjusting, "Knee Frequency - Adjust".

STOP.

- **NO** – The generator frequency is same as the rated frequency. The high voltage problem still exists. Proceed to test step 10.

Test Step 10. CHECK THE REGULATOR

A. Adjust the operating voltage range by using the voltage adjustment. Refer to the Testing and Adjusting, "Voltage - Adjust".

Expected Result:

The voltage should be adjustable between 180 and 264 V for 60 Hz operation. The voltage should be adjustable between 150 and 220 V for 50 Hz operation.

Results:

- **YES** – If the voltage regulator performs the adjustment to operating voltage range and the high voltage problem has not been eliminated, troubleshoot the attachments. Refer to the appropriate section within the Troubleshooting Section. **STOP.**

- **NO** – The regulator does not perform the adjustment to operating voltage, as described above.

Repair: Check the generator diodes. Refer to the appropriate Operations and Maintenance Manual for the particular generator. If the problem has not been eliminated, test the voltage regulator. Refer to the Testing and Adjusting, "Voltage Regulator - Test". Replace the voltage regulator, if required.

STOP.

i01533885

Unstable Voltage

SMCS Code: 4467-035

Test Step 1. PERFORM THE INITIAL CHECK

- A.** Turn off the genset.
- B.** Check for loose terminals.
- C.** Check for corroded terminals.
- D.** Check for proper connections between the voltage regulator and the generator.

Expected Result:

All initial checks show no problems.

Results:

- **YES** – There are no loose terminals or corroded terminals. The connections are correct. Proceed to test step 2.
- **NO** – One or more of initial checks shows a problem.

Repair: Tighten loose terminals. Replace corroded terminals. If the connections are incorrect, connect the wiring properly according to the wiring diagram.

STOP.

Test Step 2. CHECK METERS

- A.** Start the genset.
- B.** Run the genset at no load.
- C.** Ensure the accuracy of the voltmeter. If you are reading the voltage from the control panel, check that voltage with a multimeter.

Note: Take the voltage readings on terminals 20, 22 and 24 at the regulator.

Expected Result:

Meters are accurate.

Results:

- **YES** – Meters' readings are accurate. Proceed to test step 2.
- **NO** – The meters' readings do not match.

Repair: Troubleshoot the metering circuit. Verify the schematic for the metering circuit. Verify whether the meters are connected correctly.

STOP.

Test Step 3. CHECK ENGINE RPM

- A.** Start the genset.
- B.** Run the genset at no load.
- C.** Monitor the engine speed.

Expected Result:

Engine speed is stable.

Results:

- **YES** – Engine speed is stable. Proceed to test step 4.
- **NO** – When the engine speed is unstable, the frequency will be also unstable. The unstable frequency causes the voltage to become unstable as well.

Repair: Troubleshoot the engine RPM. Refer to the appropriate engine service manual.

STOP.

Test Step 4. VERIFY THE STABILITY ADJUSTMENT SETTING

- A.** Readjust the stability adjustment. Refer to the Testing and Adjusting, "Stability - Adjust".

Expected Result:

Voltage has stabilized.

Results:

- **YES** – The voltage is stable. Add the load to the generator. If the voltage remains stable, the problem has been resolved. Otherwise, proceed to test step 5.

- **NO** – Voltage is still unstable.

Repair: Check the voltage regulator.

Proceed to test step 6.

Test Step 5. CHECK HARMONICS

- A.** Check the harmonics distortion. Use either an oscilloscope or a harmonic analyzer.

Expected Result:

The distortion in load is above 20% or severe notching is present.

Results:

- **YES** – There is a harmonic distortion in load. Consult your Caterpillar dealer in order to reduce harmonics distortion. **STOP.**
- **NO** – There is no harmonic distortion in the load.

Repair: Check if there is a harmonic noise in the circuit from the attachments, which can cause voltage to become unstable. Disconnect the attachments one at a time in order to isolate the problem.

If the problem has not been resolved, proceed to test step 6.

Test Step 6. CHECK THE REGULATOR

- A.** Adjust the operating voltage range by using the voltage adjustment. Refer to the Testing and Adjusting, "Voltage - Adjust".

Expected Result:

The voltage should be adjustable between 180 and 264 V for 60 Hz operation. The voltage should be adjustable between 150 and 220 V for 50 Hz operation.

Results:

- **YES** – If the voltage regulator performs the adjustment to operating voltage and the problem has not been eliminated, troubleshoot the attachments. Refer to the appropriate section within the Troubleshooting Section. **STOP.**
- **NO** – The regulator does not perform the adjustment to operating voltage, as described above.

Repair: Check the generator diodes. Refer to the appropriate Operations and Maintenance Manual for the particular generator. If the problem has not been eliminated, test the voltage regulator. Refer to the Testing and Adjusting, "Voltage Regulator - Test". Replace the voltage regulator, if required.

STOP.

Diagnostic Functional Tests

i01534468

Remote Voltage Control

SMCS Code: 4467-038

Test Step 1. CHECK THE WIRING

- A. Turn off the genset.
- B. Turn the remote voltage adjust rheostat in a fully counterclockwise direction.
- C. Disconnect the wires from terminals 6A and 7.
- D. Measure the resistance of the remote voltage adjust rheostat between wires 6A and 7.
- E. Turn the remote voltage adjust rheostat in a fully clockwise direction.
- F. Measure the resistance between wires 6A and 7.

Expected Result:

Resistance between wires 6A and 7 should be less than 5 Ohm when the remote voltage adjust rheostat is turned in a fully counterclockwise direction. Resistance should be between 9.5 kOhm and 10.5 kOhm when the remote voltage adjust rheostat is turned in a fully clockwise direction.

Results:

- YES – Resistance lies within specified range. Proceed to test step 2.
- NO – Resistance is outside specified range.

Repair: Check if the wires are broken. Check for the wires that are shorted to ground. Check for bad solder joints. Check for adequate wire size to the remote voltage adjust rheostat.

STOP.

Test Step 2. CHECK THE REMOTE VOLTAGE ADJUST RHEOSTAT

- A. Reconnect the remote voltage adjust rheostat to the voltage regulator.
- B. Start the genset.
- C. Run the genset at no load.

Expected Result:

The generator voltage lies within specified range.

Results:

- YES – The problem has been eliminated. STOP.
- NO – The problem still exists.

Repair: Replace the remote voltage adjust rheostat. Refer to the Testing and Adjusting, "Wiring Diagrams".

STOP.

i01534470

Voltage Droop Control

SMCS Code: 4467-038

Test Step 1. CHECK THE DROOP CIRCUIT

- A. Turn off the genset.
- B. Connect the droop circuit to the voltage regulator. Verify that connections are correct. Refer to the Testing and Adjusting, "Wiring Diagrams".
- C. Start the genset.
- D. Add load to the genset.

Expected Result:

First, voltage increases rapidly to a very high value. Then, the voltage goes to a very low value.

Results:

- YES – The voltage acts, as described above.

Repair: Stop the genset. Switch wires to terminals 5 and 6 for a 1 Ampere current transformer (CT). Switch wires to terminals 5A and 6 for a 5 Ampere CT. Start the genset and run the genset at no load.

STOP.

- NO – The voltage is within specified range. Proceed to test step 2.

Test Step 2. CHECK THE CURRENT TRANSFORMER (CT)

- A. Check the voltage between terminals 5 and 6 for a 1 Ampere CT. Check the voltage between terminals 5A and 6 for a 5 Ampere CT.

Expected Result:

There is no voltage between specified terminals.

Results:

- **YES** – The voltage between terminals 5 and 6 is less than 100 Volts for a 1 Ampere CT. The voltage between terminals 5A and 6 is less than 100 Volts for a 5 Ampere CT.

Repair: Replace the CT. Refer to the Testing and Adjusting, "Wiring Diagrams".

STOP.

- **NO** – The voltage is present. The problem has been eliminated. **STOP.**

i01534471

Radio Frequency Interference Filter

SMCS Code: 4467-038

CHECK THE RFI FILTER

- Stop the genset.
- Disconnect the RFI filter from the voltage regulator.
- Start the genset and run the genset at no load.

Expected Result:

The problem has been eliminated.

Results:

- **YES** – The problem has been eliminated. **STOP.**
- **NO** – The RFI filter is faulty.

Repair: Turn off the genset. Replace the RFI filter.

STOP.

i01535266

Power Factor Regulation and KVAR Regulation

SMCS Code: 4467-038

CHECK THE KVAR/PF CONTROLLER

- Stop the genset.

- Disconnect the KVAR/PF controller from the voltage regulator.

- Connect a jumper to terminals 2 and 3.

- Start the genset and run the genset at no load.

Expected Result:

The problem has been eliminated.

Results:

- **YES** – The problem has been eliminated. **STOP.**
- **NO** – The KVAR/PF controller is faulty.

Repair: Turn off the genset. Replace the KVAR/PF controller. Refer to the Testing and Adjusting, "Wiring Diagrams".

STOP.

Testing and Adjusting Section

Testing and Adjusting

Stability - Adjust

SMCS Code: 4467-025

i01502445

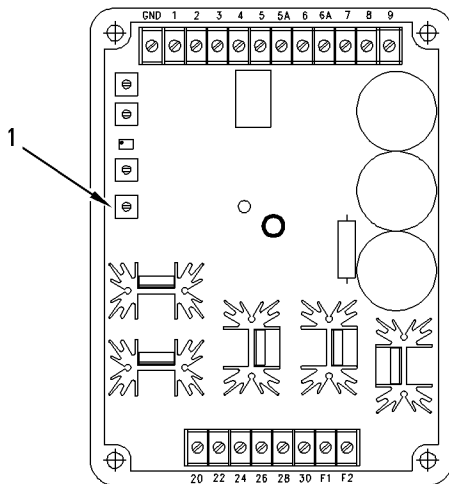


Illustration 8
VR6 Voltage Regulator
(1) Stability adjustment

An oscilloscope or other voltage recording device should be used if an optimal stability setting is desired. Rotate stability adjustment (1) in the clockwise (CW) direction if you need to slow the response time. Rotate stability adjustment in the counterclockwise (CCW) direction if you need to speed the response time. If the adjustment is rotated too far in a CCW direction, the generator voltage may oscillate or the voltage may hunt.

Good response can be obtained with the following procedure:

1. Start the generator.
2. Run the generator at no load.
3. Rotate stability adjustment (1) CW until the voltage becomes stable.
4. Rotate stability adjustment (1) CCW until the system just begins to oscillate.

5. Rotate stability adjustment (1) CW just past the point at which oscillation occurred.

Note: If the voltage remains stable when the adjustment is fully CCW, leave the adjustment fully CCW. This gives the fastest response to load changes.

i01502538

Voltage - Adjust

SMCS Code: 4467-025

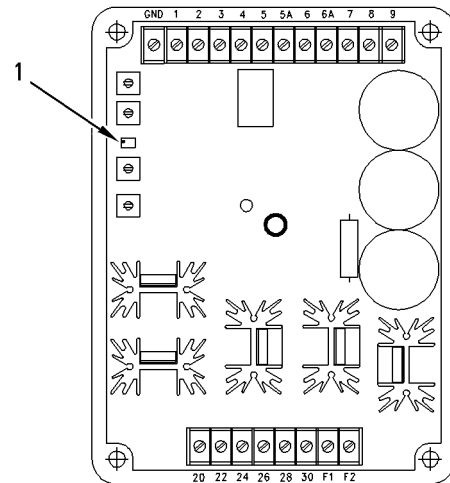


Illustration 9
VR6 Voltage Regulator
(1) Voltage adjustment

Rotate the voltage adjustment (1) in the clockwise direction in order to increase the voltage. Rotate the voltage adjustment (1) in the counterclockwise direction in order to decrease the voltage.

When the jumper is installed between terminals 4 and 7, the nominal voltage of the generator can be varied over the operating range by using the voltage adjustment (1).

In order to use an external voltage adjust rheostat, perform the following procedure:

1. Stop the genset.
2. Remove the jumper between terminals 4 and 7.
3. Connect an external voltage adjust rheostat across terminals 6A and 7. The rheostat should be rated at 10 kOhm.

Note: On some gensets, the voltage adjust rheostat is located on the control panel.

- Turn the voltage adjustment (1) on the regulator in a fully clockwise direction in order for the external adjustment to operate properly.

i01502616

Knee Frequency - Adjust

SMCS Code: 4467-025

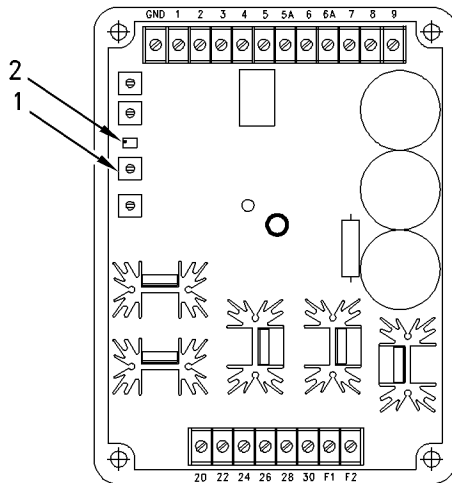


Illustration 10

g00779342

VR6 Voltage Regulator

- (1) Knee frequency adjustment
(2) Voltage adjustment

Operation at 60 Hz

- Adjust the generator frequency for 60 Hz.
- Turn the knee frequency adjustment (1) fully counterclockwise (CCW) or until voltage does not increase with further turning.
- Turn the voltage adjustment (2) until the voltage is at 240 VAC on terminals 20, 22, and 24.
- Slowly turn the knee frequency adjustment (1) clockwise (CW) until the voltage begins to decrease.
- Turn the knee frequency adjustment (1) CCW until the voltage just returns to 240 VAC. The knee frequency is now set just below the nominal operating frequency.

Note: Further rotation in the CCW direction will lower the frequency at which underfrequency compensation begins.

- Connect a jumper from terminal 8 to terminal 6A in order to provide an underfrequency slope of 1 V/Hz. No connection to terminal 8 will result in an underfrequency slope of 2 V/Hz.
- Start the generator.
- Run the generator at no load.
- Decrease the engine RPM and observe the frequency at which the voltage starts to decrease. If the knee frequency is lower than 5 Hz below the rated frequency, readjust the knee frequency.

Operation at 50 Hz

- Adjust the generator frequency for 50 Hz.
- Turn the knee frequency adjustment (1) fully counterclockwise (CCW) or until voltage does not increase with further turning.
- Turn the voltage adjustment (2) until the voltage is at 200 VAC on terminals 20, 22, and 24.
- Slowly turn the knee frequency adjustment (1) clockwise (CW) until the voltage begins to decrease.
- Turn the knee frequency adjustment (1) CCW until the voltage just returns to 200 VAC. The knee frequency is now set just below the nominal operating frequency.

Note: Further rotation in the CCW direction will lower the frequency at which underfrequency compensation begins.

- Connect a jumper from terminal 8 to terminal 6A in order to provide an underfrequency slope of 1 V/Hz. No connection to terminal 8 will result in an underfrequency slope of 2 V/Hz.
- Start the generator.
- Run the generator at no load.
- Decrease the engine RPM and observe the frequency at which the voltage starts to decrease. If the knee frequency is lower than 5 Hz below the rated frequency, readjust the knee frequency.

i01502653

Droop - Adjust

SMCS Code: 4467-025

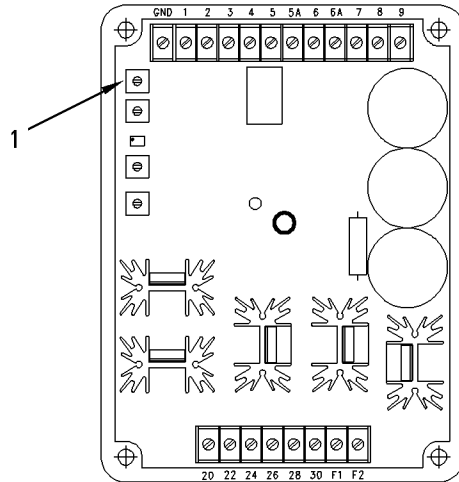


Illustration 11
VR6 Voltage Regulator
(1) Droop adjustment

Variable levels of parallel droop compensation can be obtained by adjusting the droop potentiometer (1). Clockwise rotation increases the amount of droop for a given condition.

i01502695

Voltage Adjustment Range - Calibrate

SMCS Code: 4467-524

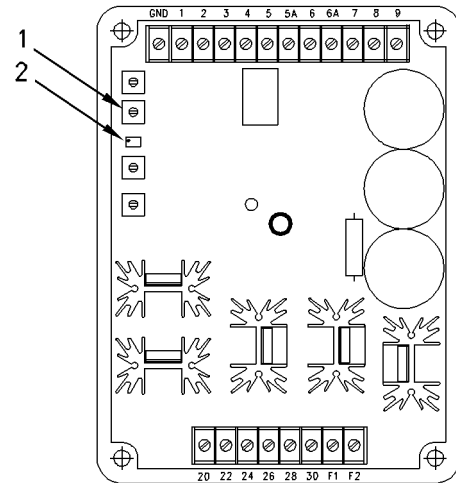


Illustration 12
VR6 Voltage Regulator
(1) Factory calibration adjustment
(2) Voltage adjustment

NOTICE

Do not operate generator at a voltage greater than 5% above the name plate rating.

The factory calibration adjustment (1) should be used by the factory technicians only. The following procedure can be used if the factory calibration has been disturbed:

1. Remove the seal from the factory calibration adjustment (1).
2. Start the genset.
3. Run the genset at no load.
4. Turn the factory calibration adjustment (1) in a fully counterclockwise direction.
5. Turn the voltage adjust rheostat (2) in a fully clockwise direction.
6. Slowly turn the factory calibration adjustment (1) CW until the voltage on 20-22-24 is 252 ± 1 VAC for 60 Hz (226 ± 1 VAC for 50 Hz).
7. Turn the voltage adjust rheostat (2) CCW.

8. Verify that the voltage on 20-22-24 is between 156 VAC and 180 VAC. The unit is calibrated.
9. Seal the factory calibration adjustment (1).

i01699728

Exciter Field - Flash

SMCS Code: 4470-025

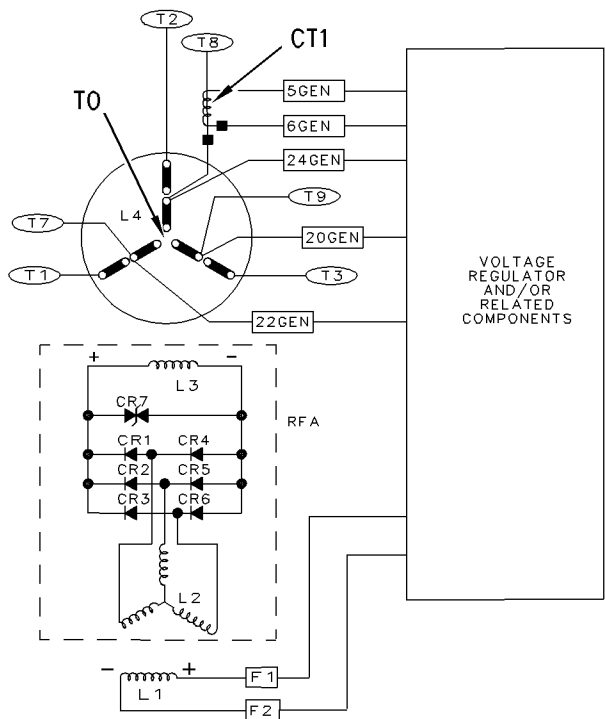


Illustration 13

g00874825

Wiring Diagram of the Self-Excited Generator

(CR1-C6) Diodes

(CR7) Varistor

(L1) Exciter field (stator)

(L2) Exciter armature (rotor)

(L3) Main field (rotor)

(L4) Main armature (stator)

(RFA) Rotating field assembly

(CT1) Optional Voltage Droop Transformer

(T0, T1, T2, T3, T7, T8, T9) Generator terminals

Self-excited generators may lose the residual magnetism that normally exists in the exciter field (L1) and the main field (L3). Residual magnetism is necessary to start the generation process. The magnetism can be restored by flashing exciter field (L1) with direct current. A 6 VDC battery can be used to supply the direct current.

NOTICE

Do not flash permanent magnet pilot excited (PMPE) generators. Damage to the generator set can occur.

There are two methods of flashing the field:

- Static Flashing (stopped engine)
- Dynamic Flashing (running engine)

Static Flashing (Stopped Engine)

Table 5

TOOLS NEEDED	
Tool	Quantity
6 VDC Battery	1

1. Stop the engine.
 2. At the voltage regulator, disconnect wire F1 GEN from terminal F1 and disconnect wire F2 GEN from terminal F2.
 3. Connect the positive cable of the 6 volt source to wire F1 GEN.
 4. Momentarily put the negative cable of the 6 volt source on wire F2 GEN (two or three times).
- Note:** Do not hold the negative cable to wire F2 GEN for more than one or two seconds.
5. Connect all wires that were previously disconnected.

Dynamic Flashing (Running Engine)

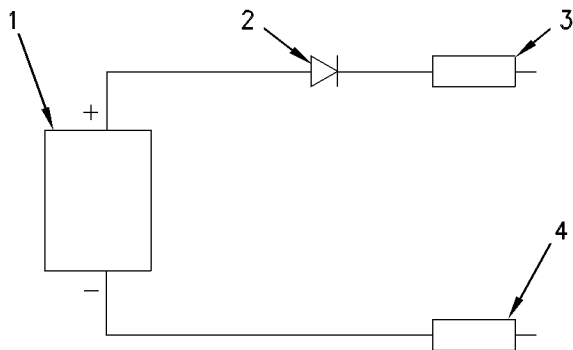


Illustration 14 g00614470

Dynamic Flashing Circuit

- (1) Battery (≤ 6 VDC)
- (2) Diode
- (3) Red test lead "+"
- (4) Black test lead "-"

Table 6

TOOLS NEEDED		
Part Number	Tool	Quantity
6V-7070	Digital Multimeter	1
9P-5153	Diode (MR-504)	1
	Dynamic Flashing Circuit	1

- Construct the dynamic flashing circuit that is shown in Illustration 14.
- Stop the engine.
- Connect a multimeter (set on ACV) to terminals 20 and 22 at the voltage regulator.
- Start the engine and run the engine at low idle.

NOTICE

Do not hold the flashing circuit's test leads on the terminals longer than necessary. This can cause the voltage to become too high. Excessive voltage can cause damage to the generator and can cause damage to the flashing circuit.

- Hold the red lead of the dynamic flashing circuit to terminal F1.
- Monitor the voltmeter. Touch the black lead to terminal F2 of the dynamic flashing circuit.

- When the voltmeter shows an increase in voltage, remove the test leads from terminal F1 and terminal F2. If the generator voltage does not increase within 5 to 10 seconds, remove the test leads from terminals F1 and F2.

i01499377

Voltage Regulator - Test

SMCS Code: 4467-081-TB

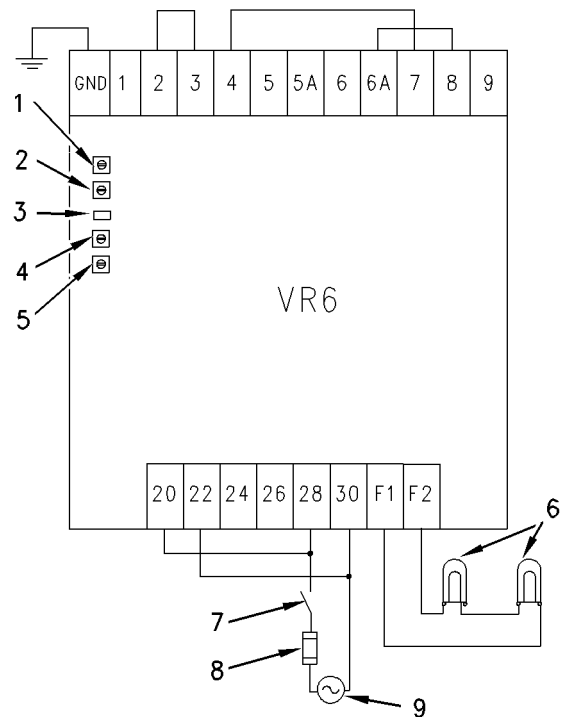


Illustration 15 g00778082

Test Circuit

- (1) Droop adjustment
- (2) Factory voltage adjustment
- (3) Voltage adjustment
- (4) Knee frequency adjustment
- (5) Stability adjustment
- (6) 100 Watt light bulbs
- (7) Switch (300 VAC and 15 Amperes)
- (8) AGC10 fuse
- (9) The AC power source (240 V \pm 5%)

Perform the following procedure in order to determine whether the voltage regulator is providing proper excitation.

- Connect the voltage regulator according to Illustration 15.
- Adjust stability (5) by turning adjustment in a fully clockwise direction.
- Turn voltage adjustment (3) for five turns in a counterclockwise direction.

4. Close switch (7) in order to apply AC power. The AC power source is 240 V \pm 5% for 60 Hz applications. The AC power source is 200 V \pm 5% for 50 Hz applications.
5. If the lights (6) turned on, turn the voltage adjustment (3) in a counterclockwise direction. The lights should decrease in intensity. The lights should finally go out. Go to step 7.

If the lights (6) did not come on, go to step 6.
6. Turn the voltage adjustment in a clockwise direction. The lights should increase in intensity as the voltage adjustment is turned CW. The regulator will shut off and the lights (6) will turn off if one of the following conditions occurs:
 - The voltage that is being applied to the lights (6) is above 90 V for 30 seconds.
 - The voltage that is being applied to the lights (6) is above 125 V for 10 seconds.
7. Open switch (7) for at least 15 seconds. The lights (6) will flash momentarily.
8. Close switch (7).
9. Slowly turn the voltage adjustment (3) CCW until the lights (6) come ON. Try to maintain a low light intensity to medium light intensity by adjusting the voltage adjustment (3).

Expected Result: The light bulbs (6) operate, as described above.

Results:

- “YES”: The voltage regulator functions properly.
- “NO”: The light bulbs (6) react differently. Replace the voltage regulator.

Note: Droop (1) should be adjusted during generator’s operation.

Note: Knee frequency (4) should be adjusted during generator’s operation.

Note: Stability (5) should be adjusted during generator’s operation.

i01534466

Voltage Regulator - Replace

SMCS Code: 4467-510

1. Install the voltage regulator. Refer to the installation instructions. See the Testing and Adjusting, “Wiring Diagrams”.
2. Start the engine.
3. Run the engine at rated engine RPM and at no load.
4. Turn the knee frequency adjustment counterclockwise (CCW).
5. Adjust the voltage level. Refer to the Testing and Adjusting, “Voltage - Adjust”.
6. Adjust the knee frequency. Refer to the Testing and Adjusting, “Knee Frequency - Adjust”.
7. Adjust stability. Refer to the Testing and Adjusting, “Stability - Adjust”.
8. Return the genset to normal operation.
9. Add load to the genset.
10. Slightly reduce the frequency of the genset. Generator voltage should decrease proportionally with the frequency. Otherwise, readjust the knee frequency again.
11. Increase the frequency to the rated frequency.

i01722914

Wiring Diagrams

SMCS Code: 4467; 7566

The following wiring diagrams are shown below:

Table 7

No. of Generator Leads	Excitation	Voltage Sensing	No. of Illustration
10/12	Permanent Magnet (PM)	three-phase	16
	Self-Excited (SE)	single-phase	17
		three-phase	18
4/6	PM	three-phase	19
	SE	single-phase	20
		three-phase	21
Medium Voltage	PM	three-phase	22
	SE	single-phase	23
		three-phase	24
Attachments			
Series Boost Module			25
Cross Current Compensation			26
Manual Voltage Control for SE Generators			27
Manual Voltage Control for PM Generators			28

The following notes are referred to throughout each illustration:

Table 8

Note	Comment
Note 1	Connect the wire to terminal 5 for a 1 Ampere CT. Connect the wire to terminal 5A for a 5 Ampere CT.
Note 2	Connect the remote voltage adjust rheostat between terminals 6A and 7. Remove the jumper between terminals 4 and 7. The remote voltage adjust rheostat should be rated at 10 kOhm and 2 Watt. Place the jumper between terminals 6A and 8 for 1 V/Hz underfrequency slope. Remove the jumper between terminals 6A and 8 for 2 V/Hz underfrequency slope. Place the jumper between terminals 6A and 9 for three-phase sensing. Remove the jumper between terminals 6A and 9 for single-phase sensing.
Note 3	Connect terminals 2 and 3 to the VAR/PF controller. Short terminals 2 and 3 when the VAR/PF controller is not used.
Note 4	For three-phase voltage sensing, connect the wiring to the secondary winding. Phase rotation with transformer T1 is important. Connect terminal 22 to the PT on T1. Connect terminal 24 to the PT on T2. Connect terminal 20 to the PT on T3.
Note 5	Use twisted, shielded cables.
Note 6	Single-phase, 220 VAC to 240 VAC secondary transformer winding, 50 / 60 Hz, 3125 VA
Note 7	Three-phase, 63 VAC to 105 VAC, 50 / 60 Hz, 3125 VA

10/12 lead permanent magnet (PM) excited generators with three-phase sensing

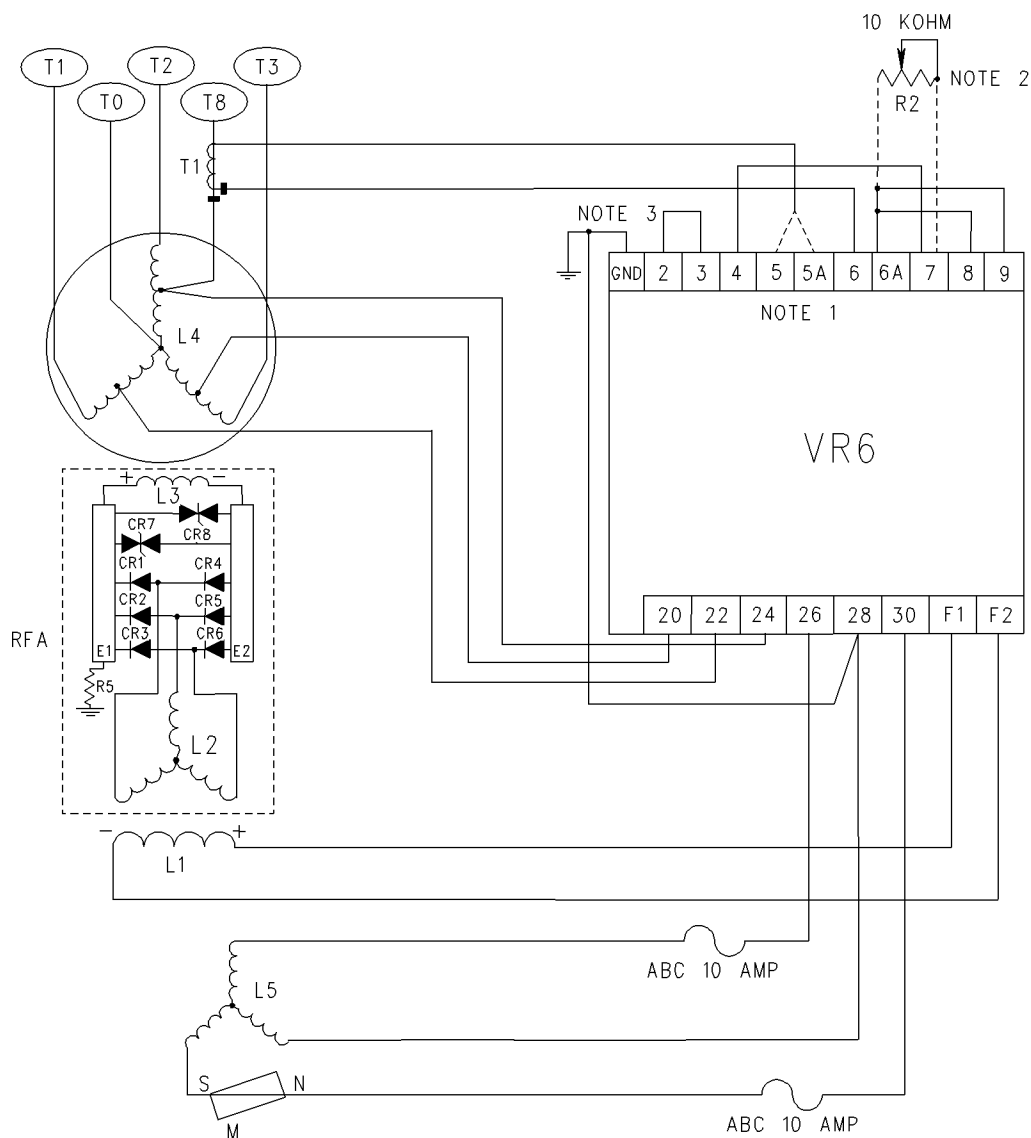


Illustration 16

g00847739

(CR1-CR6) Rotating rectifiers
(CR7, CR8) Surge suppression diodes
(E1) Positive heat sink
(E2) Negative heat sink
(L1) Exciter field (stator)
(L2) Exciter armature (rotor)
(L3) Revolving field (main rotor)

(L4) Main stator
(L5) PM exciter stator
(M) Rotating permanent magnet
(R2) Remote level rheostat
(R5) Suppression resistor
(RFA) Revolving field assembly
(T1) Voltage droop transformer (option)

Note: Refer to Table 8 for notes.

10/12 lead self-excited (SE) generators with single-phase sensing

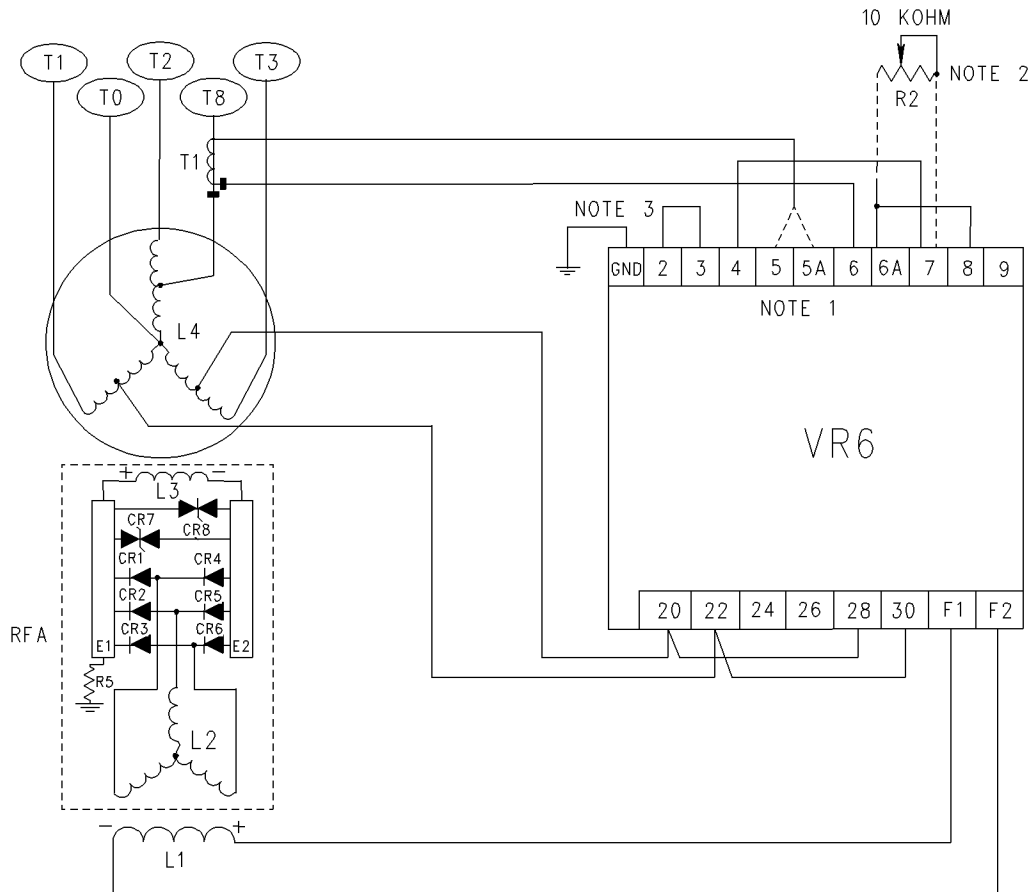


Illustration 17

g00779534

(CR1-CR6) Rotating rectifiers
(CR7, CR8) Surge suppression diodes
(E1) Positive heat sink
(E2) Negative heat sink

(L1) Exciter field (stator)
(L2) Exciter armature (rotor)
(L3) Revolving field (main rotor)
(L4) Main stator

(R2) Remote level rheostat
(R5) Suppression resistor
(RFA) Revolving field assembly
(T1) Voltage droop transformer (option)

Note: Refer to Table 8 for notes.

10/12 lead self-excited (SE) generators with three-phase sensing

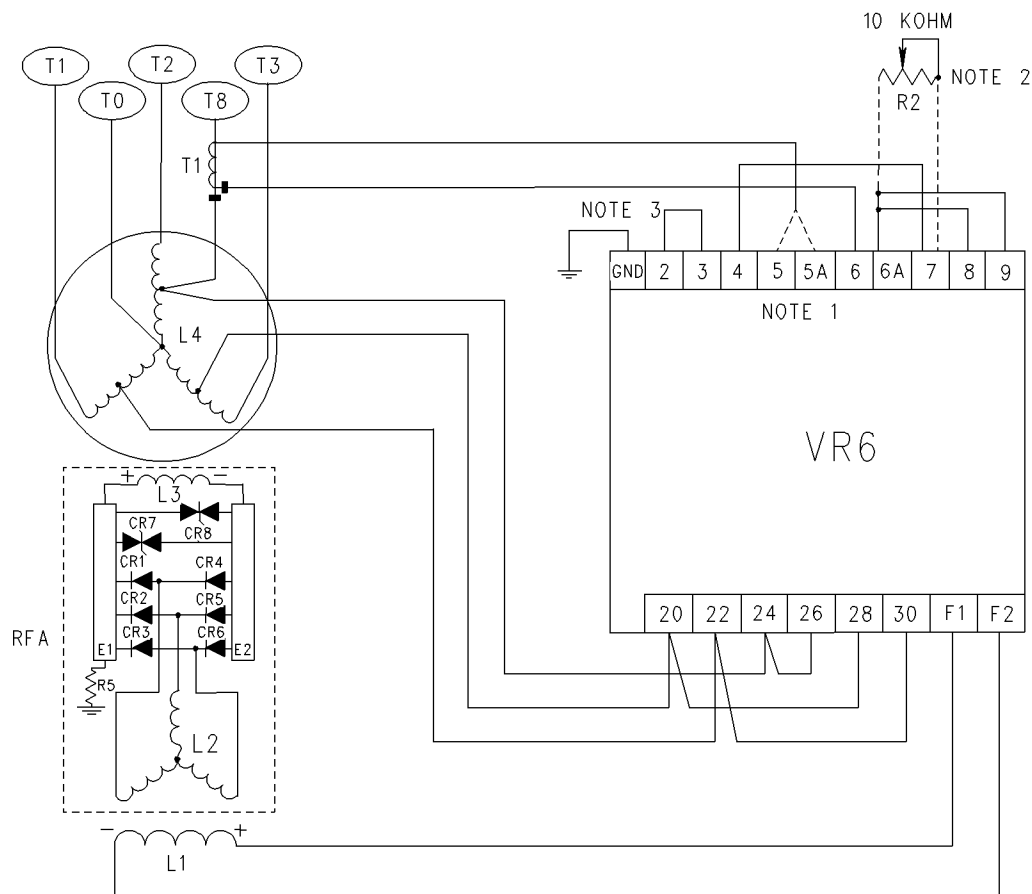


Illustration 18

g00779536

- (CR1-CR6) Rotating rectifiers
(CR7, CR8) Surge suppression diodes
(E1) Positive heat sink
(E2) Negative heat sink

- (L1) Exciter field (stator)
(L2) Exciter armature (rotor)
(L3) Revolving field (main rotor)
(L4) Main stator

- (R2) Remote level rheostat
(R5) Suppression resistor
(RFA) Revolving field assembly
(T1) Voltage droop transformer (option)

Note: Refer to Table 8 for notes.

4/6 lead permanent magnet (PM) excited generators with three-phase sensing

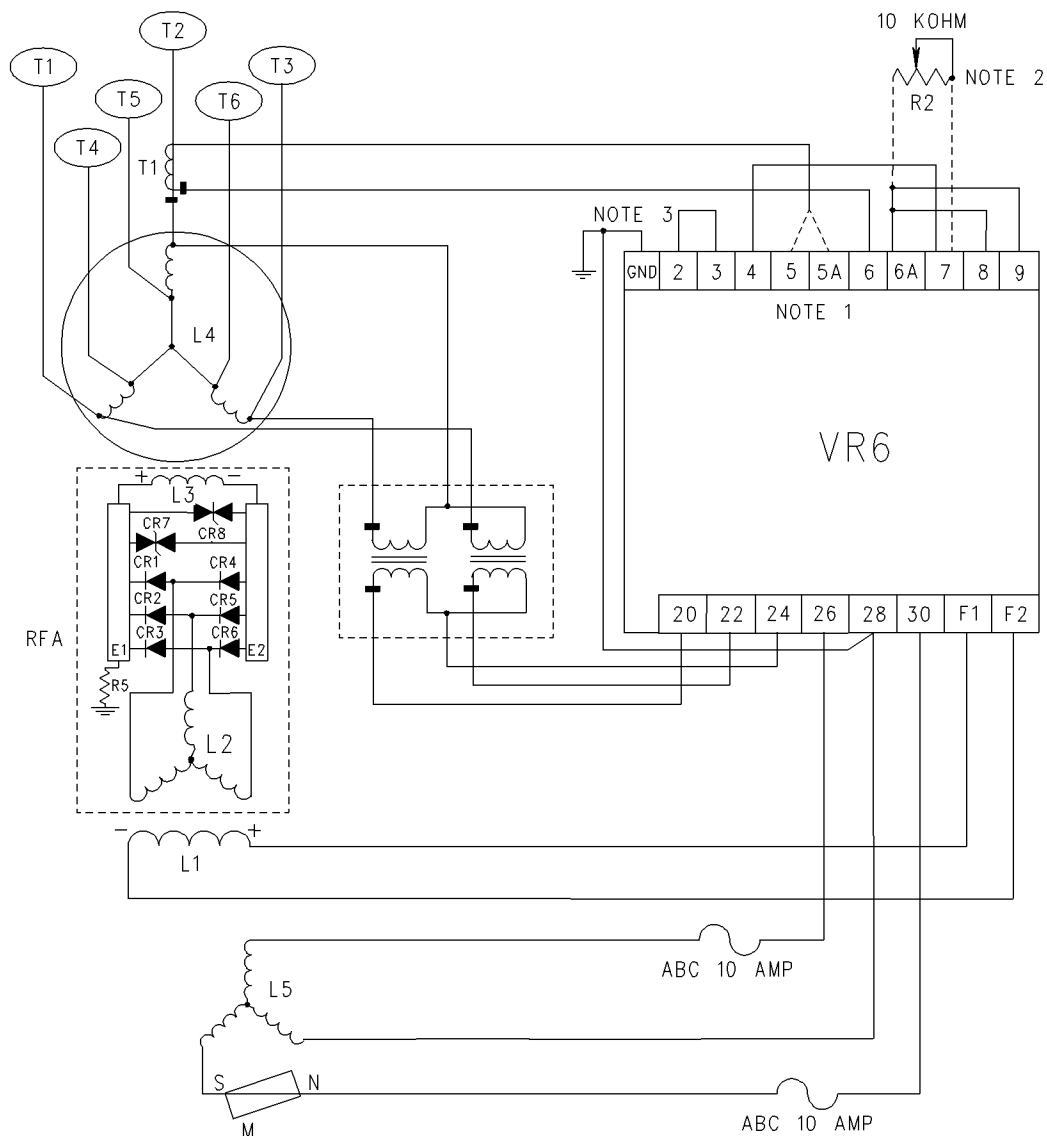


Illustration 19

g00847778

(CR1-CR6) Rotating rectifiers
(CR7, CR8) Surge suppression diodes
(E1) Positive heat sink
(E2) Negative heat sink
(L1) Exciter field (stator)
(L2) Exciter armature (rotor)
(L3) Revolving field (main rotor)

(L4) Main stator
(L5) PM exciter stator
(M) Rotating permanent magnet
(R2) Remote level rheostat
(R5) Suppression resistor
(RFA) Revolving field assembly
(T1) Voltage droop transformer (option)

Note: Refer to Table 8 for notes.

4/6 lead self-excited (SE) generators with single-phase sensing

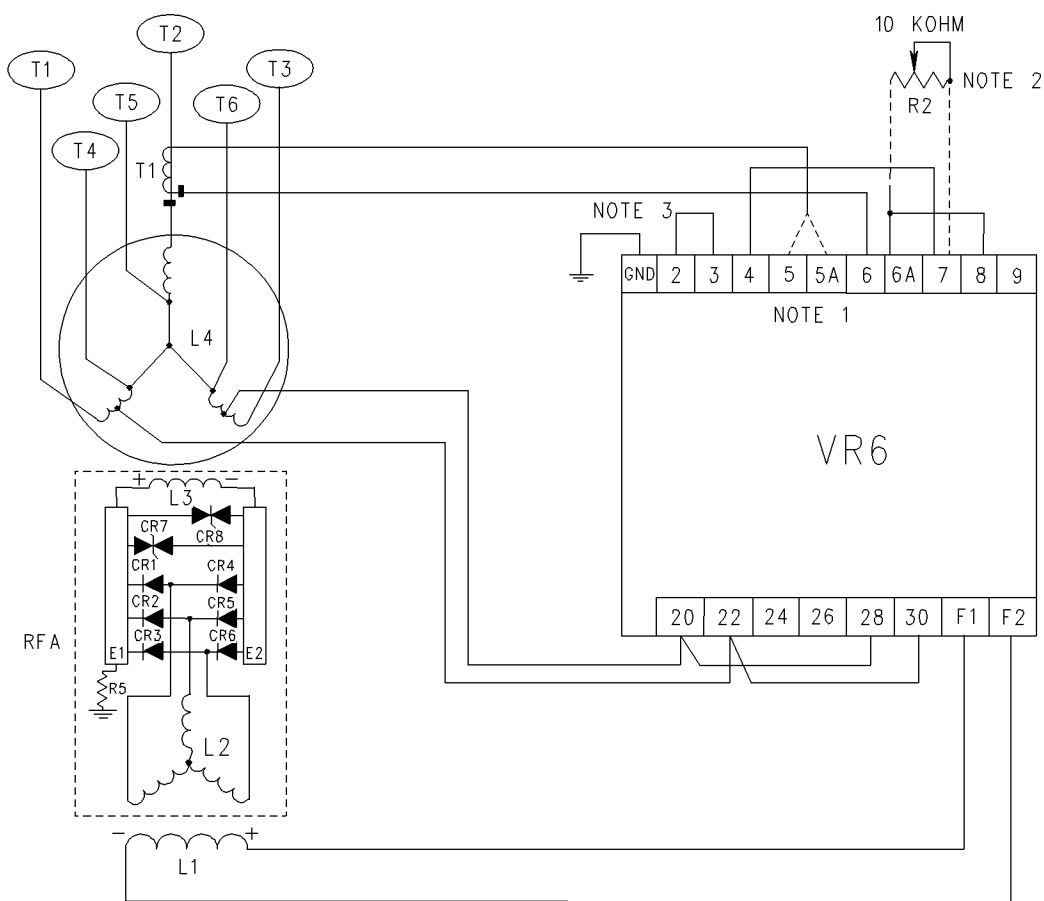


Illustration 20

g00847793

- | | | |
|-------------------------------------|-----------------------------------|---|
| (CR1-CR6) Rotating rectifiers | (L1) Exciter field (stator) | (R2) Remote level rheostat |
| (CR7, CR8) Surge suppression diodes | (L2) Exciter armature (rotor) | (R5) Suppression resistor |
| (E1) Positive heat sink | (L3) Revolving field (main rotor) | (RFA) Revolving field assembly |
| (E2) Negative heat sink | (L4) Main stator | (T1) Voltage droop transformer (option) |

Note: Refer to Table 8 for notes.

4/6 lead self-excited (SE) generators with three-phase sensing

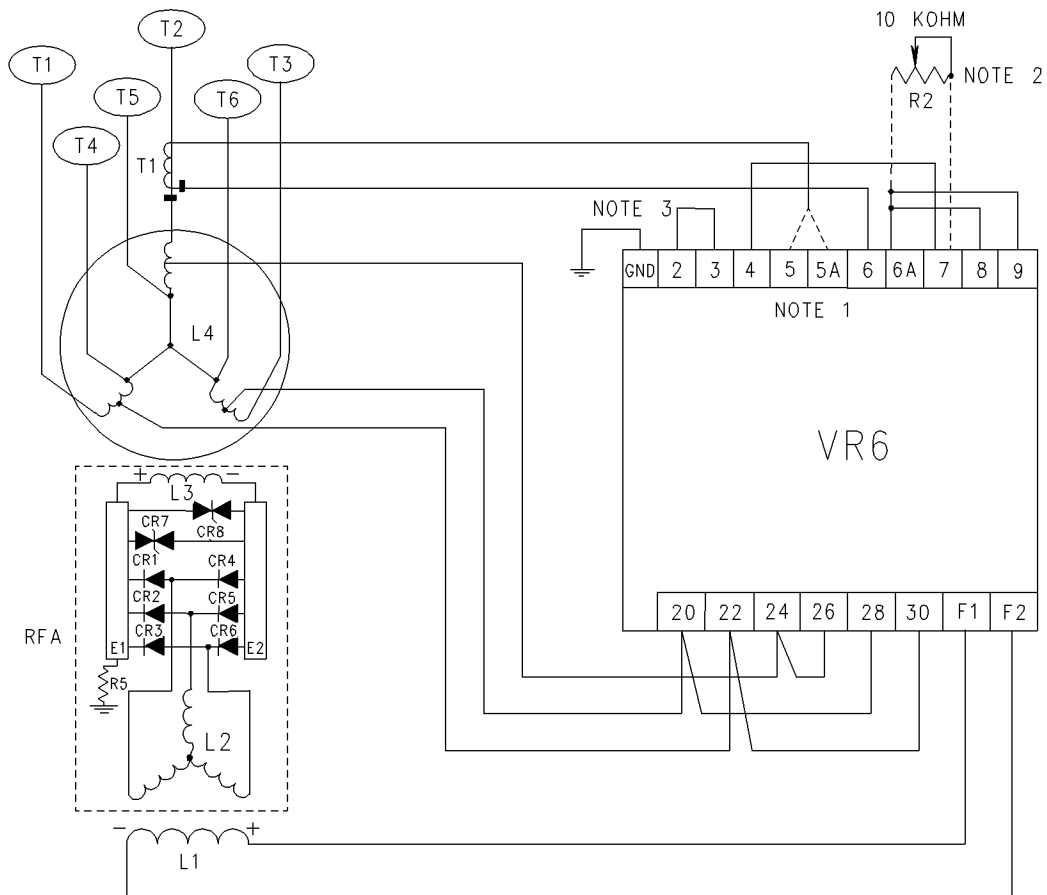


Illustration 21

g00847798

(CR1-CR6) Rotating rectifiers
(CR7, CR8) Surge suppression diodes
(E1) Positive heat sink
(E2) Negative heat sink

(L1) Exciter field (stator)
(L2) Exciter armature (rotor)
(L3) Revolving field (main rotor)
(L4) Main stator

(R2) Remote level rheostat
(R5) Suppression resistor
(RFA) Revolving field assembly
(T1) Voltage droop transformer (option)

Note: Refer to Table 8 for notes.

Medium voltage permanent magnet generators with three-phase sensing

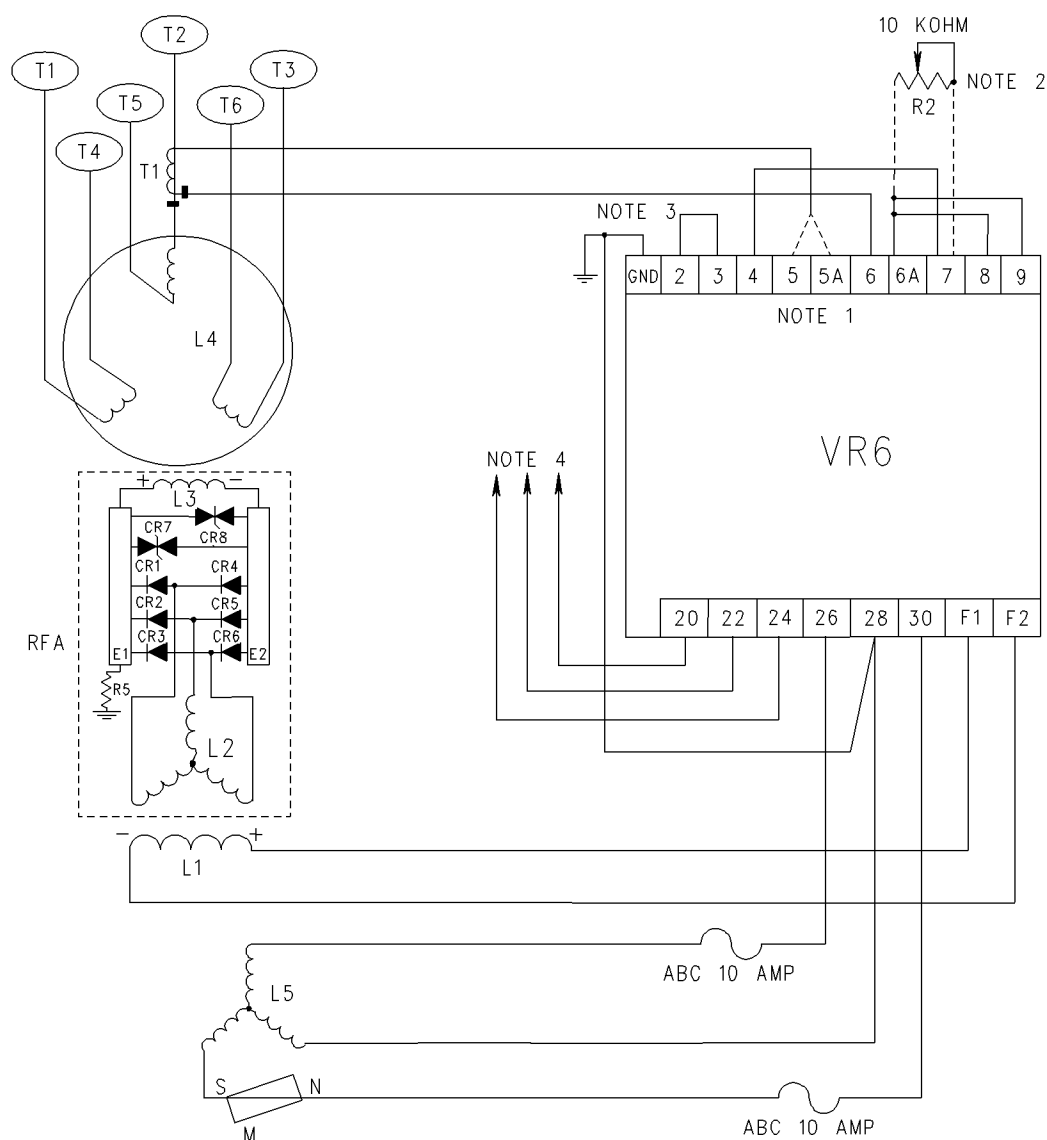


Illustration 22

g00847801

(CR1-CR6) Rotating rectifiers
(CR7, CR8) Surge suppression diodes
(E1) Positive heat sink
(E2) Negative heat sink
(L1) Exciter field (stator)
(L2) Exciter armature (rotor)
(L3) Revolving field (main rotor)

(L4) Main stator
(L5) PM exciter stator
(M) Rotating permanent magnet
(R2) Remote level rheostat
(R5) Suppression resistor
(RFA) Revolving field assembly
(T1) Voltage droop transformer (option)

Note: Refer to Table 8 for notes.

Medium voltage self-excited generators with single-phase sensing

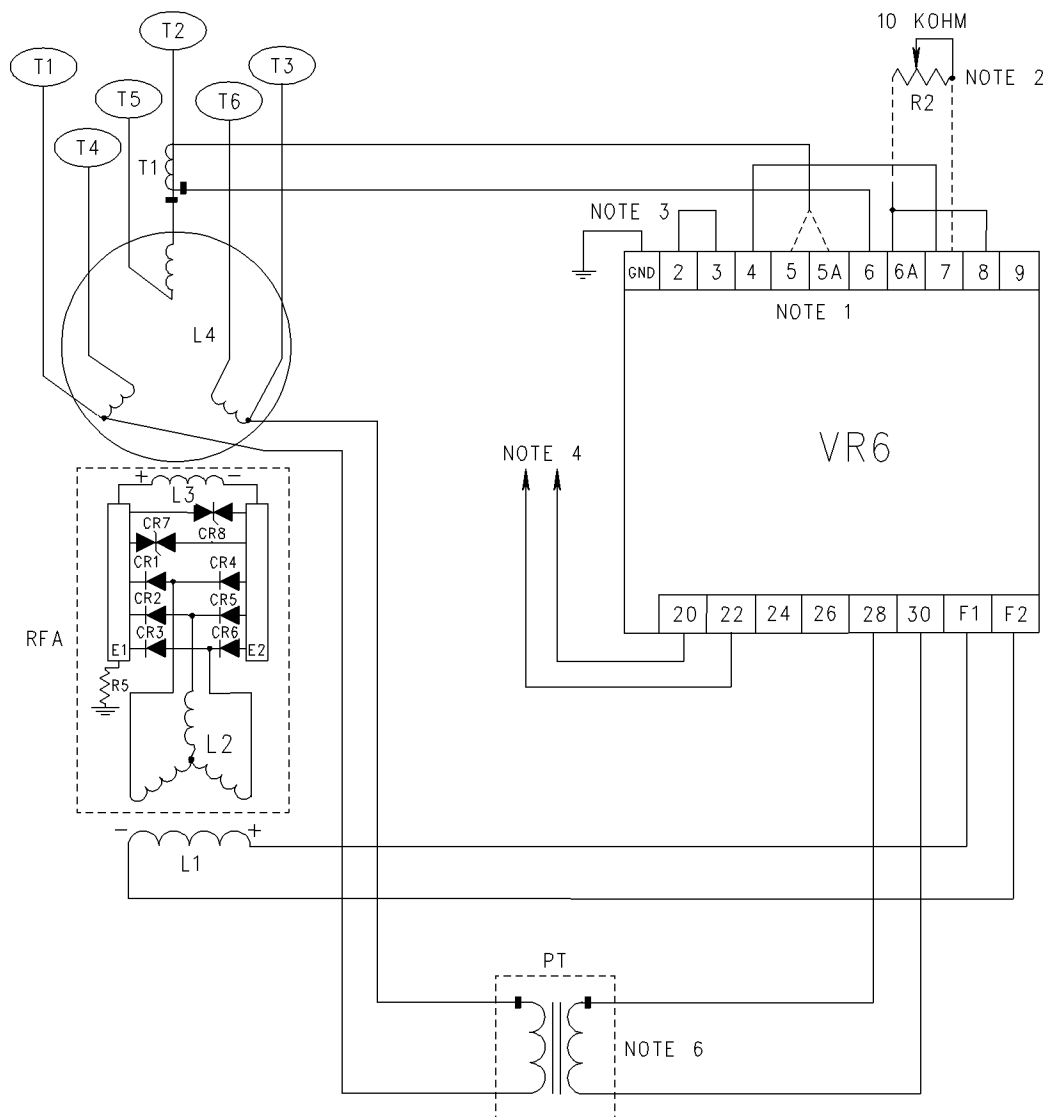


Illustration 23

g00779543

(CR1-CR6) Rotating rectifiers
(CR7, CR8) Surge suppression diodes
(E1) Positive heat sink
(E2) Negative heat sink

(L1) Exciter field (stator)
(L2) Exciter armature (rotor)
(L3) Revolving field (main rotor)
(L4) Main stator

(R2) Remote level rheostat
(R5) Suppression resistor
(RFA) Revolving field assembly
(T1) Voltage droop transformer (option)

Note: Refer to Table 8 for notes.

Medium voltage self-excited generators with three-phase sensing

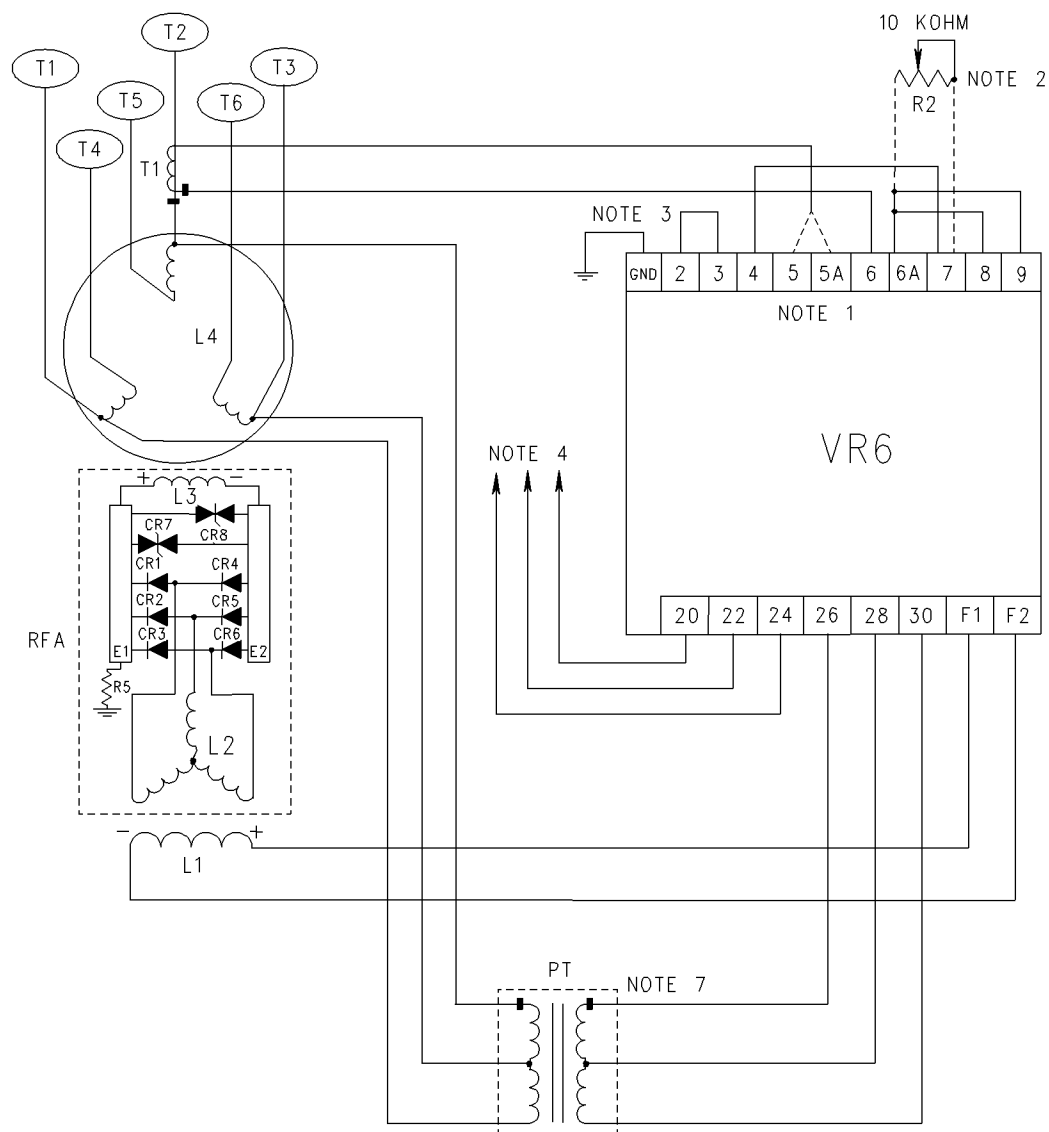


Illustration 24

g00847804

(CR1-CR6) Rotating rectifiers
(CR7, CR8) Surge suppression diodes
(E1) Positive heat sink
(E2) Negative heat sink

(L1) Exciter field (stator)
(L2) Exciter armature (rotor)
(L3) Revolving field (main rotor)
(L4) Main stator

(R2) Remote level rheostat
(R5) Suppression resistor
(RFA) Revolving field assembly
(T1) Voltage droop transformer (option)

Note: Refer to Table 8 for notes.

Series Boost Module

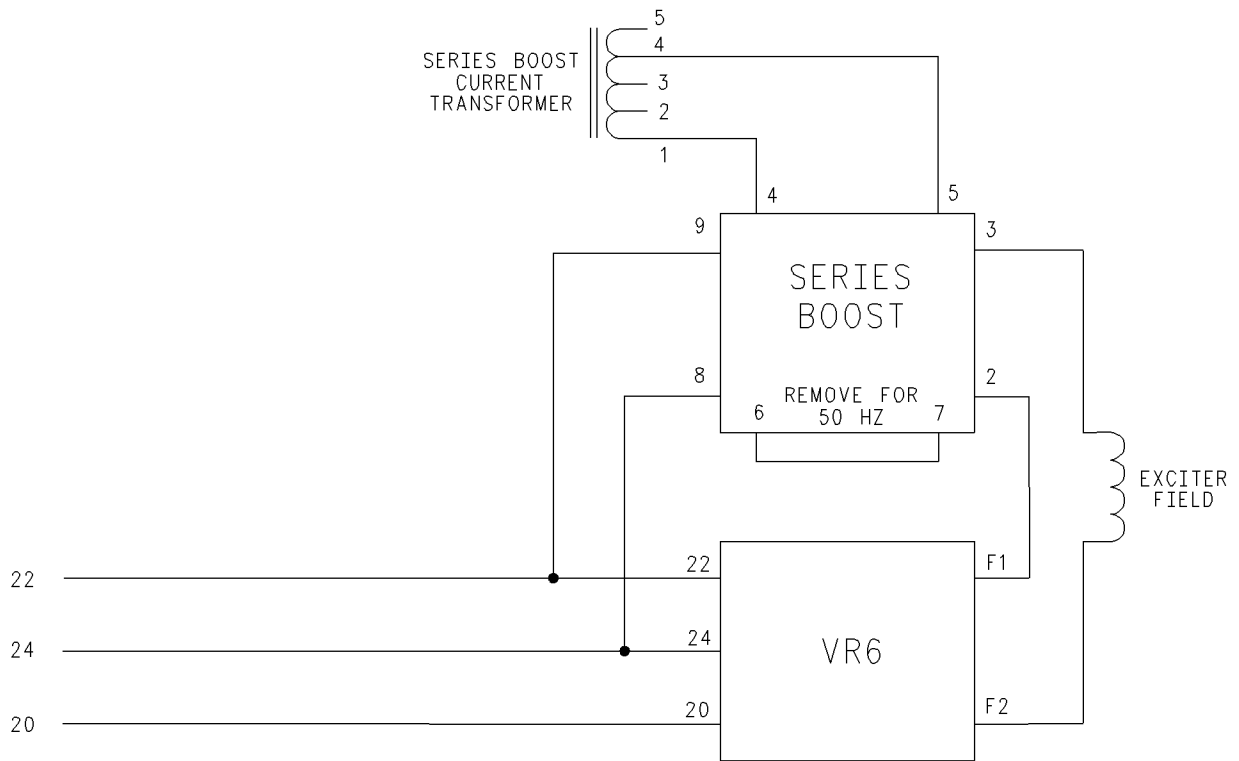


Illustration 25

g00779203

Note: Refer to Table 8 for notes.

Cross Current Compensation

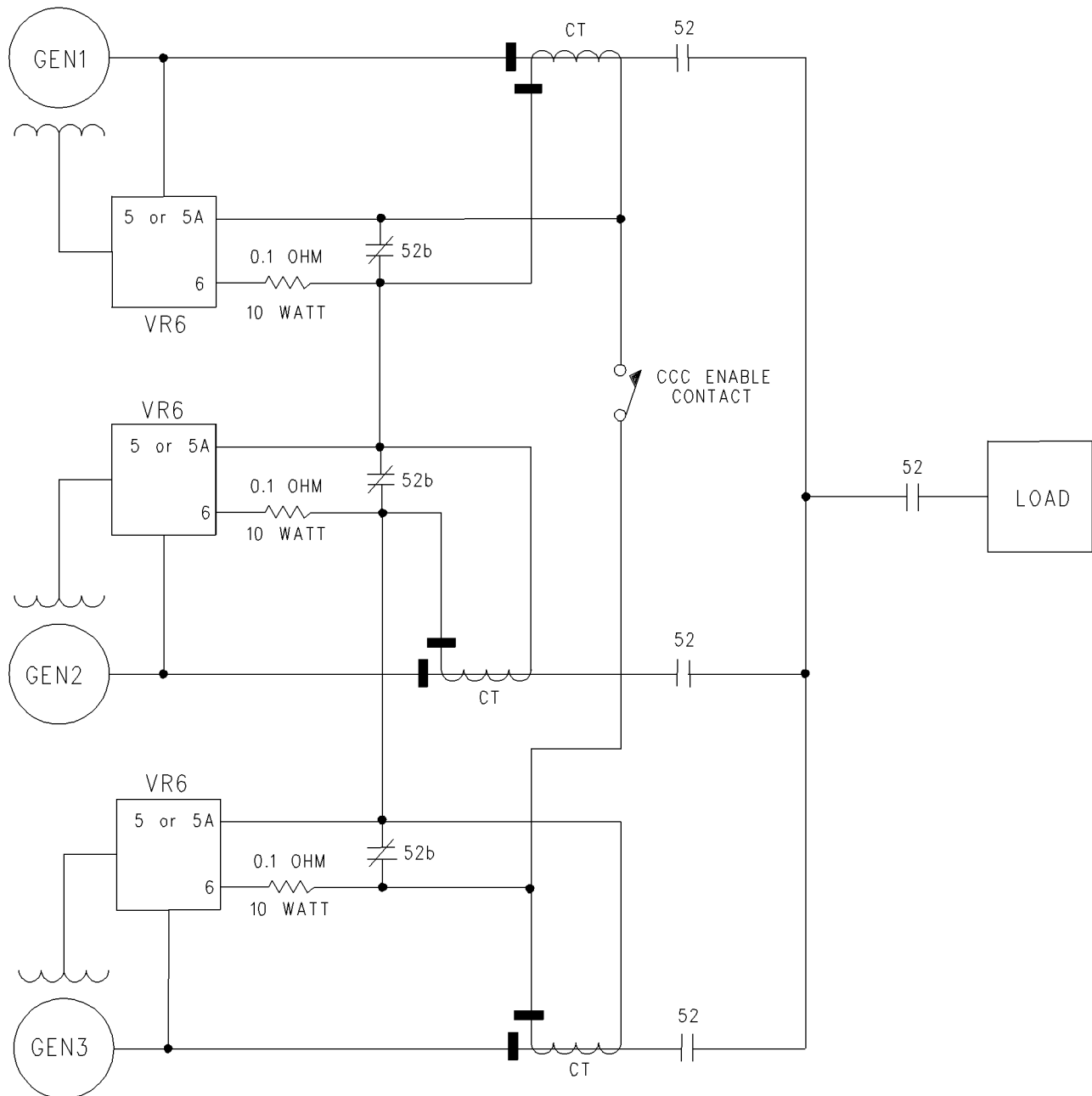


Illustration 26

g00885654

Note: Refer to Table 8 for notes.

Note: Transformer T1 must be a 5 Ampere CT.

Manual Voltage Control for SE Generators

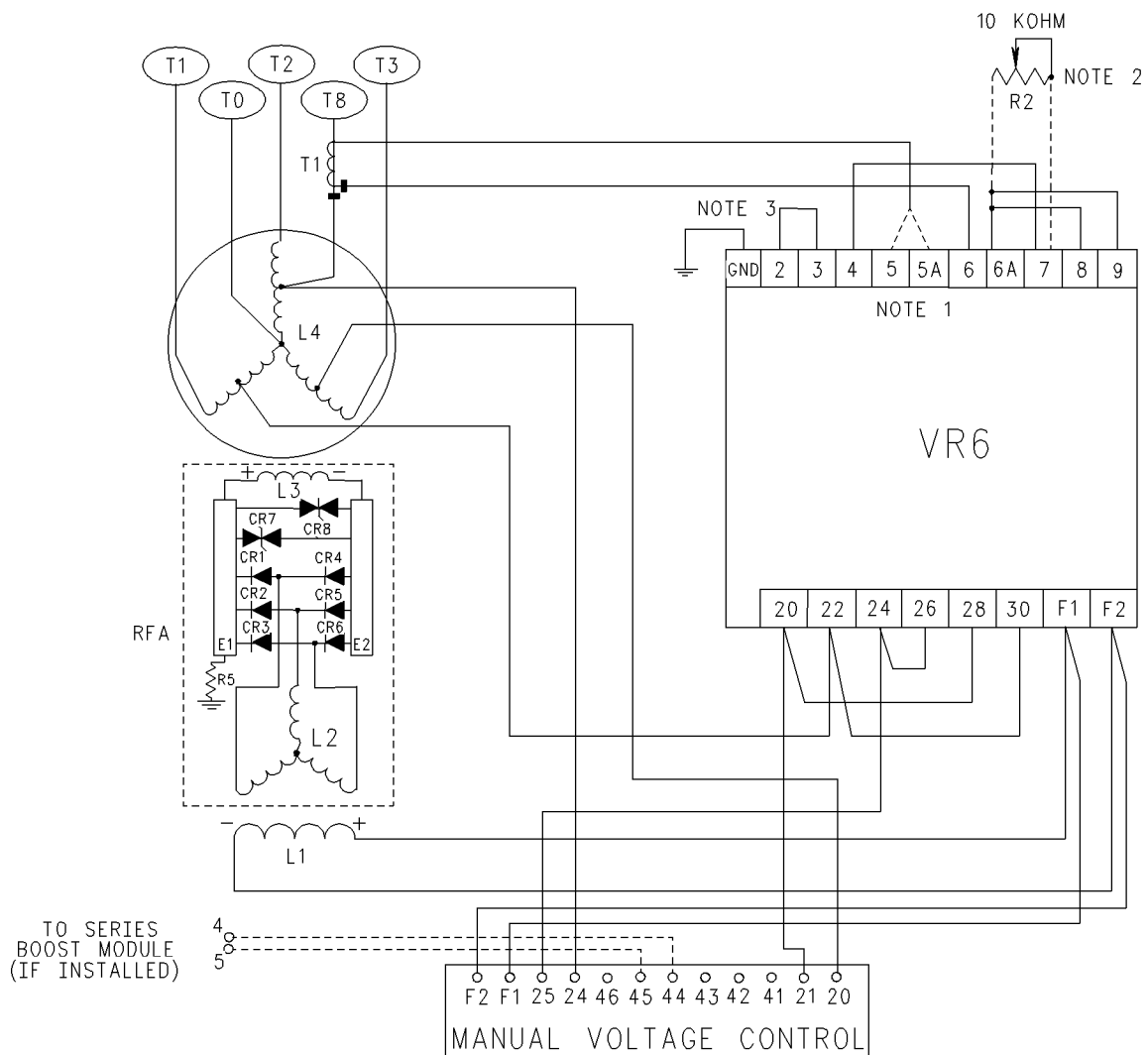


Illustration 27

g00834448

(CR1-CR6) Rotating rectifiers
(CR7, CR8) Surge suppression diodes
(E1) Positive heat sink
(E2) Negative heat sink

(L1) Exciter field (stator)
(L2) Exciter armature (rotor)
(L3) Revolving field (main rotor)
(L4) Main stator

(R2) Remote level rheostat
(R5) Suppression resistor
(RFA) Revolving field assembly
(T1) Voltage droop transformer (option)

Note: Refer to Table 8 for notes.

Manual Voltage Control for PM Generators

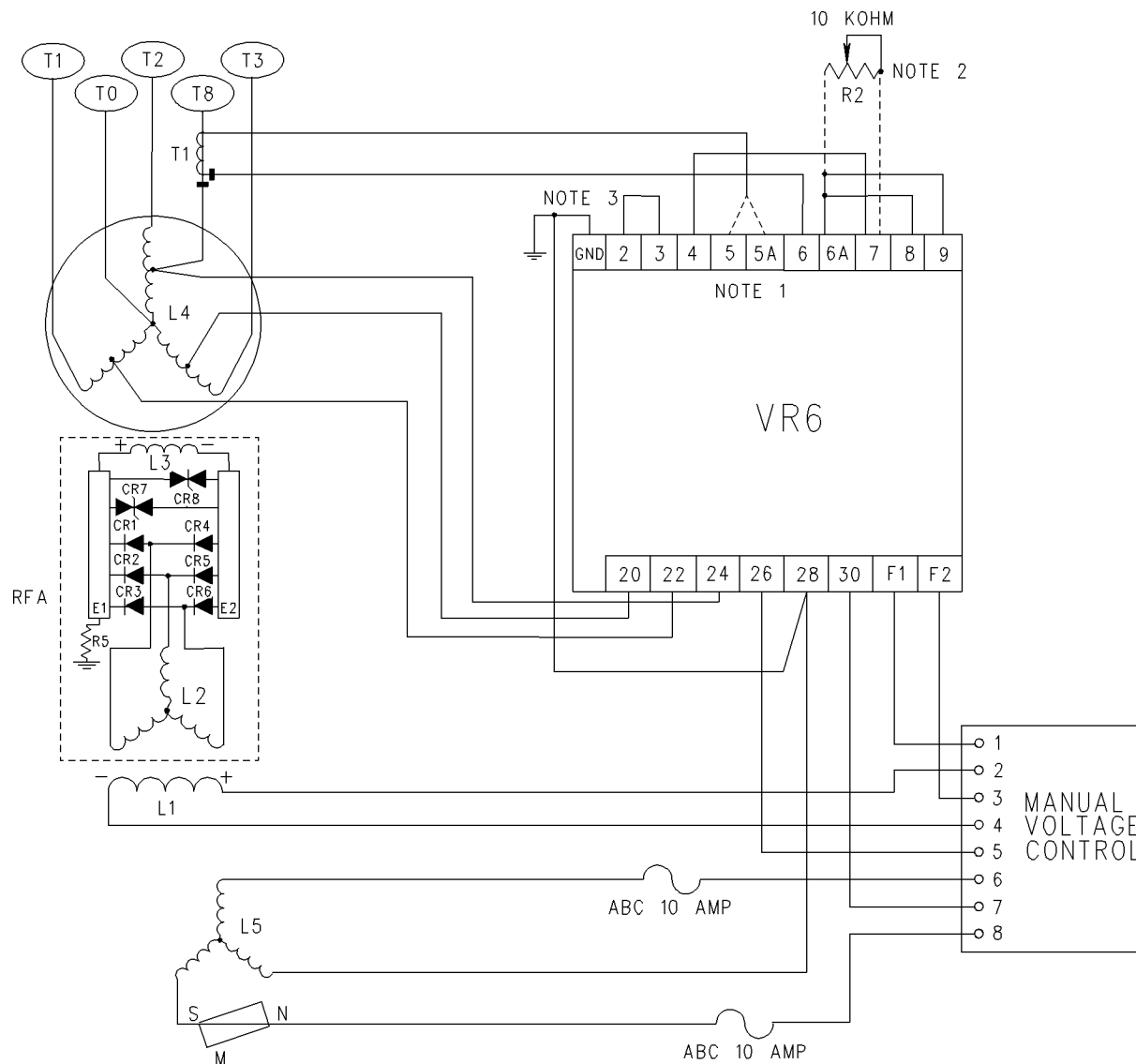


Illustration 28

g00847806

(CR1-CR6) Rotating rectifiers
(CR7, CR8) Surge suppression diodes
(E1) Positive heat sink
(E2) Negative heat sink
(L1) Exciter field (stator)
(L2) Exciter armature (rotor)
(L3) Revolving field (main rotor)

(L4) Main stator
(L5) PM exciter stator
(M) Rotating permanent magnet
(R2) Remote level rheostat
(R5) Suppression resistor
(RFA) Revolving field assembly
(T1) Voltage droop transformer (option)

Note: Refer to Table 8 for notes.

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