A-C POWER SYSTEM

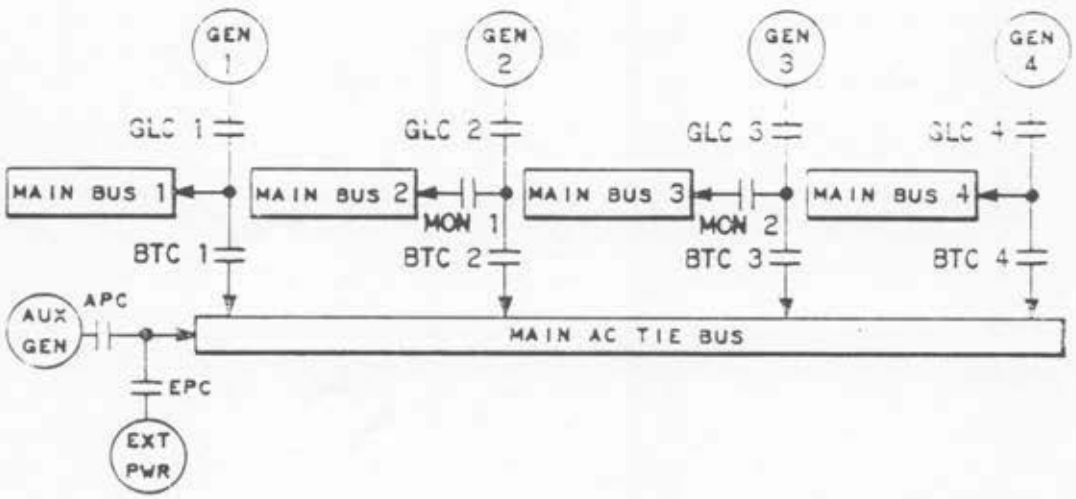
GENERAL

Electrical system power is normally supplied by four engine-driven A-C generators operating in parallel. Power can also be supplied from an external source, or an APU-driven generator, for ground checkout. Each source is capable of supplying sufficient power to checkout the electrical systems. Care should be exercised during ground checkout to ensure that overloading does not occur, since generator cooling air temperature is higher on the ground.

An emergency A-C/D-C generator can be used if hydraulic pressure is available to check part of the systems. The generator is quite small and can be used with the isolated and emergency A-C and D-C buses only.

BUS DISTRIBUTION

The primary A-C buses include four main A-C buses, two essential A-C buses, main A-C tie bus, isolated A-C bus, and emergency A-C bus. Other minor buses, such as the avionics and navigation buses, are energized by the primary buses.

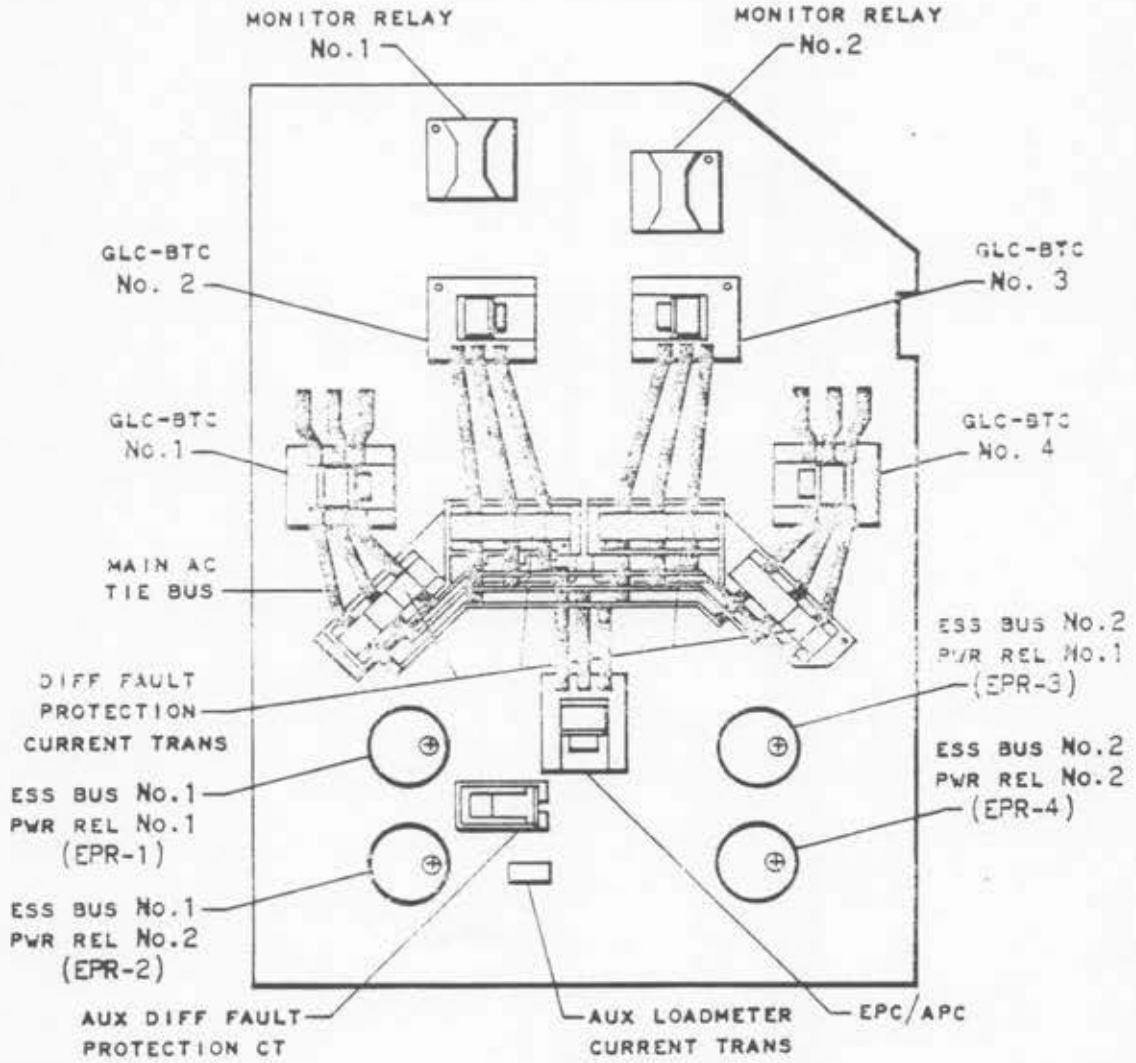


AC DISTRIBUTION

EXTERNAL POWER

External A-C power connects to the main A-C tie bus through an External Power Contactor (EPC). The Bus Tie Contactors (BTC) automatically close when the tie bus is energized. Main A-C buses 1 and 4 energize from the tie bus through the BTC's. Main buses 2 and 3 are energized through BTC's and Monitor Relays. The monitor relays automatically energize when external power is used.

If an operational main generator is turned on while external power is in use, the BTC of the associated generator opens to isolate the generator and respective main A-C bus from the tie bus. The Generator Line Contactor (GLC) closes, energizing the associated main bus from the generator. External power continues to supply the tie bus and other main and essential buses, but the sources do not parallel. The relays and contactors associated with the generators and bus distribution systems are located in the main A-C distribution center.



MAIN AC DISTRIBUTION CENTER

AUX GENERATOR

When the AUX (APU) generator is used, the Auxiliary Power Contactor (APC) is energized to connect the generator to the main A-C tie bus. The EPC and monitor relays are open when auxiliary power is used. Main A-C buses 1 and 4 are energized from the tie bus through the BTC's. If "OVERRIDE" is selected on the AUTO LOAD DISC (ALD) switches, the monitor relays energize, allowing the auxiliary generator to supply main A-C buses 2 and 3. If the auxiliary generator is in use and a main generator is turned "ON," the respective BTC will open to isolate the power sources. The main generator supplies the associated main A-C bus through the GLC, and the auxiliary generator supplies the tie bus and other main buses. Main buses 2 and 3 cannot be energized from the auxiliary generator unless "OVERRIDE" is selected.

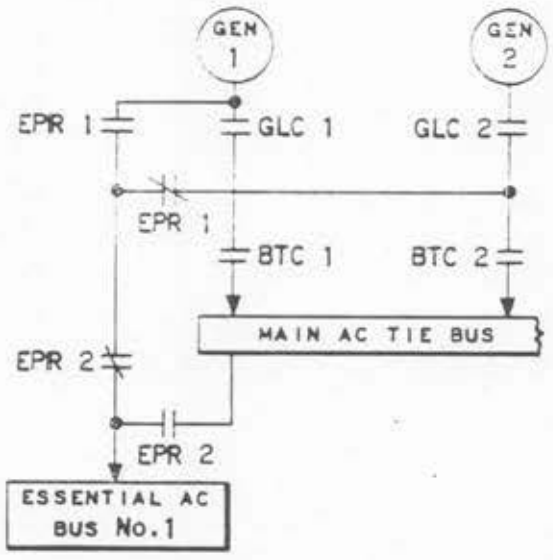
MAIN GENERATORS

The main generators normally supply the individual main buses through GLC's, and parallel at the main A-C tie bus through the BTC's. Monitor relays 1 and 2 automatically energize when two or more main generators are operating. "OVERRIDE" must be selected to energize the monitor relays when only one main generator is operating.

When a main generator is turned to the "ON" position, the respective GLC and BTC close thus energizing the main A-C bus and the main A-C tie bus. The tie bus causes the other BTC's to close. As the remaining generators are turned to the "ON" position, the GLC's and BTC's energize through the automatic paralleling circuits. With all four generators operating, the BTC's, GLC's, and monitor relays are energized and the generators share the load.

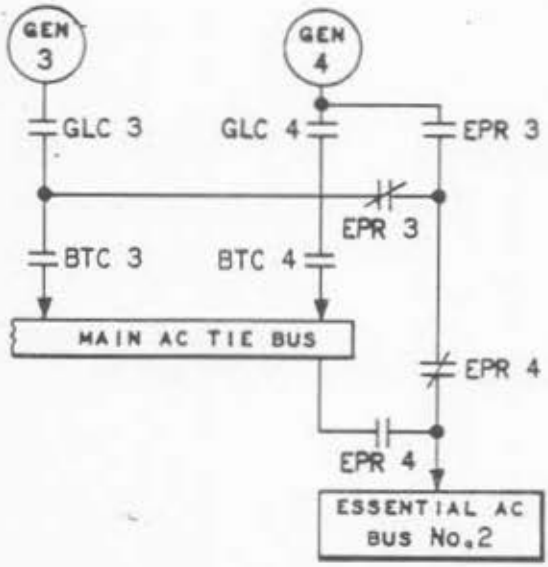
ESSENTIAL A-C BUSES

The essential buses are controlled by two power relays for each bus. The normal power source is the main A-C tie bus. When the tie bus is energized, the No. 2 Essential (Bus) Power Relays (EPR-2 and EPR-4) energize, and both essential buses receive power from the tie bus. If the tie bus fails, or is not energized, EPR-2 and EPR-4 deenergize. Essential power is then obtained from alternate power sources through EPR-1 and EPR-3.



ESSENTIAL AC BUS NO.1 POWER SOURCES

Main generator 1 is the first alternate and generator 2 the second alternate source for essential A-C bus 1. Main generator 4 and 3 are the first and second alternates for essential A-C bus 2. EPR-1 and EPR-2 determine which alternate source is used. If the first alternate power source is operating, EPR-1 and EPR-3 are energized and generator 1 supplies essential bus 1. Generator 4 supplies essential bus 2. When the first alternate source is not operating, the relays are deenergized and the second alternate supplies the bus.



ESSENTIAL AC BUS NO.2 POWER SOURCES

The alternate power source in use causes illumination of GEN 1 or GEN 2 light for essential bus 1, and a GEN 4 or GEN 3 light for essential bus 2. When the main A-C tie bus or alternate sources are not energized, bus power fails, and the main and essential bus OFF lights illuminate. The tie bus causes all lights to extinguish when energized.

SUMMARY CHART

The following summary chart provides a listing of primary power sources, relays, contactors, and buses. As each power source or combination of power sources are energized, relays and contactors energize to provide power to the correct buses. The buses are listed and power sources identified under various operational conditions. Switches necessary for operation are considered to be in the "ON" or "NORMAL" positions as required.

POWER SOURCES						RELAYS - CONTACTORS								AC BUSES		
						EPC	APC	G L C				MONITOR		BTC-NORMAL	EPR	MAIN	TIE BUS	ESS
EXT	AUX	G1	G2	G3	G4			1	2	3	4	1	2	1 2 3 4	1 2 3 4	1 2 3 4		1 2
*						*						*	*	* * * *	* *	E E E E	E	E E
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*		*				*		*				*	*	* * *	* * *	1 E E E	E	E E
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*		*	*			*		*	*			*	*	* *	* * *	1 2 E E	E	E E
*						*						*	*	BTC'S OPEN	* *		E	E E
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				*						*				" "				3

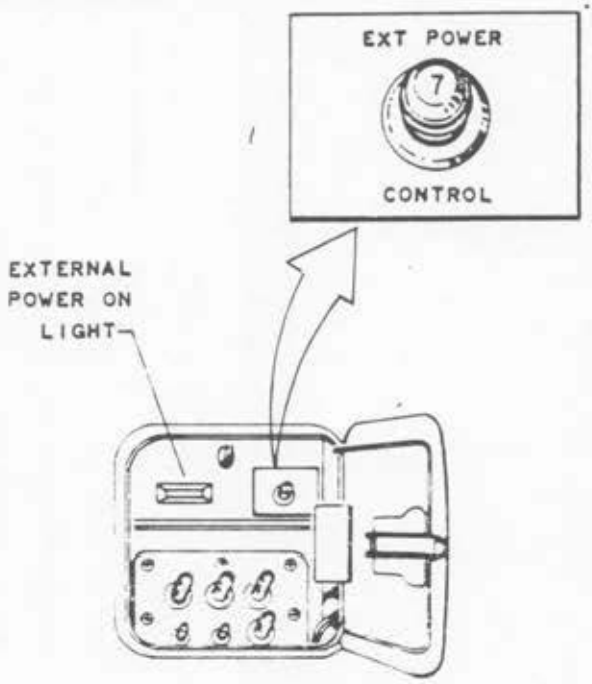
* - ENERGIZED
E - EXTERNAL POWER
A - AUX GEN POWER
1-4 - MAIN GEN POWER
P - PARALLEL SOURCES
BLANK - DEENERGIZED OR NO POWER
EPR - ESSENTIAL POWER RELAYS

A-C DISTRIBUTION RELAY CHART

EXTERNAL A-C POWER

Power from an external A-C source can be supplied to all A-C buses. The external power unit should be capable of 50/60 KVA, three-phase 115/200-volt AC at a frequency of 400 Hertz. Phase sequence should match the phase sequence (A, B, C) of the aircraft's generating systems. Incorrect phase sequence, or loss of individual phase voltage, prevents use of the unit with the aircraft.

The external power system consists of a receptacle, external power contactor, and bus protection panel. The receptacle is on the forward right side of the fuselage. The contactor is in the main A-C distribution center, and the protection panel is in the electrical equipment rack.

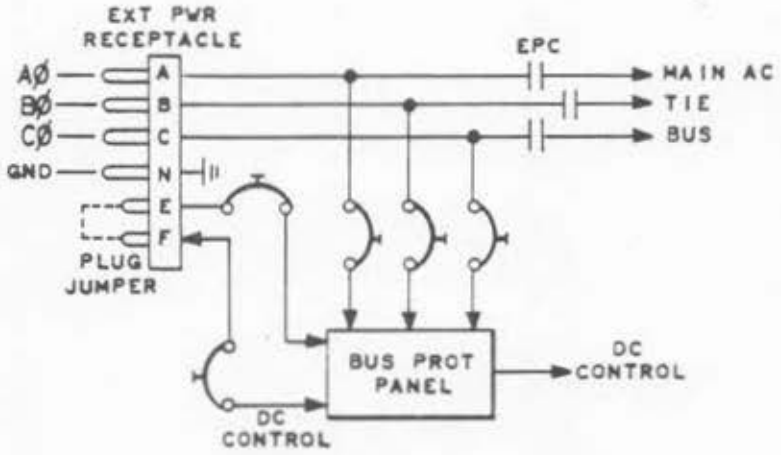


EXTERNAL POWER RECEPTACLE

The receptacle is in a recessed compartment which also contains an external power control circuit breaker and an external power "on" light. The circuit breaker is in the control circuit for external power and prevents the use of external when pulled. The light illuminates when the external power unit is supplying power to the aircraft systems.

The receptacle has four large pins and two small pins. Three of the large pins carry three-phase (A, B, C), 115-volt, AC from the power unit. The fourth pin is grounded to the aircraft structure. The small (short) pins are used in the control circuit to prevent arcing at the receptacle. No load can be applied until the plug is firmly engaged and the short control pins are mated.

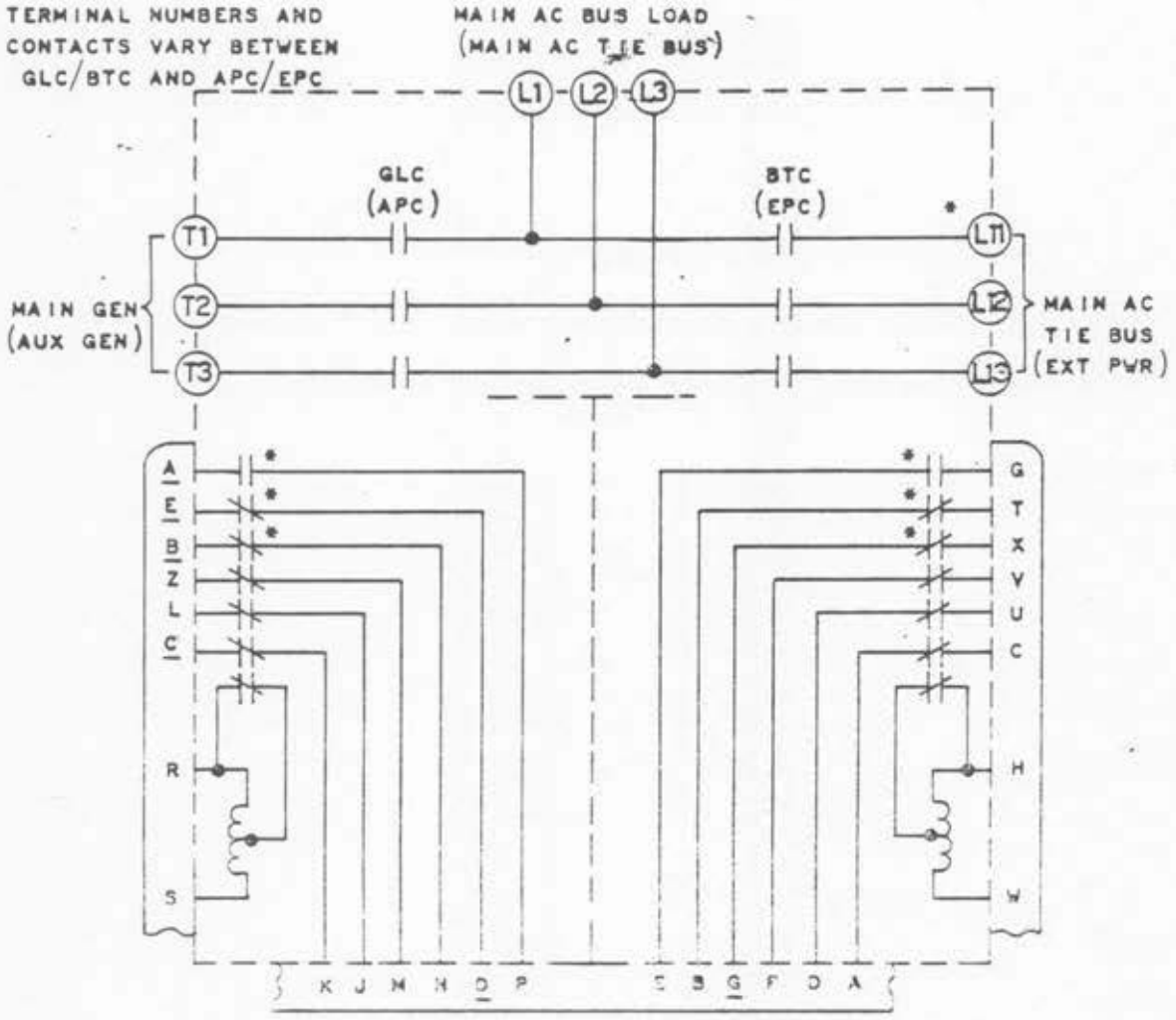
Control voltage is provided from the bus protection panel which changes the three-phase AC from the power unit to a D-C output. A jumper is provided in the plug, or GPU, between the small pins. When the plug is inserted into the receptacle, control voltage is supplied through the jumper to the aircraft's external power circuit for use with the EPC. If the power source is operating properly, the green EXT POWER READY light on the control panel illuminates.



EXTERNAL POWER CONTROL

EXTERNAL POWER CONTACTOR/AUXILIARY POWER CONTACTOR (EPC/APC)

This contactor is a relay containing interlock switches and heavy-duty relay contacts. Two functional contactors are enclosed in one housing. The EPC is energized when external A-C power is selected as a power source. The APC is energized when the auxiliary generator is selected. The actuators are mechanically interlocked to prevent simultaneous use of the contactors. The system is also electrically interlocked by the AUX/EXT power selector switch and the contacts of the GLC's and BTC's of the main generators.



GLC/BTC - EPC/APC , CONTACTOR SCHEMATIC

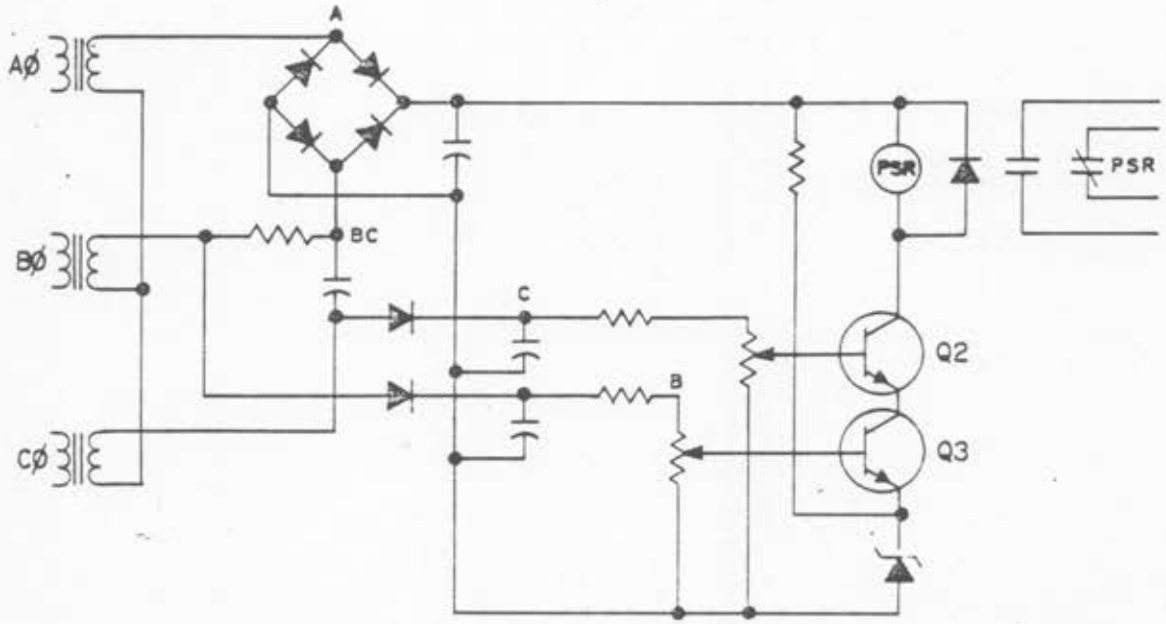
BUS PROTECTION PANEL

A combination of static components and relays is provided in the protection panel. The relays provide undervoltage and phase sequence protection when external power is being used. Panel relays are the Phase Sequence Relay (PSR), LOR, Auxiliary External Power Relays (AER-1 and AER-2), and the Synchronizing Bus Relay (SBR). The panel controls the BTC's to allow the main A-C buses to be energized from external, auxiliary generator, or main generator power.

PHASE SEQUENCE CIRCUIT

Three-phase A-C voltage is supplied to stepdown transformers and full-wave rectifiers in the bus protection panel. The D-C output is used to control the

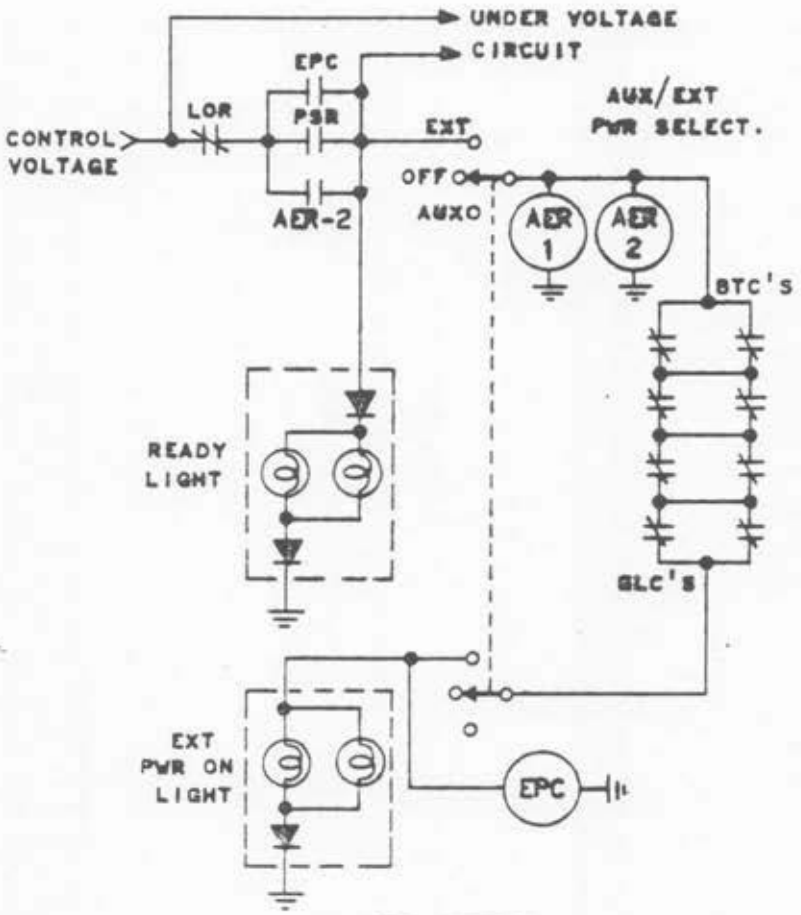
EPC and undervoltage circuit; AG is supplied to the phase sequence circuit. Phase sequence must be A, B, C or the PSR cannot energize.



PHASE SEQUENCE CIRCUIT

The phase sequence circuit consists of the PSR in series with two transistor switches and a Zener diode. The Zener diode establishes a D-C reference voltage for the transistor switches. Collector voltage for the transistors is obtained from a full-wave bridge rectifier which produces a pulsating D-C output. Output voltage is proportional to the phase A to phase BC voltage inputs. Phase BC is obtained by phase-shifting phase C and adding the result to phase B at one side of the bridge rectifier. Phase A is applied to the other side of the bridge. The positive pulsating D-C output is filtered by a capacitor and applied to the PSR in the transistor collector circuit. The PSR is energized when both transistor switches conduct. Phase B and phase C voltage is applied to half-wave rectifiers and filters then to the base of the transistor switches. When Q3 base voltage (1/2 of phase B) is more positive than the Zener voltage reference, the transistor can conduct. At the same time Q2 base voltage (1/2 of phase C) must be more positive than the collector of Q3. When its condition exists, both switches conduct to energize the PSR. Any other phase sequence, or loss of phase voltage, will not allow the PSR to energize. The PSR is energized when the three-phase average A-C input is above 93 volts, AC.

The energized PSR completes the control circuit to the external power READY light and opens the undervoltage sensing circuit. If the power selector switch is in "EXT," the EPC is energized, thus connecting external power to the main

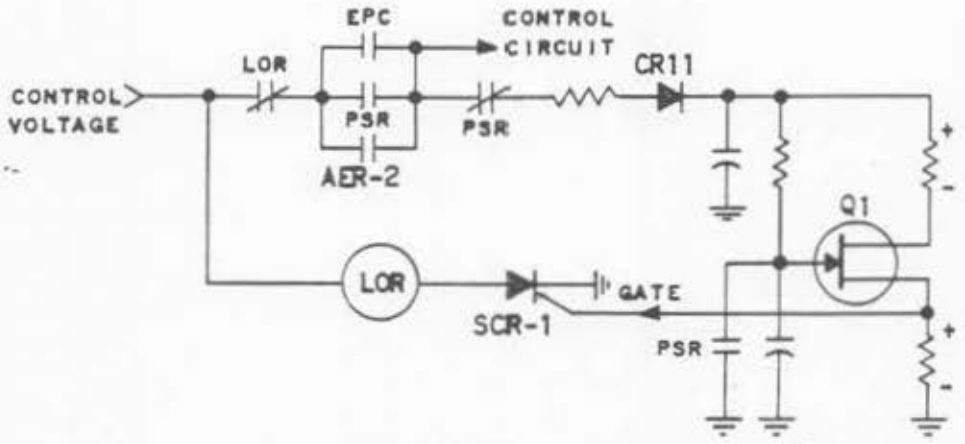


EPC CONTROL

A-C tie bus. A combination of GLC-BTC contacts controls the EPC to ensure that paralleling of internal and external power sources does not occur. A set of EPC contacts bypass the PSR contacts when energized, allowing the PSR to deenergize during low-voltage conditions. A low-voltage condition exists when the three-phase average is 93 volts, AC, or less.

UNDERVOLTAGE CIRCUIT

The undervoltage circuit is normally open due to PSR contacts. A second set of PSR contacts bypasses a time delay capacitor (C1). During a low-voltage condition, the PSR is deenergized, and the delay capacitor starts charging. Emitter voltage of a unijunction transistor (Q1) is controlled by the charging capacitor. If the low-voltage condition exists for 3 to 7 seconds, the capacitor is charged to a sufficient voltage to cause the transistor switch to conduct. Current between the two bases of the unijunction transistor develops a positive D-C output



UNDERVOLTAGE CIRCUIT

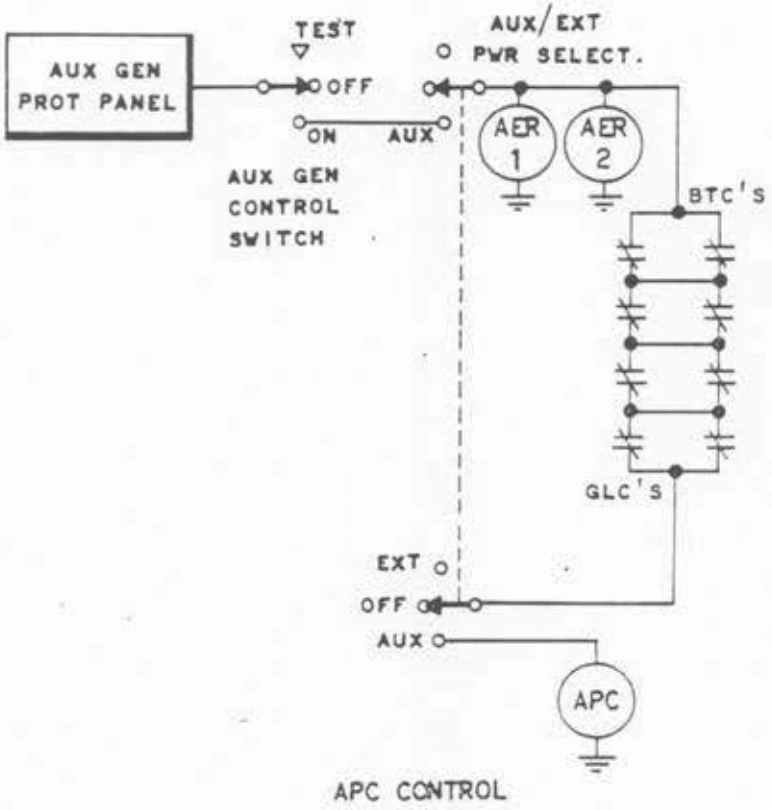
voltage. The output is supplied to a Silicon Control Rectifier (SCR). The D-C voltage gates the SCR into conduction, energizing the LOR.

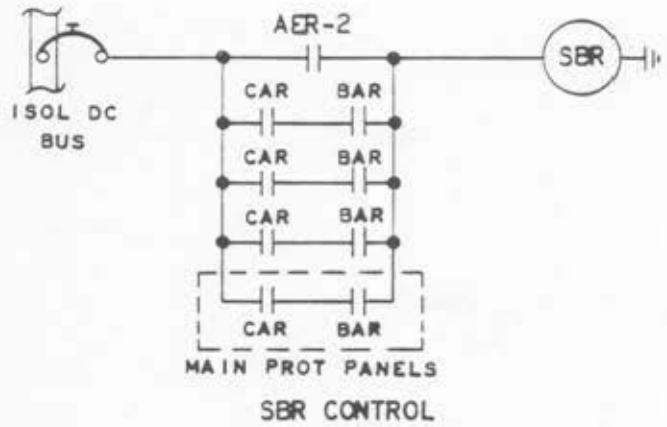
The energized LOR opens the D-C control circuit to the EPC and extinguishes the READY light. External power control voltage keeps the LOR energized through the SCR which is conducting. The SCR conduction can be stopped (reset) only by removing the control voltage. To reset the circuit, the EXT POWER CONTROL circuit breaker can be momentarily pulled to deenergize the LOR. Other methods of reset would be to remove the external power plug from the receptacle or to shut down the ground power unit. Normal power can be restored after reset of the LOR is accomplished. External A-C power cannot be used until the circuit is reset.

The "AUX" position of the power selector switch is used to energize the APC, thus connecting auxiliary generator power to the main A-C tie bus. The GLC-BTC combination of contacts again prevent paralleling of power sources. Additional relay contacts for the EPC or APC are provided by the AER-1 and AER-2 in the protection panel. The relays energize when the power selector switch is in "EXT" or "AUX" position. When the auxiliary generator is used, a set of AER-2 contacts bypasses the PSR contacts for the undervoltage circuit. External undervoltage protection is provided even though external power is not in use.

SYNCHRONIZING BUS RELAY CIRCUIT

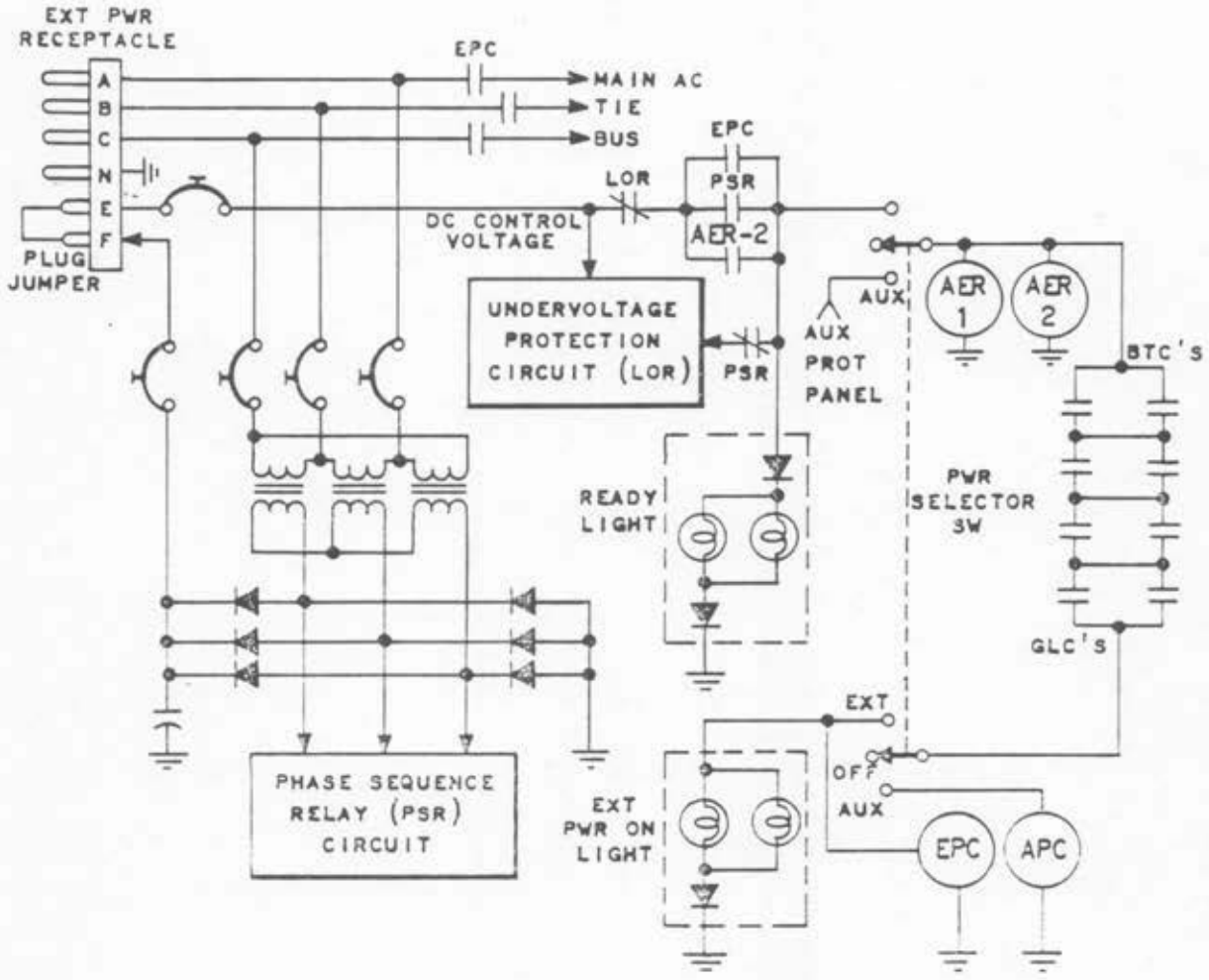
The SBR circuit is energized through contacts of AER-2 when external or auxiliary generator power is used. The SBR is also energized through the main generator protection panels when the main generators are connected to the main A-C tie bus. Contacts of the SBR allow the BTC's to energize when external or auxiliary power is used or will allow the BTC to energize when the generator switch is in the "OFF" position. The Contactor Auxiliary Relay (CAR) is energized when the GLC is energized, and the BTC Auxiliary Relay (BAR) is energized when the BTC is energized. The SBR is energized through series BAR-CAR contacts when a generator is supplying the main A-C tie bus, automatically energizing the BTC of an inoperative generator.





MAIN GENERATOR SYSTEM

The main generating system consists of four generators, CSD's, Voltage Regulators (VR's), protection panels, and load controllers. Each generator is bolted to a CSD unit which mounts on the engine accessory drive case. A Quick Attach-Detach (QAD) bolt and ring secures the CSD to the engine. The QAD is used to remove the generator and



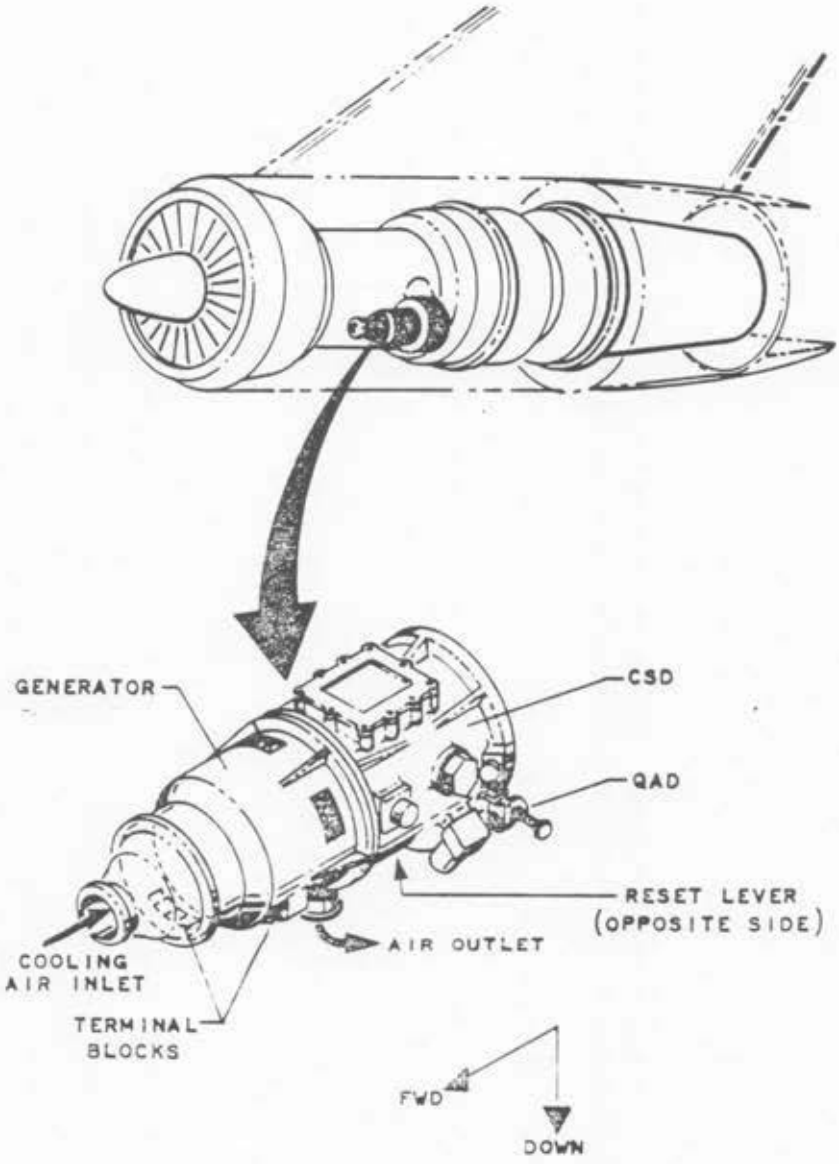
EXTERNAL AC POWER SCHEMATIC

CSD as a unit for replacement. Protection panels, VR units, and the load controllers are installed in the electrical equipment rack.

The generating systems are practically identical. The protection panels contain circuits and relays for control and protection of the generators. The voltage regulator maintains the generator voltage output at 115 volts, AC. The load controller is used in generator parallel operation to control the CSD for load equalization between generators.

GENERATOR

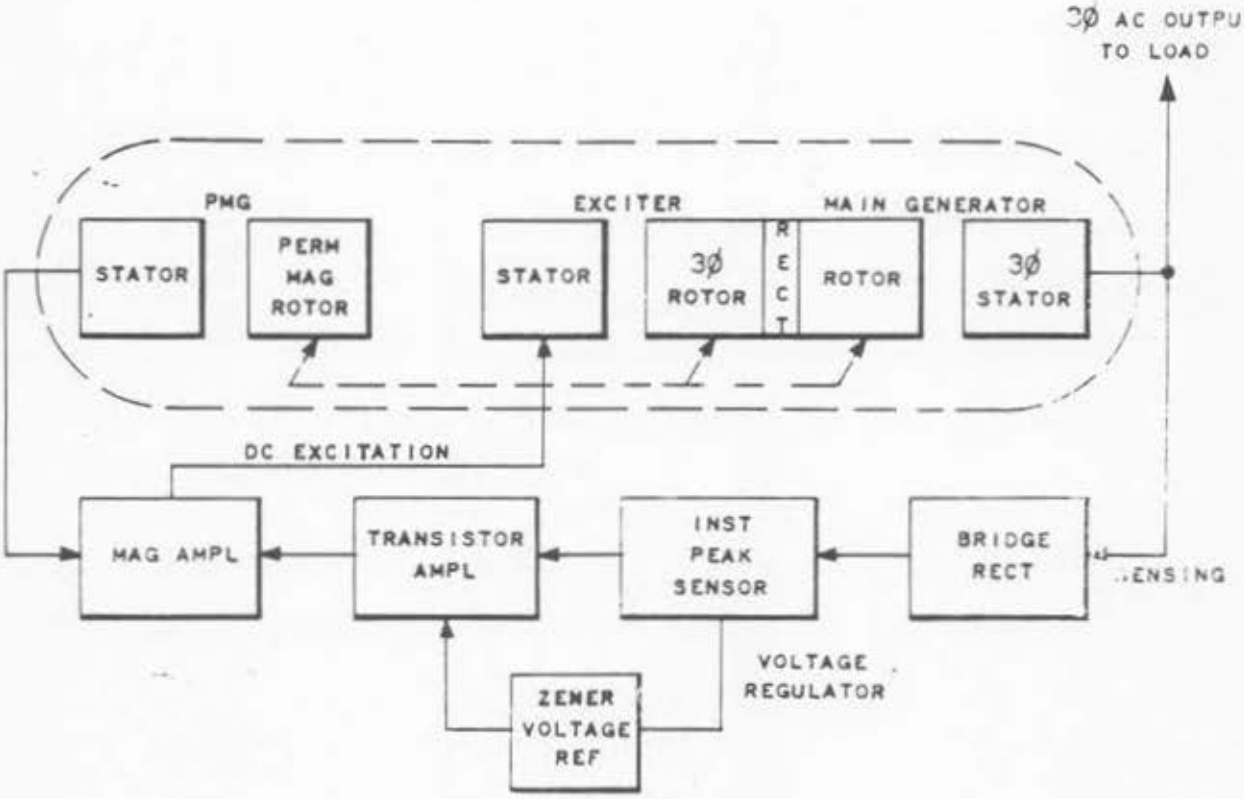
The generator is an electro-mechanical device which converts mechanical energy into electrical energy. The generator electrical output rating is 40 KVA but each generator has a thermal output rating of 50 KVA as a continuous power source.



ENGINE DRIVEN GENERATOR LOCATION

Cooling is provided by the engine fan discharge air. Output three-phase voltage rating is 120/208 volts, AC, but is maintained at 115/200 volts, AC, by the VR unit for use with the load. The CSD is a hydraulic mechanical constant speed drive which provides a generator shaft speed of 6000 RPM. At 6000 RPM the generator produces a frequency of 400 Hertz.

A brushless generator is actually three generators in one housing. It has no sliprings, brushes, or commutator. The housing contains a Permanent Magnet Generator (PMG), exciter generator, and main generator.



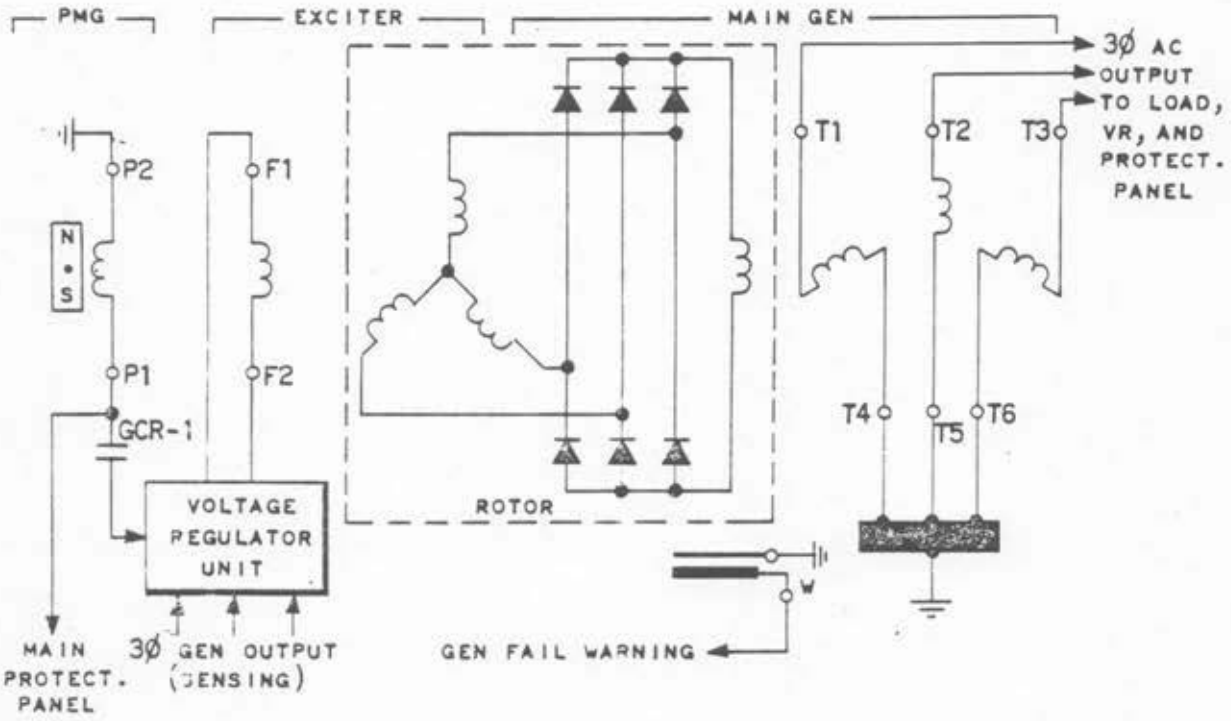
BRUSHLESS GENERATOR AND REGULATOR

The PMG rotor, which is part of the same shaft as the main rotor, contains 8 permanent magnets and produces a single-phase output of 105 volts, AC, at a frequency of 1600 Hertz. The output from the stator (terminal P1) is supplied to the protection panel and then to the VR unit. The PMG voltage is used for protection and control of the generator system.

Contacts of a Generator Control Relay (GCR-1) in the protection panel complete the PMG circuit to the VR unit. The contacts disable the generator exciter and high-voltage output until the generator is turned to the "ON" position. The PMG output to the protection panel is continuous when the engine is running.

The VR unit's D-C output is supplied to the generator exciter field (stator) in the exciter section. The exciter rotor contains three windings 120 degrees apart and generates a three-phase, A-C voltage. The AC is changed to DC by a three-phase, full wave rectifier which provides excitation to the main generator's rotor field windings.

The main field windings consist of four rotating electromagnets (8 poles). The main stator has three fixed windings at 120-degree intervals. Each stator has



BRUSHLESS GENERATOR

develops 115 volts, AC, at 400 Hertz when the shaft is 6000 RPM. The VR unit determines the generator voltage by sensing the output voltage and varying exciter field current accordingly to maintain the 115-volt output.

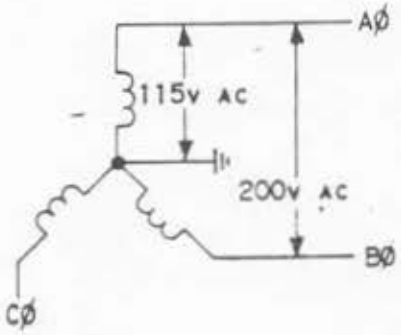
The main generator's stator windings provide three A-C voltages at 120-degree phase relationships. Terminals T4, T5, and T6 are connected to ground (aircraft structure) to provide a three-phase, four-wire (WYE) generating system. Three-phase AC is obtained from terminals T_1 (phase A), T_2 (phase B), and T_3 (phase C). It is supplied to contactors in the main A-C distribution center. The fourth wire is grounded to the aircraft structure. Voltage from phase-to-ground is 115 volts, AC. The voltage from phase-to-phase is 200 volts, AC (1.70 times phase voltage) since the voltages are 120-degree out of phase.

A Warning (W) terminal provides an indication of generator bearing failure. An insulated copper bar runs lengthwise along the surface of the stator, close to the rotor. The stator frame is the ground. If the bearings fail, the rotor shears the bar causing it to ground against the stator frame. When this occurs, a GEN FAIL light on the electrical panel illuminates. The generator can be disabled by disconnecting the CSD. The CSD disconnect switch energizes a solenoid in the CSD which causes the CSD to disconnect from the engine drive. Disconnect must not be attempted with a stopped engine. Reset of the CSD can be accomplished only when the engine is fully stopped by pulling the RESET lever on the CSD unit.

MAIN PROTECTION PANEL

The protection panels provide relay control and protection of each generating system. The panels provide the following:

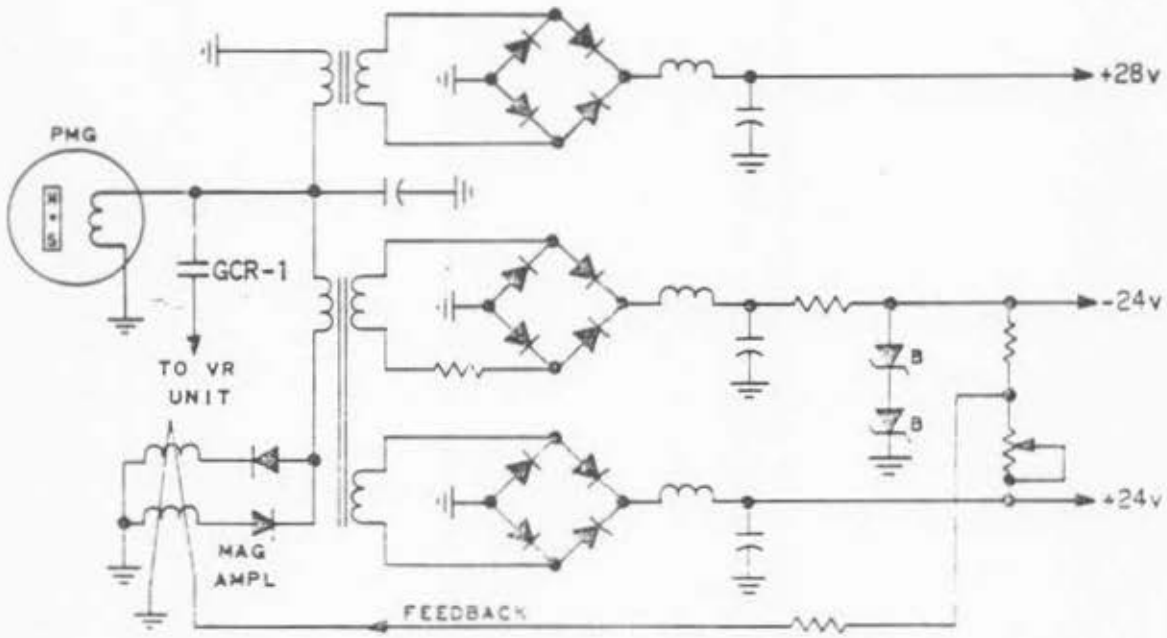
- o A D-C source for control of each system
- o Individual phase voltage sensing
- o Undervoltage protection with fixed time delay
- o Overvoltage protection with variable time delay, time inverse to amplitude
- o Differential fault (ground fault) protection with fixed time delay
- o Neutral current protection with fixed time delay
- o Unbalanced current protection with fixed time delay
- o Reactive bias circuit for load equalization
- o Underexcitation protection
- o Power lockout circuit
- o Automatic paralleling circuit
- o Auxiliary relays



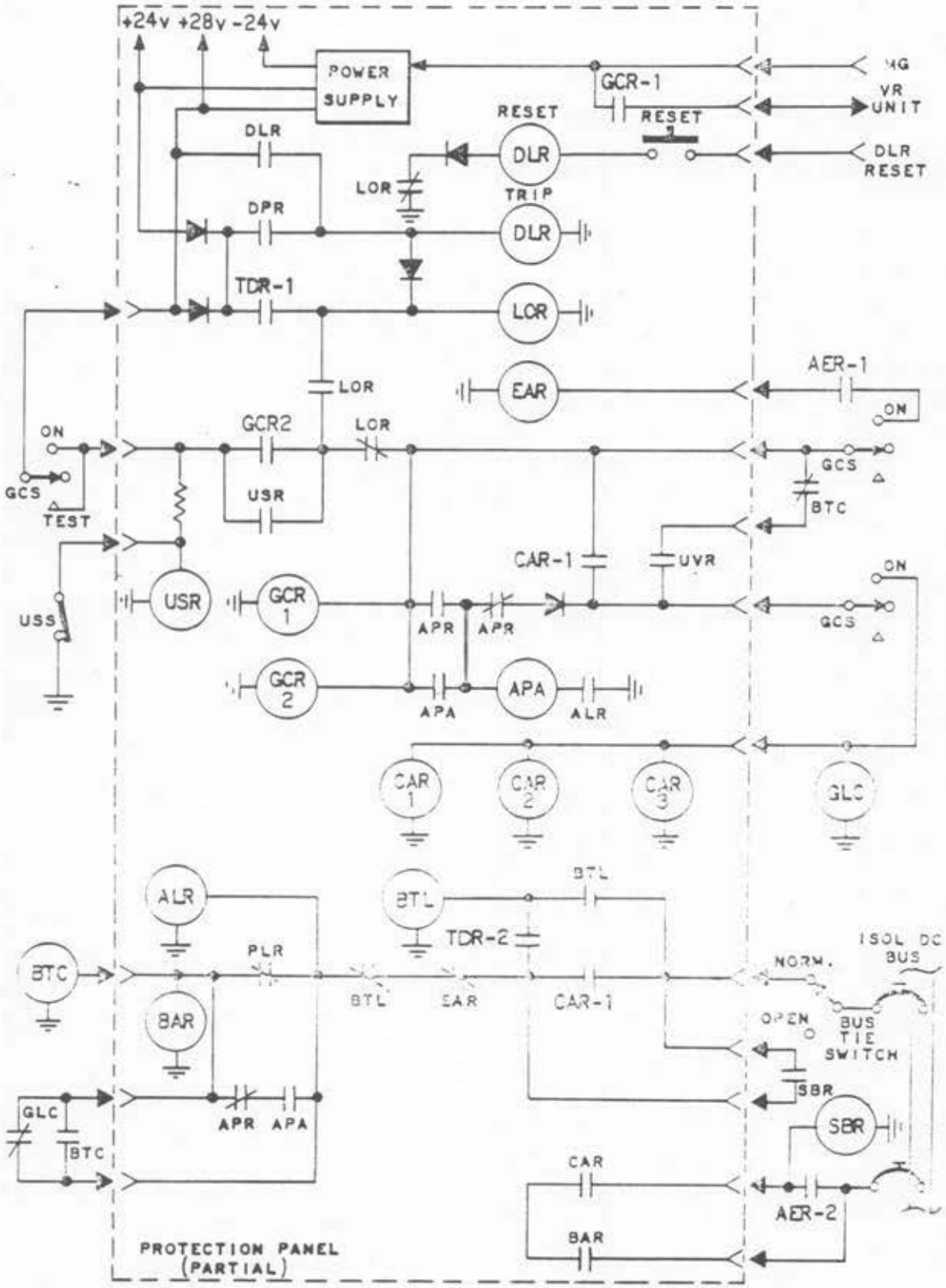
115/200 V AC GENERATOR OUTPUT

POWER SUPPLY CIRCUIT

The protection panel D-C supply provides positive and negative D-C voltage for the various protection, control, and relay circuits. The power supply input is PMG voltage from the main generator which is supplied to stepdown transformers. A variable impedance magnetic amplifier in series with one transformer primary controls primary current. The transformer secondary windings supply AC to a bridge rectifier which produces positive and negative 24-volt, D-C outputs. Zender diodes regulate the negative 24-volt D-C output.



PROTECTION PANEL POWER SUPPLY



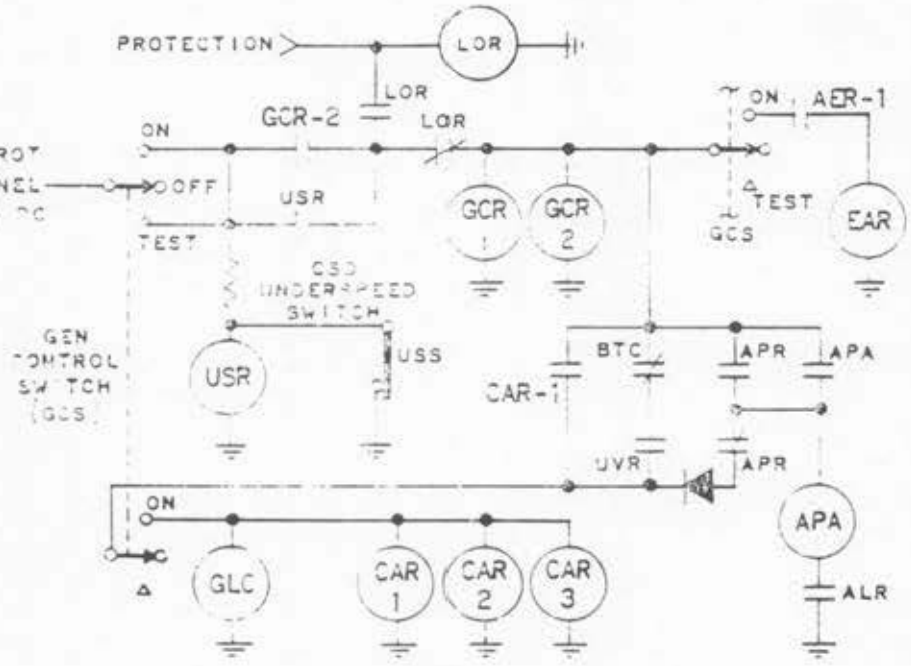
GENERATOR PROTECTION PANEL

Feedback is supplied to the magnetic amplifier from the center point between the negative and positive supply. If the D-C voltage changes, feedback to the magnetic amplifier varies the transformer primary current to maintain a constant 24-volt output. The PMG voltage is supplied to a second transformer and bridge rectifier which provides a positive 28-volt D-C output.

UNDERSPEED RELAY CIRCUIT

The 28-volt, D-C output of the power supply is routed through the "ON" position of the generator control switch to the Underspeed Relay (USR). The USR is energized when the underspeed switch (USS) in the CSD opens. The switch opens when the CSD operating speed is above 5700 RPM and closes when the speed is below 5400 RPM.

The energized USR contacts allow GCR-1 and GCR-2 to energize. Relay GCR-1 connects the PMG output of the generator to the VR unit which then provides excitation to the generator. Contacts of GCR-2 provide a holding circuit to the GCR's, bypassing the USR contacts. The bypass prevents loss of power during momentary underspeed conditions.



GLC CIRCUIT

GLC CONTROL

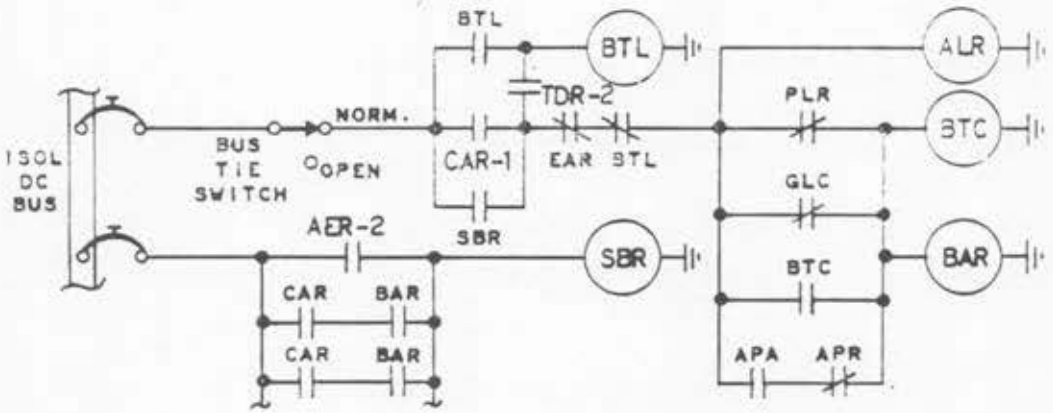
When the generator output voltage is above 103 volts, AC, per-phase, the under-voltage relay (UVR) is energized thus completing a circuit through BTC contacts to the GLC and CAR-1, CAR-2, and CAR-3. Relay CAR-1 is used with the GLC-BTC circuit; CAR-2 is used with the SBR circuit; and CAR-3 is used with the unbalanced current circuit.

The GLC can be energized through normally closed BTC contacts or through the automatic paralleling circuits. When the GLC and CAR's energize, the BTC is controlled by the automatic paralleling circuits. If the BTC is energized, the GLC is controlled by the automatic paralleling circuits.

Contacts of CAR-1 bypass the BTC-UVR contacts and GLC paralleling circuit to hold the GLC energized, thus preventing power loss during momentary undervoltage conditions. The GLC connects the generator output to the main A-C bus. If the generator control switch is in the "TEST" position, the generator produces an output, but the GLC cannot energize. The generator operates but does not supply a load.

The normally deenergized LOR is energized from the protection circuits during a fault or trouble to disable the generator (GEN OUT). It remains energized after a trouble through LOR holding contacts.

The system is reset by positioning the generator control switch to "OFF" then "ON," breaking the LOR holding circuit.

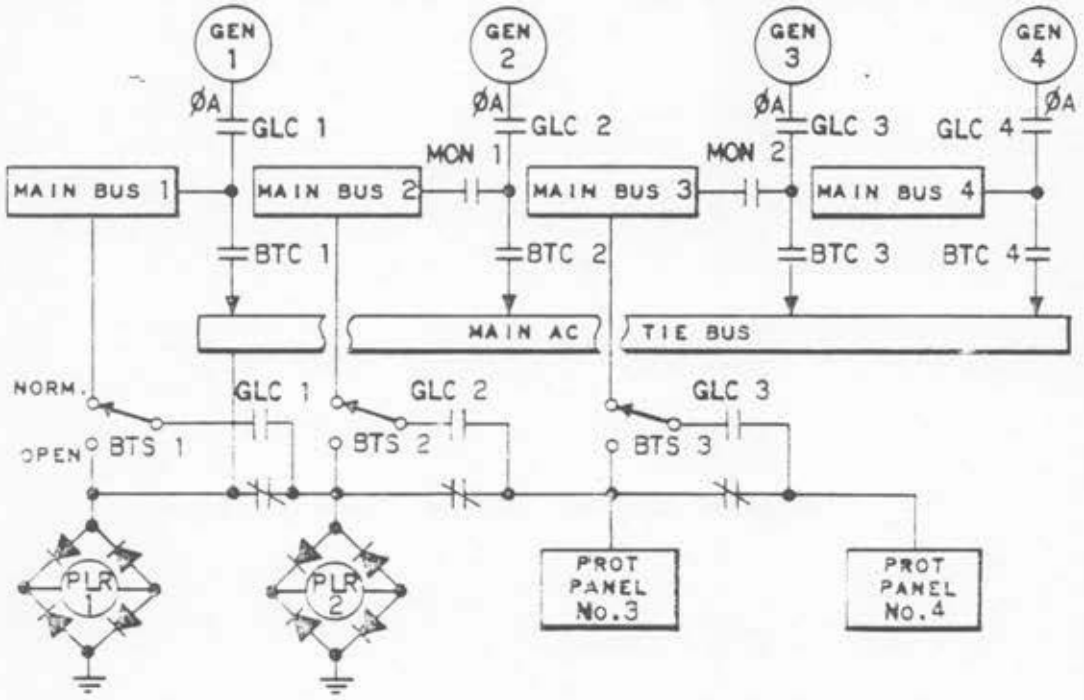


BTC CIRCUIT

BTC CONTROL

The BTC can be energized when the BUS TIE switch is in "NORMAL" and D-C voltage is supplied through CAR-1, External Power Auxiliary Relay (EAR), and Bus Tie Lockout Relay (BTL) contacts. The CAR-1 contacts are used when the generator is operating and the SBR contacts are used if the generator switch is in the "OFF" position. The BTC and BTC Auxiliary Relay (BAR) energize through the Power Lockout Relay (PLR) contacts, or through the GLC contacts if the generator switch is in the "OFF" position. Contacts of the BTC connect the power source to the load and provide a holding circuit to the BTC. The main A-C bus source can supply the main A-C bus through the BTC.

The EAR controls the BTC to prevent auxiliary or external power from paralleling with the generators. If external or auxiliary power is supplying the main A-C tie bus, the EAR is energized due to relay AER-1 which causes the BTC's to deenergize. The AER-1 is energized when external or auxiliary power is in use.



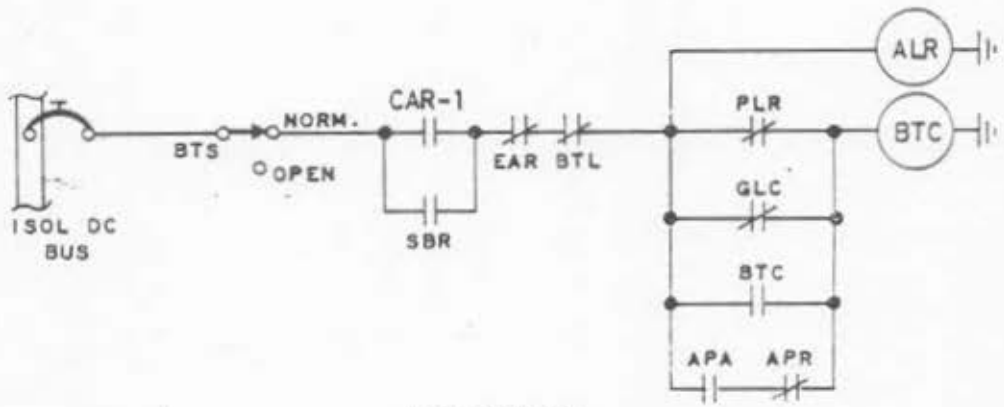
PARALLELING SEQUENCE CIRCUIT

AUTOMATIC PARALLELING

The PLR, the Automatic Paralleling Auxiliary Relay (APA), and the Automatic Paralleling Relay (APR) are part of the automatic paralleling control circuits. The paralleling sequence and synchronizing circuits allow the main generators

to operate in parallel. The first generator in operation is connected to the main A-C tie bus through the BTC. The remaining generators synchronize with the tie bus source and then parallel through the respective BTC's or GLC's.

Normal paralleling priority of the generators when all four are operating is the Main Generators 1, 2, 3, or 4 to the main A-C tie bus. The priority is established by the PLR's. PLR-1 is energized by the first power source connected to the tie bus. If generator 1 is in the "ON" position, GLC-1 and the CAR's energize. The BTC-1 is energized through the PLR-1 contacts since the tie bus and PLR-1 are not yet energized. Generator 1 supplies power to the tie bus through BTC-1, and PLR-1 is energized. BTC-1 remains energized through holding contacts of BTC-1. The remaining generators automatically synchronize with Generator 1 and then connect to the tie bus.

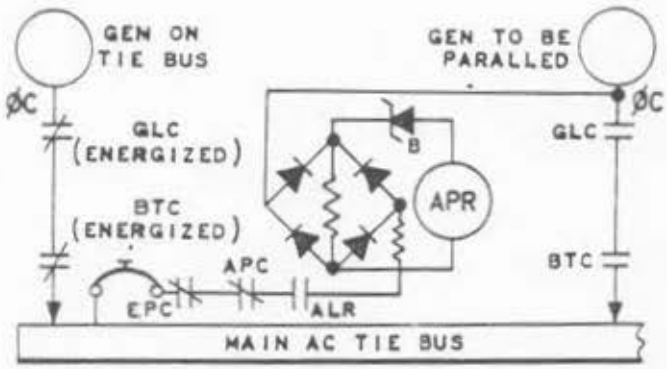


BTC CONTROL

PLR-2 is energized from main A-C bus 1 (Generator 1) through the Bus Tie Switch (BTS) and GLC-1 contacts (energized). BTC-2 can be energized only through the series contacts of APA and APR since PLR-2 contacts are open. The APR is energized by D-C voltage from Bridge A rectifier. The rectifier changes the tie bus Phase C voltage and generator Phase C voltage to DC for the APR. The APR is normally energized until the voltages are approximately equal in amplitude and phase. A Zener diode in series with the APR determines the minimum voltage difference below which the APR is deenergized. The deenergized APR allows the APA to energize. The APA-APR contacts are then closed and BTC-2 is energized thus paralleling the sources to the tie bus. The remaining generators automatically parallel in a similar manner through the respective BTC's or GLC's due to the PLR, APR, and APA.

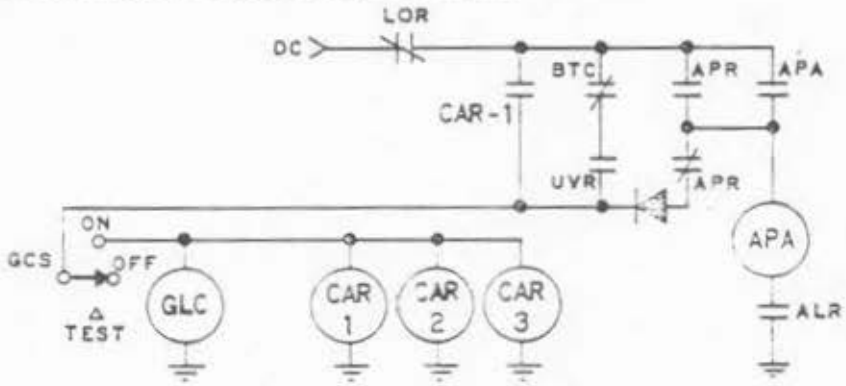
Holding contacts of the APA bypass the APR contacts to keep the APA energized, during voltage fluctuations to the APR. The sequence circuits are bypassed through the BTC holding contacts after paralleling is completed. Paralleling is indicated by equal readings on the generator loadmeters.

If Generator 1 switch is in the "OFF" position, Generator 2 would be the first generator connected to the tie bus. If the bus tie switch of an operating generator is placed in the "OPEN" position, the BTC cannot energize. The associated PLR is energized from the tie bus to allow paralleling of the bus loads. The BTC is energized through GLC contacts, allowing the main A-C to be energized from the tie bus power source.



AUTOMATIC PARALLELING

The automatic paralleling circuits control the GLC when the generator switch is "OFF" and the BTC is energized. When the generator control switch is placed in the "ON" position, the APR is energized. The APR allows the APA to energize and to hold through APA contacts. The APR is already energized through the BTC control circuit. When the generator phase C voltage is approximately in-phase with the main A-C tie bus voltage, the APR is deenergized. The GLC is then energized through the series APA contacts.



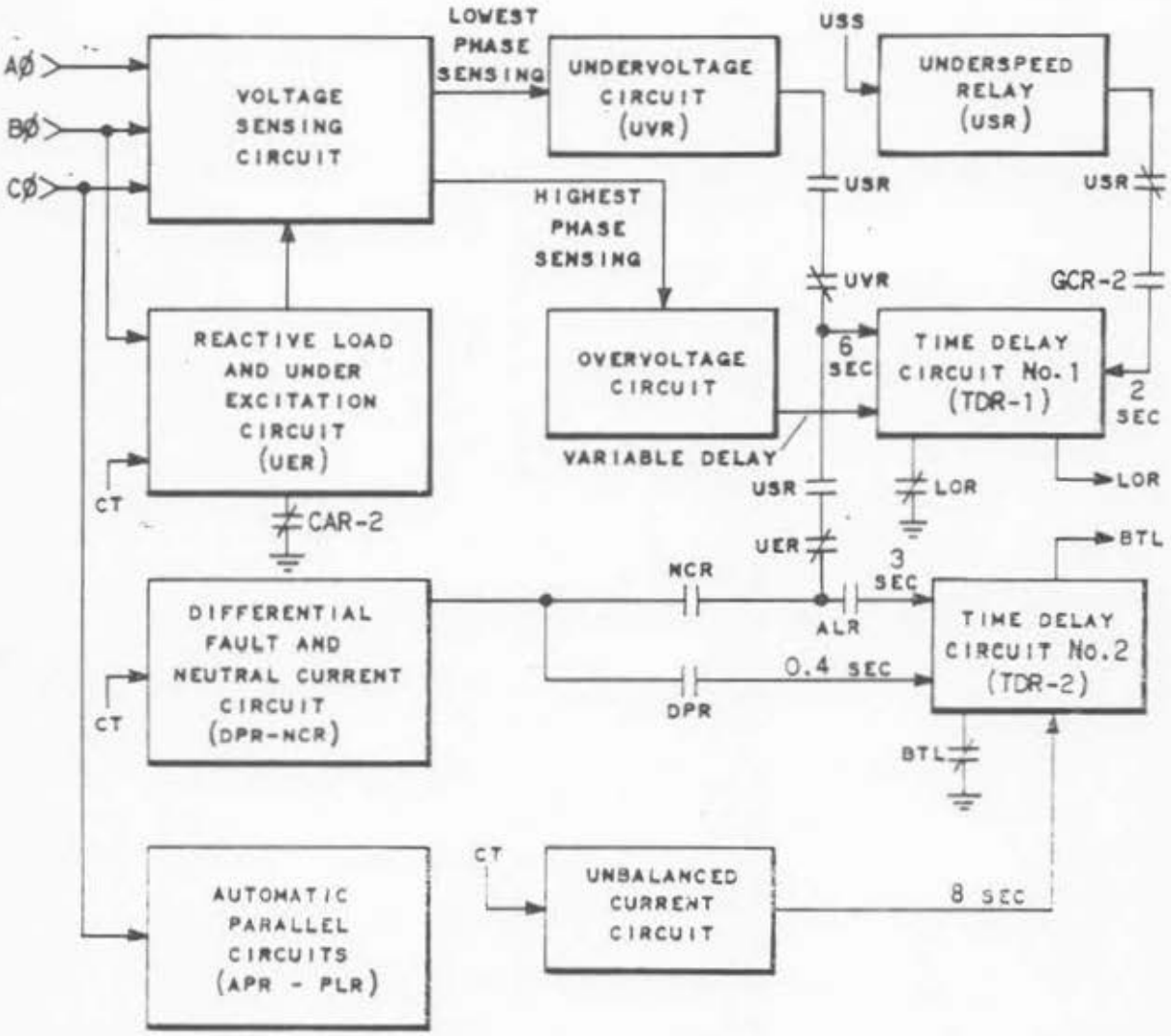
GLC CONTROL

If external A-C power or auxiliary generator power is in use, the BTC's are energized through the SBR contacts. The BTC's are also energized through SBR contacts if the associated generator switch is in the "OFF" position thus allowing the tie bus source to supply power to the main A-C bus.

PROTECTION CIRCUITS

The generator protection panel contains circuits which protect the generating and bus distribution system. The panel provides undervoltage, overvoltage, differential

fault, neutral current, unbalanced current, and underspeed protection. Delay circuits are used to prevent transient conditions from energizing the protective relays.



PROTECTION CIRCUITS

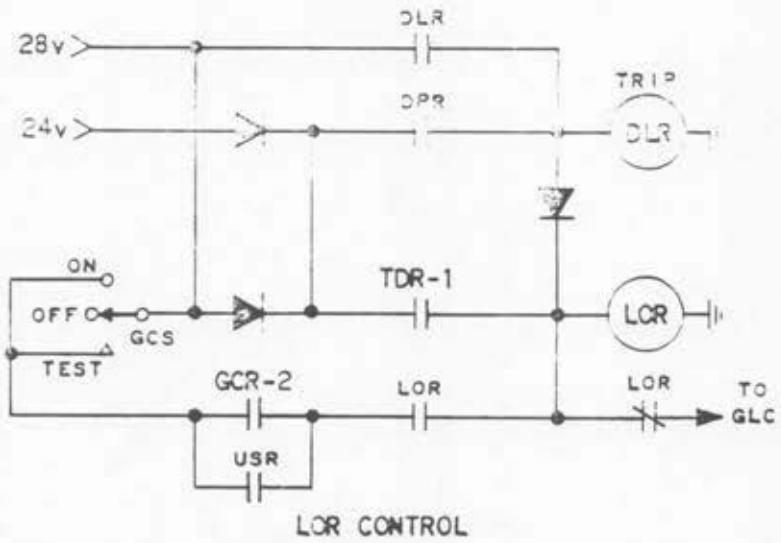
An undervoltage condition trips the BTC in 3 seconds and the GLC in 6 seconds. If the undervoltage condition is due to underexcitation of the generator, the BTC does not trip. An overvoltage condition trips the GLC in a time period inverse to voltage, maximum time not to exceed 10 seconds. A differential fault trips the GLC immediately. If the GLC does not clear the fault, the BTC is tripped 0.4 second after the GLC.

CONDITION	TRIP	TIME	REMARKS	AUX GEN
UNDERVOLTAGE	BTC	3 SEC	DOES NOT TRIP IF DUE TO UNDEREXCITATION	
UNDERVOLTAGE	GLC	6 SEC		*
OVERVOLTAGE	GLC	VARIABLE	TIME IS INVERSE TO VOLTAGE, MAX. TIME 10 SEC	*
DIFFERENTIAL FAULT	GLC	INSTANT		*
DIFFERENTIAL FAULT	BTC	0.4 SEC	BTC TRIPS IF FAULT IS BETWEEN GLC-BTC	
NEUTRAL CURRENT	BTC	3 SEC		
UNBALLANCED CURRENT	BTC	8 SEC		
UNDERSPEED	GLC	2 SEC	CONTROLLED BY UNDERSPEED SWITCH	*

NOTE: * AUX GENERATOR PROTECTION

GENERATOR PROTECTION CHART

The GLC is controlled by the LOR which is normally deenergized. The LOR is energized through TDR-1 or through the DPR. The TDR-1 is energized during an overvoltage, undervoltage, or underspeed condition, causing the LOR to energize. The DPR is energized during a differential fault (ground fault) condition, causing the LOR and trip coil of the Differential Lockout Relay (DLR) to energize. The DLR is a two coil relay which remains in either condition (tripped or reset).

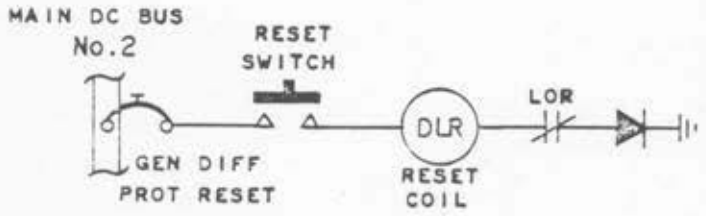


LOR CONTROL

The energized LOR disables the generator by deenergizing the GLC, CAR's and

GCR's. The LOR is held energized through LOR contacts, or through DLR contacts after a differential fault.

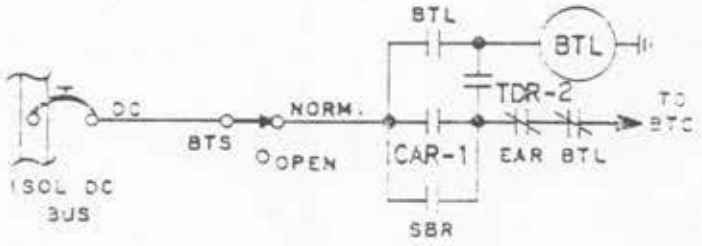
The LOR can be reset by stopping the engine in order to remove the PMG input voltage to the power supply. Loss of the power supply causes the LOR to deenergize. The DLR can be reset by energizing the DLR reset coil after the LOR is reset. A reset pushbutton on the protection panel must be pushed to energize the DLR reset coil.



DLR RESET

A differential fault is indicated by illumination of the GEN OUT light when the generator control switch is in the "ON" and "OFF" positions. The other faults require the generator control switch to be "ON" before the GEN OUT light illuminates.

The BTC is controlled by the BTL relay which is normally deenergized. The BTL is energized through TDR-2 and is held through BTL contacts. The TDR-2 is energized due to an undervoltage, differential fault, neutral current, or unbalanced current condition. The energized BTL opens the circuit to the BTC and BAR.

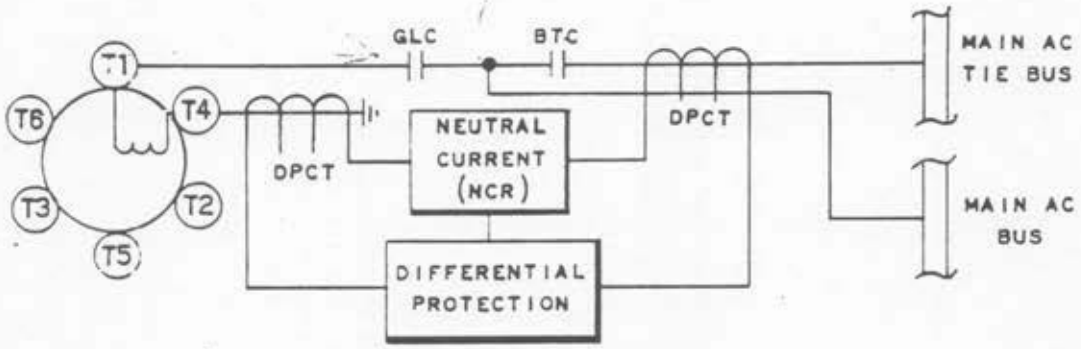


BTL CONTROL

The BTL is reset by positioning the Bus Tie Switch (BTS) to "OPEN" then "NORMAL." The bus tie OPEN light illuminates when the BTC is open and is extinguished after reset is accomplished.

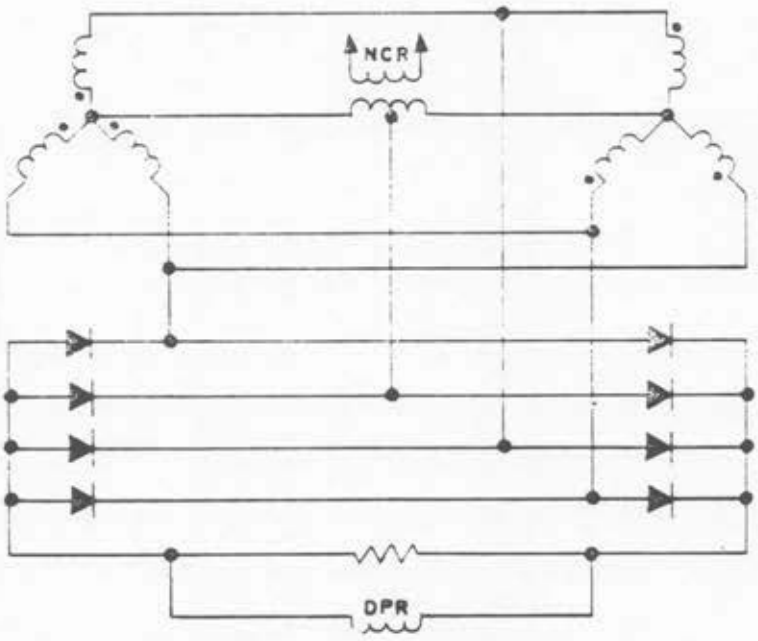
DIFFERENTIAL FAULT PROTECTION

The differential fault circuit disables the generator immediately if a fault occurs on a feeder wire between the generator and GLC. If the fault is between the BLC and BTC, the BTC is opened 0.4 second after the GLC thus isolating the fault from the main AC Tie Bus. The generator is disabled through the BLC circuit due to the LOR. The main bus is isolated by opening the BTC due to the BTL. The BTL is controlled by TDR-2 which provides the 0.4 second delay.



DIFFERENTIAL PROTECTION CURRENT TRANSFORMERS

A differential fault is sensed by current transformers around the phase feeders and ground wires of the generator. Two transformers are connected in opposition to each other on each phase of the generator. An output, which is proportional to the current difference between the feeder and ground wire, is provided by the transformers. If a sufficient difference exists due to a fault, the resultant output is rectified and energizes the Differential Protection Relay (DPR).



DIFFERENTIAL FAULT PROTECTION CIRCUIT

The DPR contacts cause the LOR to energize. The LOR opens the circuit to the GLC and GCR's disabling the generator. The DPR contacts also start the timing circuit of TDR-2. If the fault is not cleared by opening the GLC, TDR-2 is energized 0.4 second later. Contacts of TDR-2 allow the BTL to energize, deenergizing the BTC and BAR.

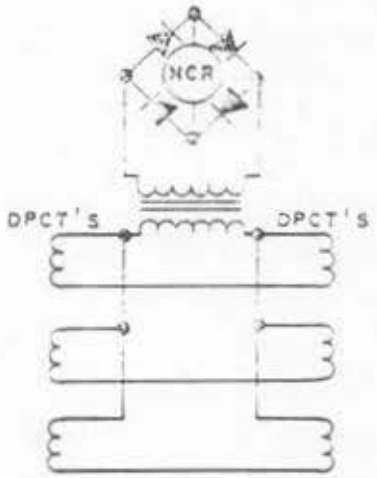
An indication of a differential fault is provided by illumination of the GEN OUT light with the generator control switch in the "OFF" or "ON" position. After the fault is corrected, the system can be reset by stopping the generator and pressing the reset pushbutton on the protection panel. The generator is stopped in order to remove the PMG input to the protection panel power supply. Loss of power supply voltage will deenergize the LOR in the GLC circuit. The BTC circuit can be reset by positioning the BUS TIE switch to "OPEN" then "NORMAL" position, which deenergizes the BTL.

NEUTRAL CURRENT PROTECTION

The neutral current sensing detects an open generator phase, or fault, not detected by the differential protection or undervoltage protection circuits. Current in the common wire between the current transformers is sensed by a transformer. Rectifiers change the transformer voltage to DC, which controls a Neutral Current Relay (NCR).

If the sensing current between the current transformers is unequal, the NCR is energized. Contacts of the NCR start the TDR-2 timing cycle. If the condition still exists after 3 seconds, TDR-2 is energized. TDR-2 opens the BTC by energizing the BTL. The generator continues to supply the main bus load but is isolated from the main A-C tie bus.

If the unbalance condition continues, protection is provided by the undervoltage circuit which disables the generator. The NCR contacts also bypass the reactive biasing circuit to prevent tripping of a good generator system. The BTC tripped condition is indicated by illumination of the BUS TIE OPEN light. The BTC can be reset, and the light extinguished, by positioning the BUS TIE switch to "OPEN" then "NORMAL."



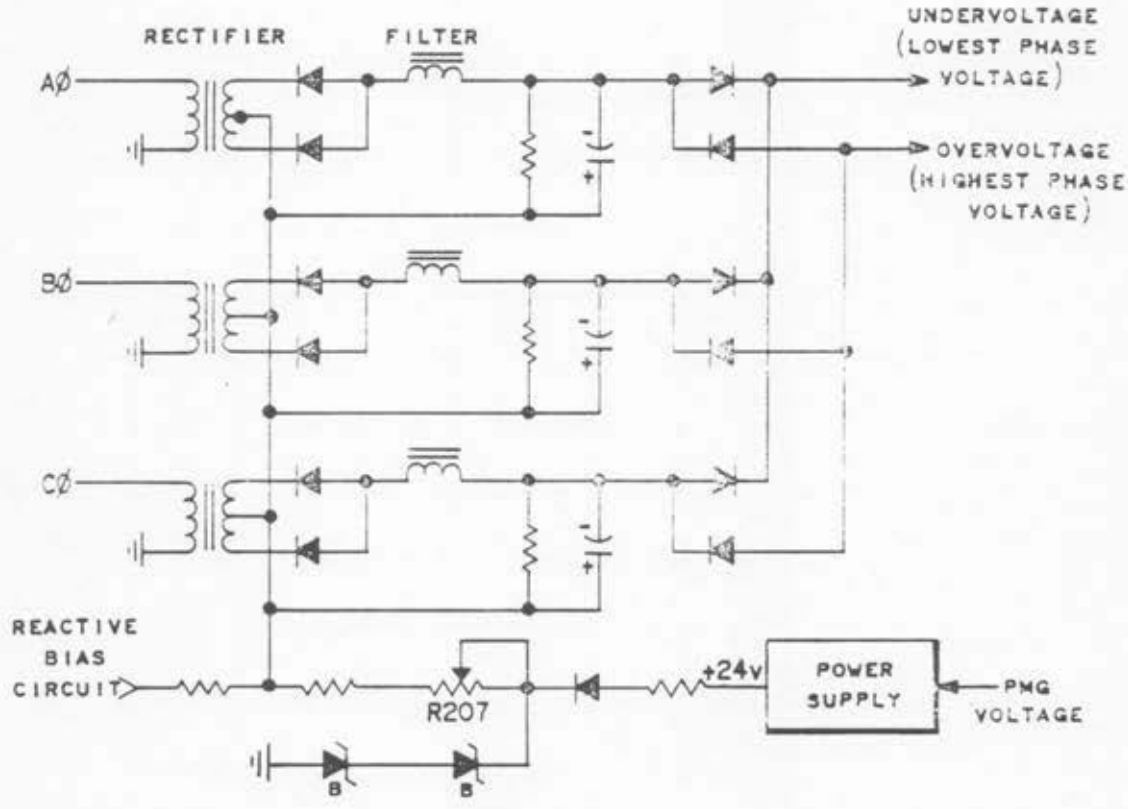
NEUTRAL CURRENT CIRCUIT

VOLTAGE SENSING

The three-phase A-C output of the generator is stepped down by transformers, rectified, and filtered to provide a D-C output. The output is referenced to the 24-volt output of the protection panel power supply. Zener diodes regulate the D-C reference voltage.

Isolating diodes between the individual-phase DC outputs control which phase voltage is used with the overvoltage circuits. Only one of each group of three diodes conducts, providing reverse bias to the other diodes. The overvoltage circuit senses the highest phase voltage which is rectified and coupled as a negative input to the overvoltage circuit. The overvoltage isolating diodes are normally cutoff until the overvoltage condition exceeds 129 volts, AC.

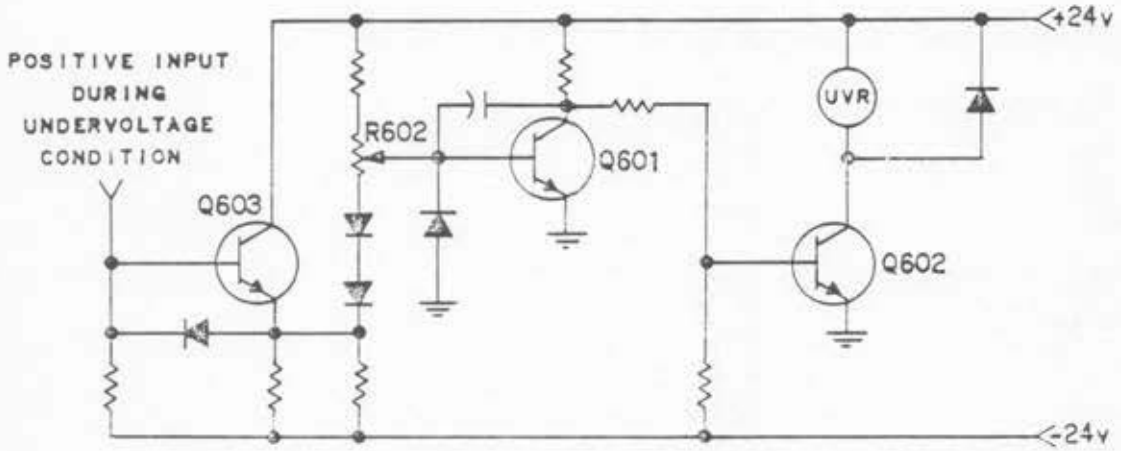
The undervoltage isolating diodes are normally cutoff while phase voltage is above 103 volts, AC. If phase voltage decreases, a diode conducts due to the positive reference voltage. The diode with the lowest phase voltage provides a positive output to the undervoltage circuit. The overvoltage and undervoltage sensing reference is also varied by the reactive load circuit.



VOLTAGE SENSING

UNDERVOLTAGE PROTECTION CIRCUIT

In the undervoltage circuit the UVR is normally energized due to conduction of transistor Q602. Transistor Q603 and Q601 are normally cutoff. During an undervoltage condition the positive input from the voltage sensing circuits cause transistor Q603 to conduct. The positive output from the emitter of Q603 causes Q601 to conduct. The negative collector voltage of Q601 turns off Q602, and the UVR is deenergized.



UNDERVOLTAGE

Contacts of the UVR start the timing cycle of TDR-1 and TDR-2. If the undervoltage condition continues, TDR-2 will time out in 3 seconds and TDR-1 in 6 seconds. The TDR-2 opens the BTC, and TDR-1 opens the GLC which disables the generator. If the condition is momentary the TDR's will not time out. If the undervoltage condition is eliminated by TDR-2 and the BTC, TDR-1 will not time out since the UVR is again energized. If the undervoltage condition is caused by underexcitation of the generator, the UER is energized to prevent loss of the BTC.

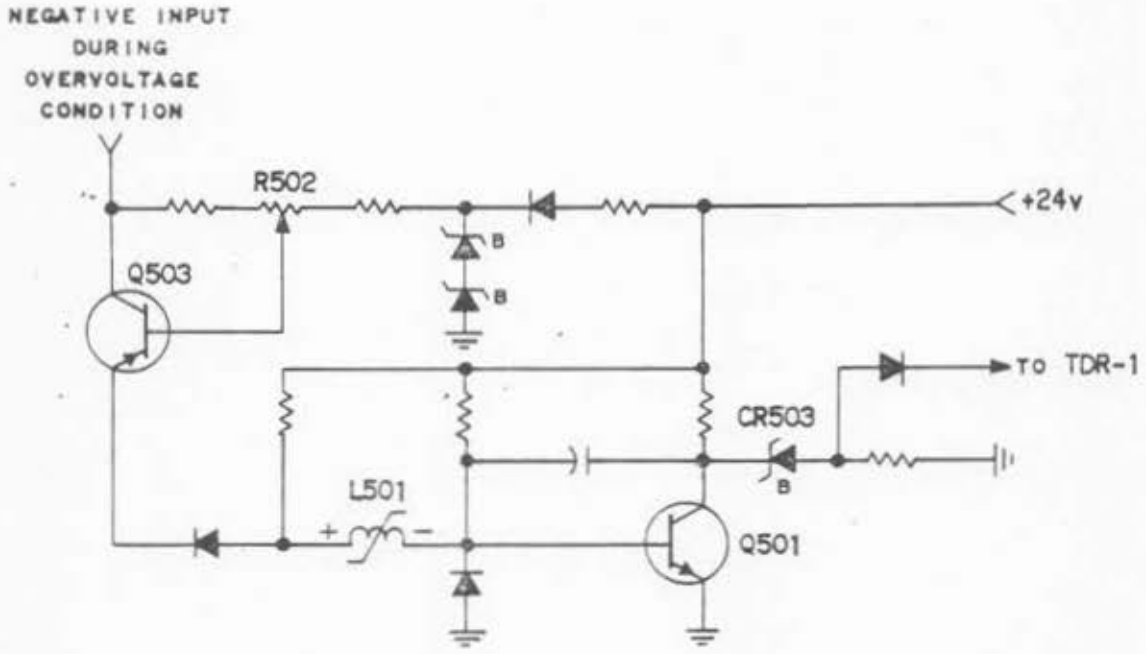
OVERVOLTAGE PROTECTION CIRCUIT

The overvoltage circuit produces an output with a delay time which varies inversely to the amplitude of the overvoltage condition. A maximum of 10 seconds delay is produced at 129 volts, AC. Delay time is equal to 5 divided by the number of volts above 129, or

$$\text{Delay} = \frac{5}{\text{number of volts} - 129.}$$

Example: At a phase voltage of 134 volts,

$$\text{Delay} = \frac{5}{134 - 129} = \frac{5}{5} = 1 \text{ second.}$$



OVERVOLTAGE

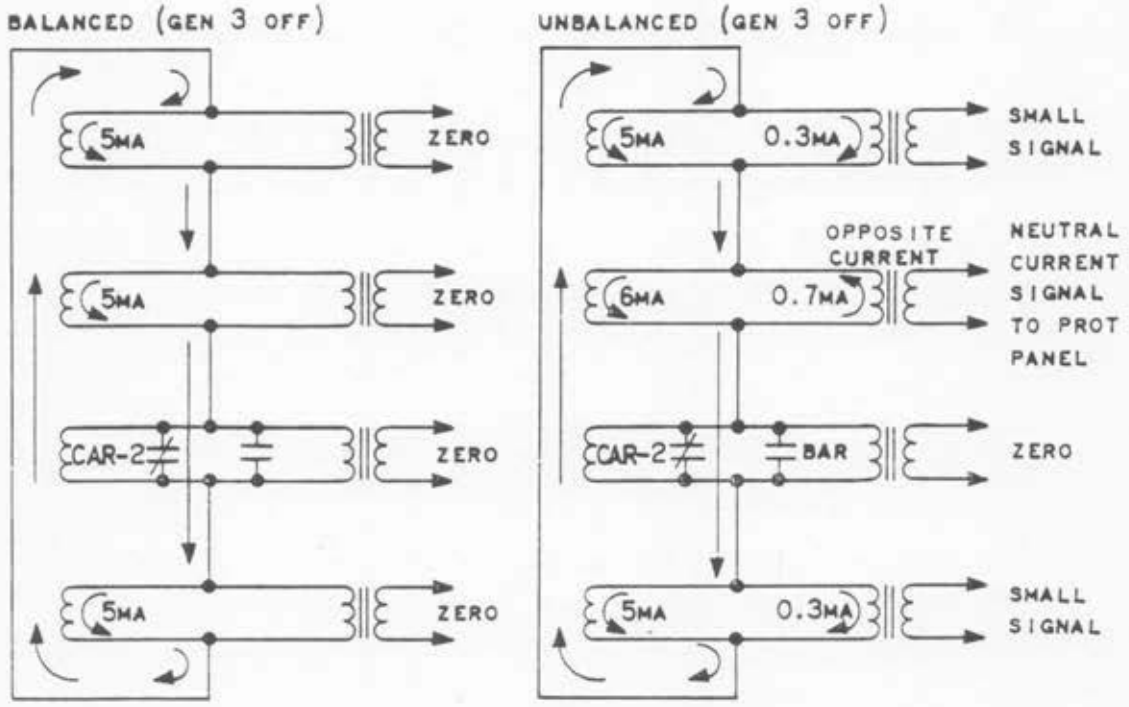
In the overvoltage circuit, delay time is determined by saturation of reactor L501. Transistor Q503 is normally cutoff and Q501 is conducting. The reactor is saturated due to base current of transistor Q501.

During an overvoltage condition, the negative output from the voltage sensing circuit causes Q503 to conduct. The negative emitter signal is coupled to the reactor, reversing the reactor current. The delay time is the time required for the reactor field to collapse and saturate in the opposite direction, causing Q501 to cutoff. A larger signal saturated the core earlier thus decreasing the delay time.

As Q501 stops conducting, collector voltage increases towards the 24-volt source voltage. When the voltage is above the breakdown voltage of the Zener diode, the diode conducts, producing a positive output. The positive output gates an SCR to energize TDR-1 immediately. The TDR controls the LOR, which deenergized the GLC and GCR's. To reset after an overvoltage condition, position the generator control switch to "OFF" then "ON."

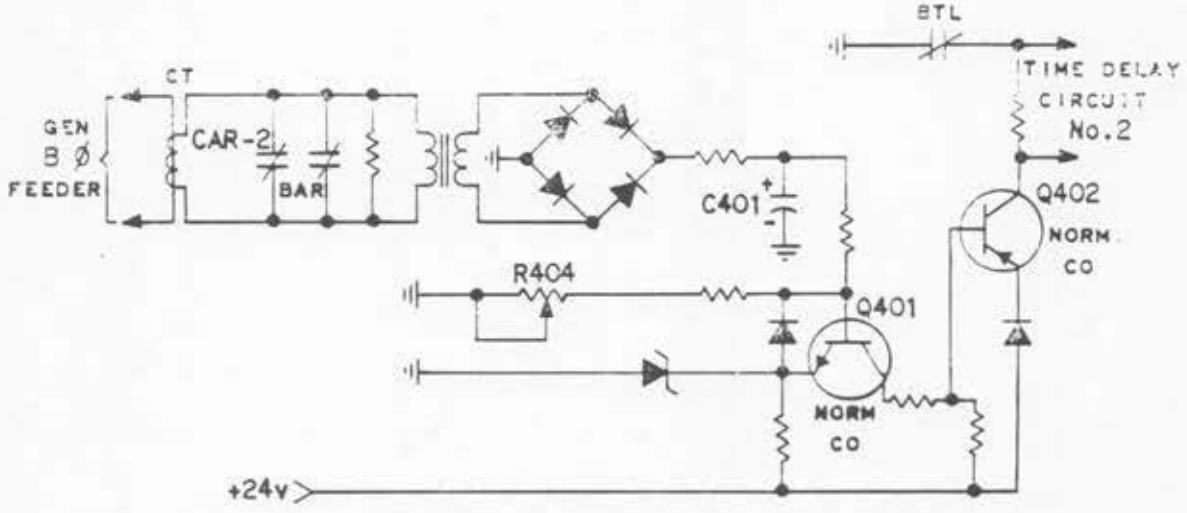
UNBALANCED CURRENT PROTECTION

During generator parallel operation, the unbalanced current circuit senses the load current of each generator. If the load currents are not equal, an output is provided to the protection panel of the faulty generator system. The faulty generator is disconnected from the main A-C tie bus in 5.5 seconds. Current is



CURRENT TRANSFORMER LOOP

sensed by current transformers around the phase B feeder of each generator. When the generators are paralleled, the CAR-2 and BAR contacts open. In a balanced current transformer (CT) circuit, current is through the low impedance of the CT's bypassing the transformer input of the protection panels. When an unbalance exists between the generator loads, the current change of the CT results in current through the parallel transformer since the series circuit current is average current. The transformer provides an input to the unbalanced current circuit. The input is



UNBALANCED CURRENT CIRCUIT

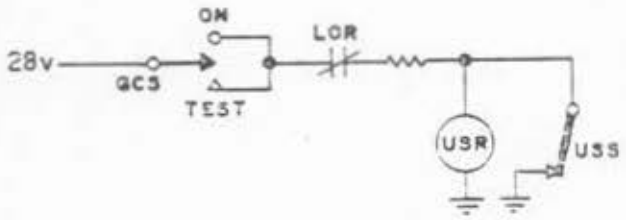
rectified, filtered, and supplied to transistor Q401. Transistor Q401 and Q402 are normally cutoff. A Zener diode in the emitter circuit of Q401 determines the signal amplitude necessary before Q401 conducts. The rectifier's positive output causes Q401 to conduct and breakdown the Zener diode.

The negative output from the collector of Q401 causes Q402 to conduct, producing a positive output to time delay circuit No. 2. The delay circuit controls TDR-2 which is energized after 8.5 seconds. The TDR-2 controls the BTL and BTC to disconnect the generator from the main A-C tie bus. The BTC can be reset by positioning the BUS TIE switch to "OPEN" then "NORMAL."

Contacts of the energized BTL open the unbalanced current circuit when the generator is not paralleled. Contacts of the CAR-2 bypass the current transformer when the generator is "OFF," completing the CT circuit for the remaining generators. The BAR contacts bypass the CT when the generator is operating but not paralleled (BTC open).

UNDERSPEED PROTECTION

Underspeed protection is provided by the underspeed switch (USS) in the CSD unit. At a normal CSD operating speed above 5700, the switch is opened, allowing the underspeed relay (USR) to energize. Contacts of the USR control the GLC and CAR's

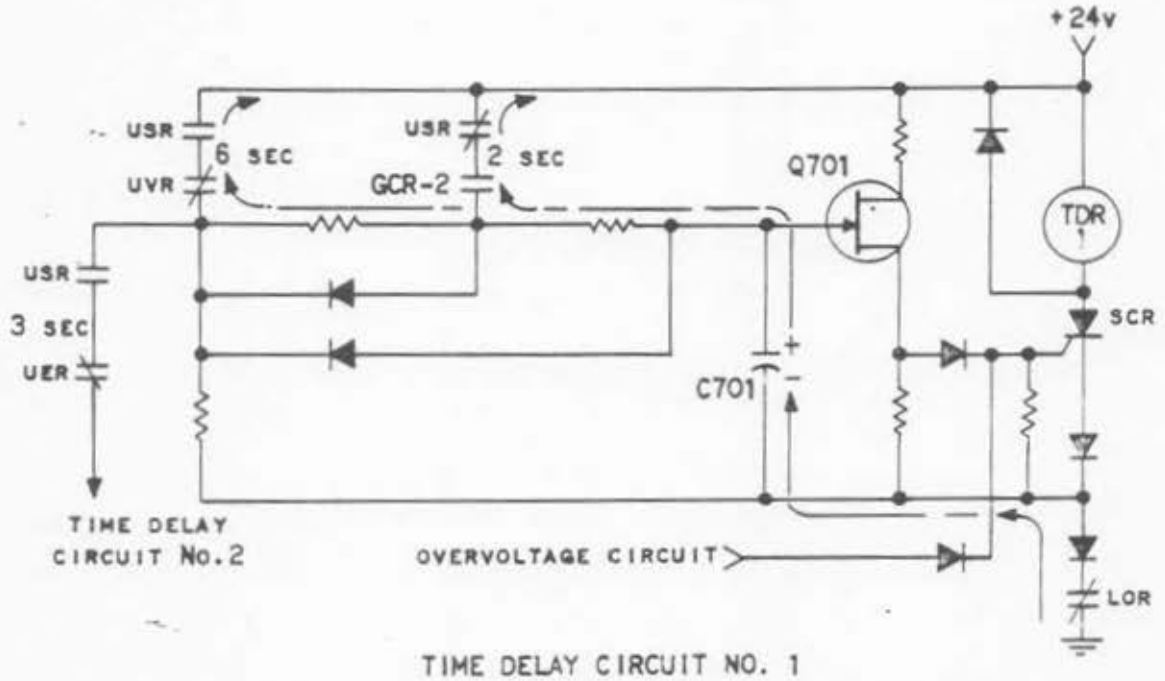


UNDERSPEED CIRCUIT

During an underspeed condition with the generator in operation, the USR contacts start the 2-second timing cycle of TDR-1. If the CSD remains in the underspeed condition for more than 2 seconds, the TDR-1 times out to energize the LOR and disable the generator. The USR contacts also disable the undervoltage protection circuit during an underspeed condition. Overspeed protection of the generating system is not required since the CSD and APU are already protected against the overspeed.

TIME DELAY CIRCUIT NO. 1

The delay timing is controlled by a resistor-capacitor network in the emitter of a unijunction transistor (Q701). The transistor is normally cutoff until capacitor Q701 charges to a sufficient voltage to overcome the transistor base supply voltage. The rate of capacitor charge determines delay time and is varied by adding resistors in series with the capacitor. The resistors are selected through contacts of the protection relays.



TIME DELAY CIRCUIT NO. 1

In normal operation, the USR's, UVR, and GCR-2 energize opening the capacitor circuit. An underspeed condition causes the USR to deenergize, and the capacitor starts charging. Two seconds later, capacitor voltage is sufficient to cause the transistor to conduct. Base-to-base current through the transistor produces a positive output, which is supplied as a gating voltage to an SCR. The SCR conducts, energizing TDR-1.

The TDR-1 contacts control the LOR to disconnect the generator and to open the TDR-1 circuit. During an underspeed condition, the USR contacts in the LOR holding circuit are open. The LOR is energized momentarily to disconnect the generator. If engine speed increases to normal, the USR is energized and the generator automatically connects to the load through the GLC. The circuit does not require reset of the Generator Control Switch (GCS) for an underspeed condition.

An undervoltage condition causes the circuit to time out in 6 seconds, energizing TDR-1. An additional resistor is in the capacitor charging circuit to increase time by decreasing the charging rate. In normal operation, the USR and UVR are deenergized. During an undervoltage condition, the UVR is deenergized to start the timing cycle. After 6 seconds, TDR-1 is energized and the generator is disabled.

The undervoltage condition also supplied 24 volts through the USR-UER contacts to timing circuit No. 2. The circuit times out in 3 seconds to energize TDR-2 and open the BTC. If TSR-2 clears the undervoltage condition, the UVR is again energized

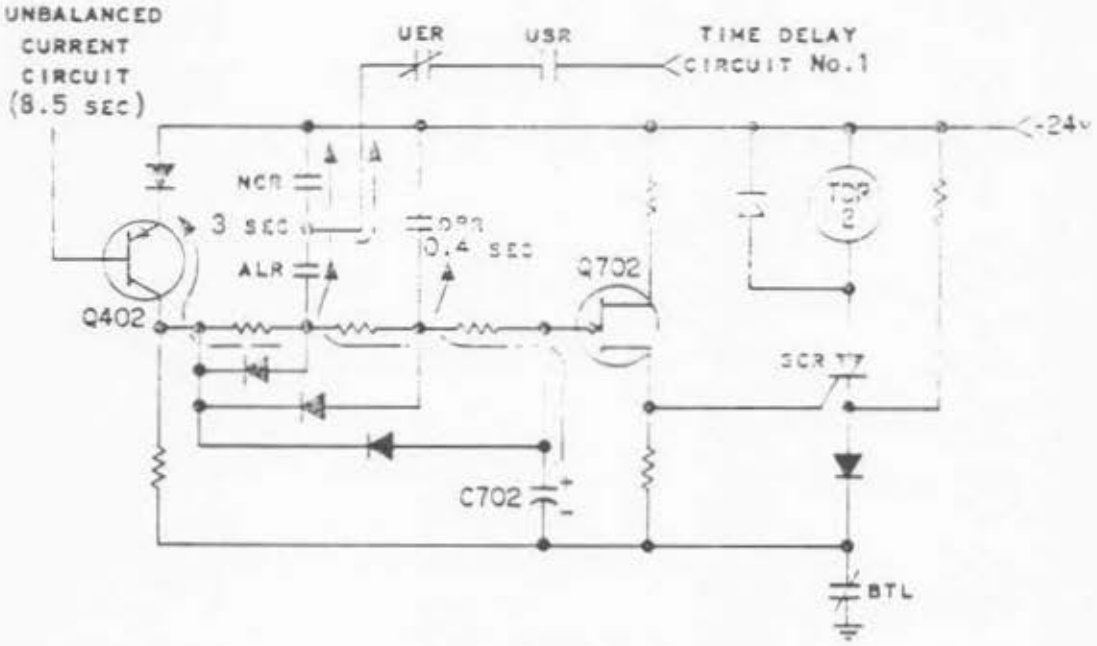
to stop the timing of TDR-1. If TDR-2 does not clear the undervoltage condition, TDR-1 times out after 6 seconds to disable the generator. The TDR-2 timing cycle does not start if the UER is energized, preventing loss of the BTC during a generator underexcitation condition.

The circuit can be reset by positioning the generator control switch to "OFF" then "ON," and the BUS TIE switch to "OPEN" then "NORMAL." Reset is required to break the holding circuit of the LOR which controls the GLC and the holding circuit of the BTL which controls the BTC.

The overvoltage circuit provides an input to the SCR of TDR-1 through an isolating diode. Delay time is determined in the overvoltage circuit. The SCR is gated into conduction energizing TDR-1. To reset the generator circuit, the control switch must be positioned to "OFF" then "ON."

TIME DELAY CIRCUIT NO. 2

The circuit of TDR-2 is similar to the circuit of TDR-1 except for timing. When the generator is operating normally, the USR and UVR energize. In parallel operation, the ALR is energized due to the BTC circuit. The UER, NCR, DPR and BTL are normally deenergized.



TIME DELAY CIRCUIT NO. 2

During an undervoltage condition, the UVR is deenergized and the circuit times out in 3 seconds. The TDR-2 is energized, causing the BTL to energize. The BTC and TDR-2 circuit is opened and locked out by the BTL. If the undervoltage condition results from underexcitation, the UER is energized. The UER contacts open the undervoltage circuit to TDR-2, preventing the timing cycle. The TDR-1 circuit does not time out if the undervoltage condition is cleared by TDR-2 since the UVR will energize.

If a differential fault (ground fault) occurs, the Differential Protection Relay (DPR) is energized. The DLR and LOR in the GLC control circuit immediately disable the generator due to DPR contacts. The DPR contacts of timing circuit No. 2 start the timing cycle. If the fault is cleared by disabling the generator, the DPR is deenergized and TDR-2 does not time out. A fault between the GLC and BTC would not be cleared by disabling the generator since the main A-C tie bus continues to supply the load through the BTC. The TDR-2 circuit times out in 0.4 second after the DPR is energized, opening the BTC.

A neutral current abnormal condition will energize the NCR, starting the timing cycle. If the condition continues for 3 seconds, TDR-2 is energized, opening the BTC.

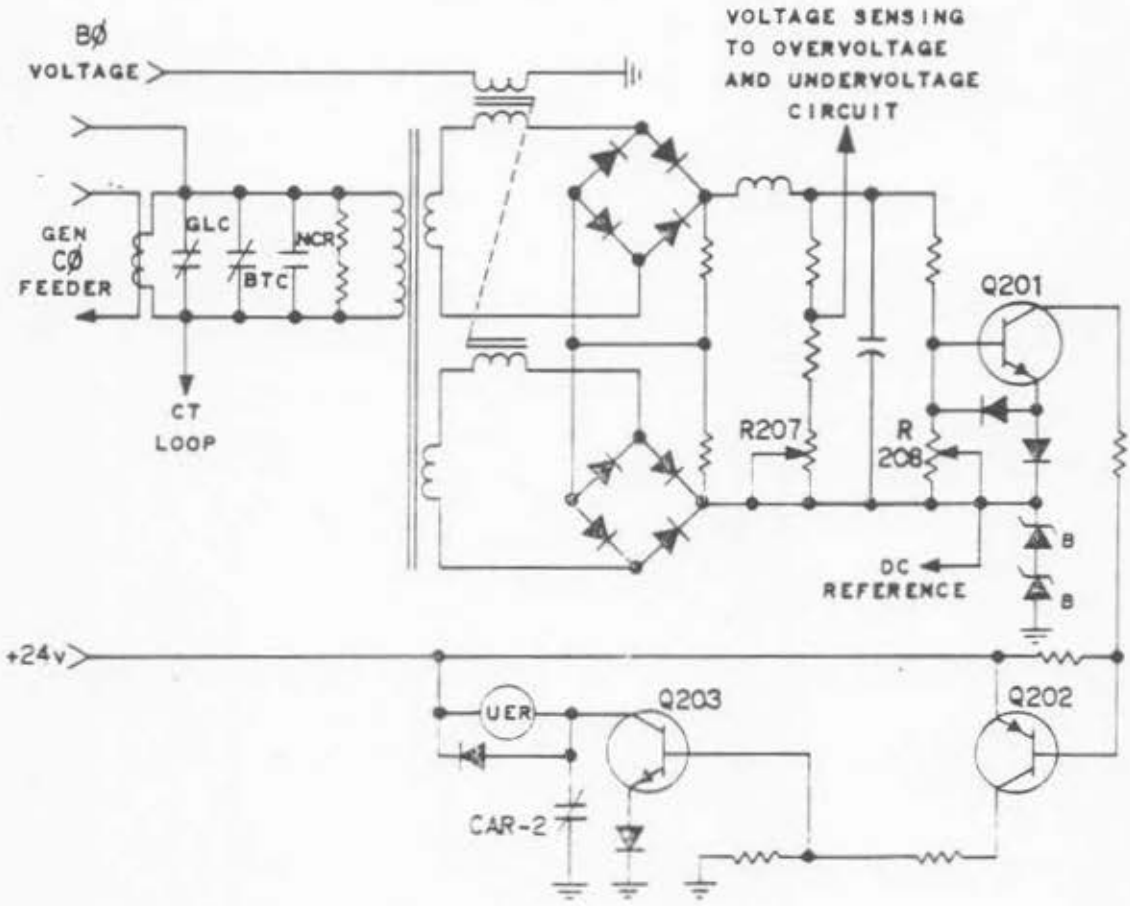
An unbalanced current condition between the generators operating in parallel causes TDR-2 to energize. The parallel generators normally share the load equally. If an unbalance exists, transistor Q402 conducts. The charging circuit of the timing capacitor is through the series resistors and the transistor. TDR-2 is energized after a delay of 3.5 seconds, and the BTC is opened. The circuit is reset by positioning the BUS TIE switch to "OPEN" then "NORMAL."

REACTIVE BIAS CIRCUIT

The Reactive Bias Circuit (RBC) of the protection panel is paralleled by the RBC circuit of the VR unit, using the same current transformers. The VR unit bias ensures equal reactive load sharing between generators in parallel. The protection panel bias changes the reference voltage to the overvoltage and undervoltage sensing circuits. The bias also controls the UER to open the undervoltage protection circuit of TDR-2 during an underexcitation condition.

Generators in parallel share the resistive and reactive loads equally. If one generator has more or less reactive load, an input is supplied to the protection panel. If the load is larger than the load on the other generators, the reactive bias decreases the reference voltage, increasing voltage amplitude to the overvoltage circuit. The overvoltage protection is biased closer to the trip point for the defective system.

Since the generators are paralleled, the actual bus voltage does not change. The defective systems generator is disabled due to the changing reference voltage when



REACTIVE LOAD AND UNDEREXCITATION CIRCUIT

the reactive load is sufficiently large. The remaining generators pick up and share the additional load. Reactive bias to the normal generator systems increases the reference voltage to prevent disabling.

The reactive bias input signal is obtained from current transformers and phase B generator voltage. The CT input is bypassed by contacts of the GLC or BTC if the generator is not paralleled, or by NCR contacts if the neutral current is excessive. The inputs are applied to transformers, bridge rectifiers, and filters. The rectifier outputs are positive and result in zero difference in potential when voltages are equal. The phase B input produces a zero output until the CT input unbalances the bridge rectifiers. The resultant output is a negative or positive difference voltage which is compared with the fixed reference voltage of Zener diodes. The difference voltage increases or decreases the reference voltage of the overvoltage circuit and is the input to the underexcitation circuit.

The UER is controlled by transistors Q201 and Q203, which are normally cutoff. If the generator has low excitation, the reactive bias output is a positive signal to

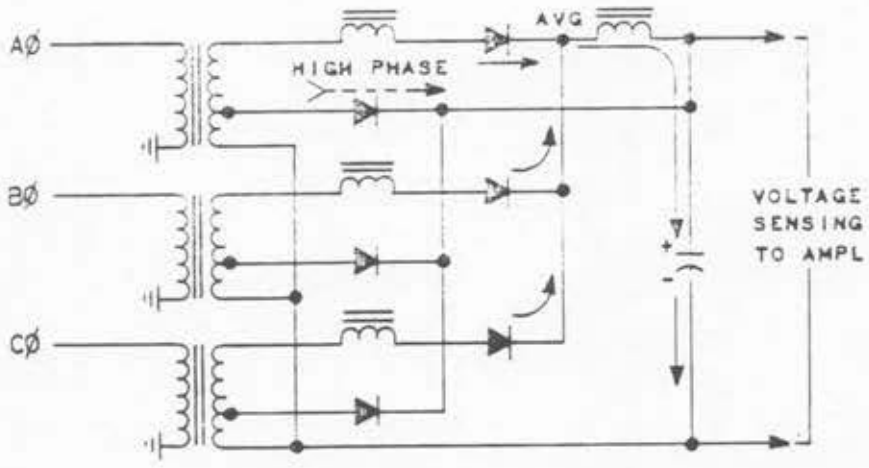
the base or A201. A signal of sufficient amplitude will cause Q201 to conduct, turning on Q202. Conduction of Q202 causes Q203 to conduct, energizing the UER. The UER contacts open the undervoltage circuit to TDR-2 preventing loss of the BTC during an underexcitation condition. Contacts of CAR-2 bypass Q203 to keep the UER energized when the generator is off.

VOLTAGE REGULATOR

Each voltage regulator provides automatic regulation of generator output voltage. The regulators are located in the electrical equipment rack. The regulator maintains a constant 115-volt, AC, at the generator terminals under the various load conditions by sensing output voltage and comparing the voltage with a preset reference. Excitation to the generator field is varied to maintain voltage to the desired level.

The VR is a static device consisting of a High Phase Takeover (HPT) circuit, Zener diode voltage reference, transistor preamplifier, reactive bias, and magnetic amplifier. The regulator input is PMG voltage, three phase A-C generator voltage, and a reactive bias current transformer signal. The current transformers are also used with the reactive bias circuit in the protection panel.

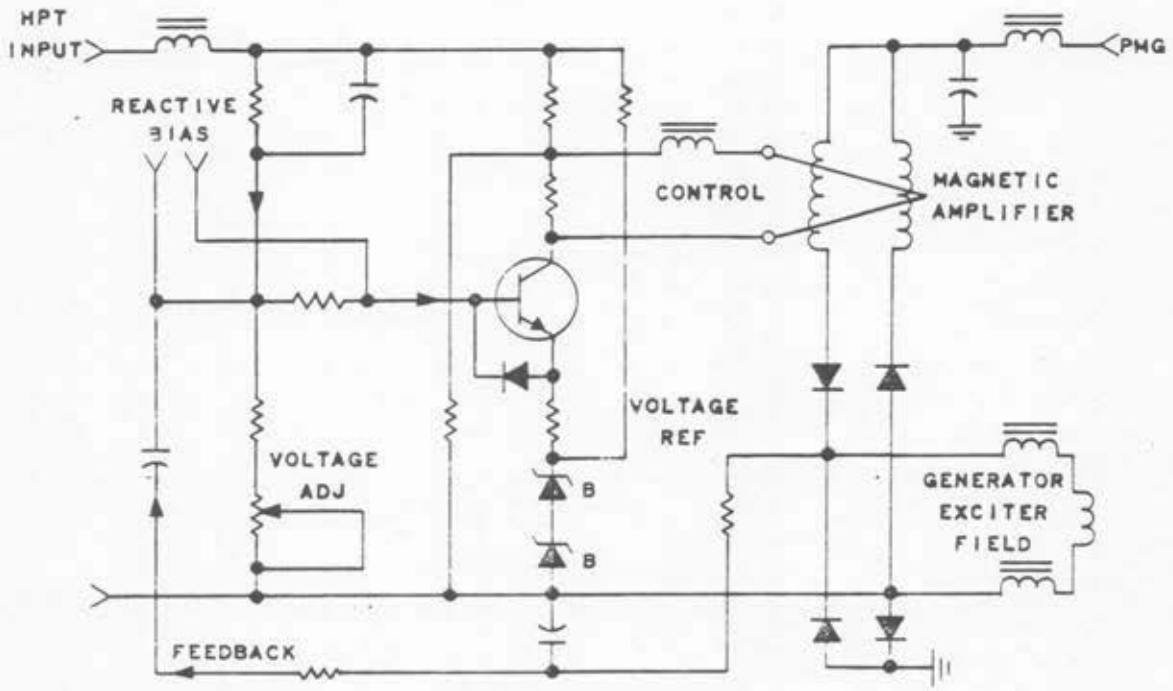
When the generator is operating. PMG voltage is supplied through GCR contacts to the VR unit. The PMG voltage is approximately 108 volts, AC, at 1600 Hertz. The voltage is rectified and supplied through a magnetic amplifier to the exciter field of the generator. When excitation is applied, an A-C output is obtained from the generator.



HIGH PHASE TAKEOVER (HPT)

Output of the generator is applied as a sensing voltage into the VR unit transformer. The transformer supplied the three-phase AC to the high-phase takeover circuit, consisting of diodes and filters. The positive half-cycle of each phase input voltage

will forward-bias sensing diodes to charge a filter capacitor. The capacitor is charged to the average voltage of the three inputs. The high-phase takeover diodes are reverse-biased by capacitor voltage. The highest phase voltage input overcomes the average capacitor voltage and a diode conducts, charging the capacitor to the high-phase voltage.

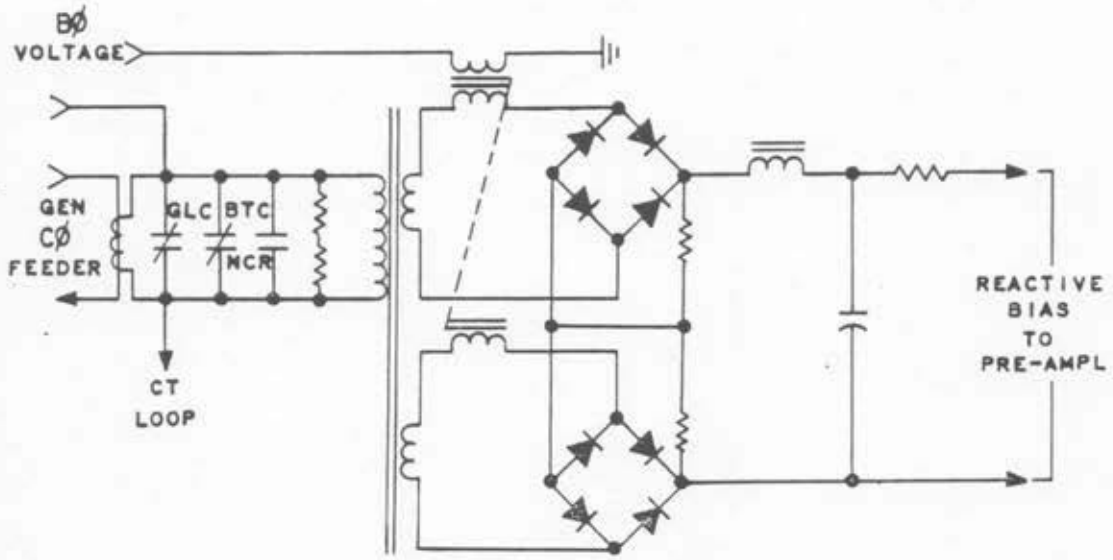


PRE-AMPLIFIER - MAGNETIC AMPLIFIER

The sensing output is filtered and applied through a voltage divider to the transistor amplifier. Zener diodes provide a constant D-C reference signal for the amplifier and establish the operating point. The transistor is normally conducting, providing current through the control winding of the magnetic amplifier. Collector current controls the output of the magnetic amplifier by controlling its saturation.

With minimum control current, the magnetic amplifier provides maximum average current output. The output is rectified and supplied to the generator exciter field As transistor current increases, the magnetic amplifier current decreases to maintain the generator voltage at 115 volts, AC.

In generator parallel operation, load sharing is accomplished by an RBC. The biasing circuit produces a signal proportional to the unbalance of reactive current between generators, as detected by the reactive load current transformers. The bias signal adds to, or subtracts from, the reference voltage to change the input to the amplifier.



REACTIVE BIAS CIRCUIT

The RBC inputs are obtained from phase B of the generator and a reactive bias current transformer. When the generator is not paralleled, contacts of the BTC or GLC bypass the CT and the bias circuit is inoperative. The CT is also bypassed when the neutral current relay is energized.

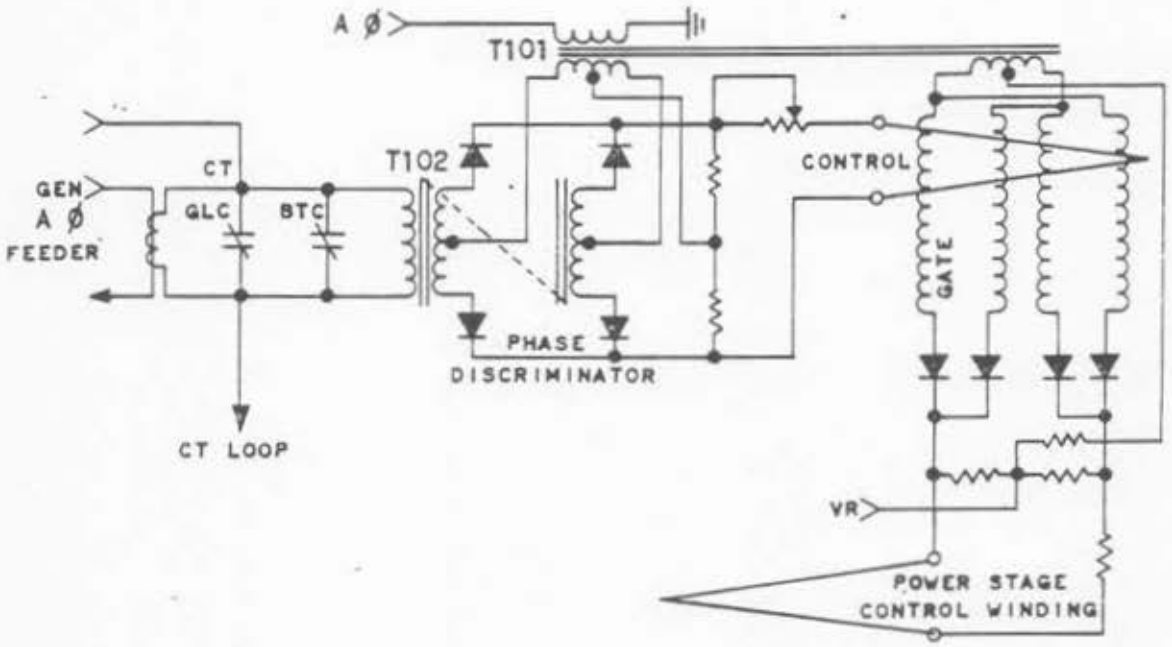
The error signal from the CT's, due to generator reactive load, is applied to transformers and rectifiers. The rectifier outputs are of the same polarity and result in a zero signal until the CT input unbalances the bridge rectifiers. If the generator is supplying a larger reactive load, the bridge is unbalanced and the resultant D-C voltage of the reactive bias circuit is applied to the transistor. An increase in transistor collector current causes a decrease in exciter field current, decreasing generator output. If the generator output is decreased, the load decreases. The parallel generators then pick up more of the reactive load, equalizing the load between generators.

LOAD CONTROLLER

The load controller provides an electrical trimming signal to the load-biasing solenoid of the CSD. The solenoid controls fine trimming of CSD torque which drives the generator. The load controller varies CSD torque to ensure load sharing between parallel generators. The load controllers are located in the electrical equipment rack.

During generator parallel operation, the load controller receives inputs from phase A of the generators and from load-biasing current transformers. The CR signal consists of the real (watts) and reactive (vars) load components and varies with the unbalance of load between generators. The phase of the CT signal indicates the generator is supplying more, or less, load than the other generators.

Each CT is paralleled by contacts of the BTC and GLC, bypassing the CT when the generator is not paralleled. The load controller is used only in parallel operation.



LOAD CONTROLLER INPUT

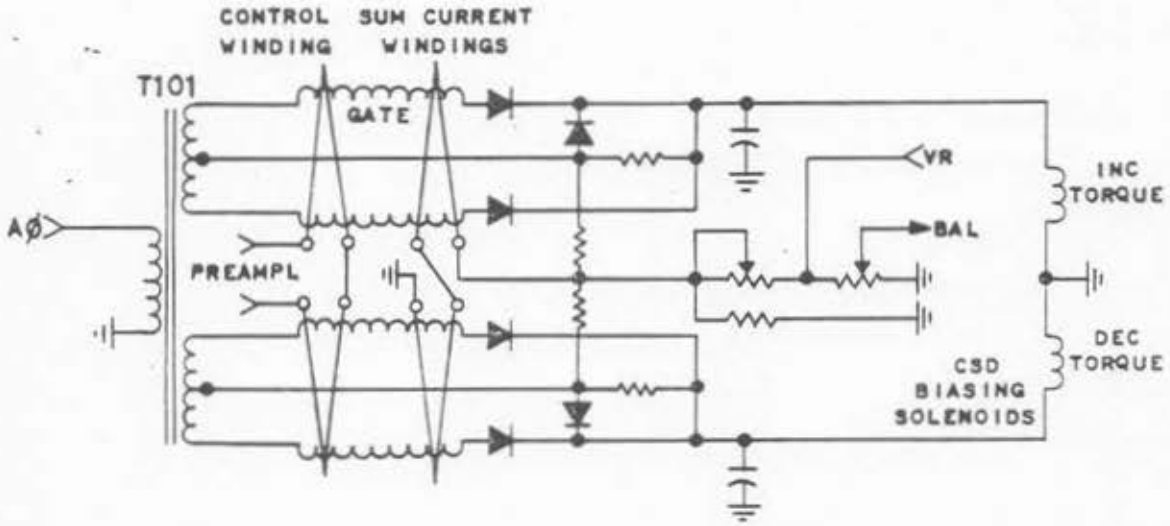
The load controller is a static device containing magnetic amplifiers, phase discriminator, and voltage regulator. Magnetic amplifiers are used as a preamplifier, transient response amplifier, and power amplifier. The voltage regulator provides D-C reference voltages to the amplifier windings.

The phase discriminator inputs are phase A voltage of the generator and the load biasing current transformer signal. Both inputs are required to produce an output. The D-C output is proportional to the real component of the CT input, with a polarity determined by the phase of the CT input. The output polarity determines if CSD torque is to increase or decrease.

Discriminator D-C output is supplied to the control winding of the preamplifier, and controls saturation of the magnetic amplifier. Each magnetic amplifier output winding receives an A-C input from the power transformer and uses rectifiers to provide D-C outputs. The preamp operates as a push-pull amplifier and provides control current to the power stage magnetic amplifier.

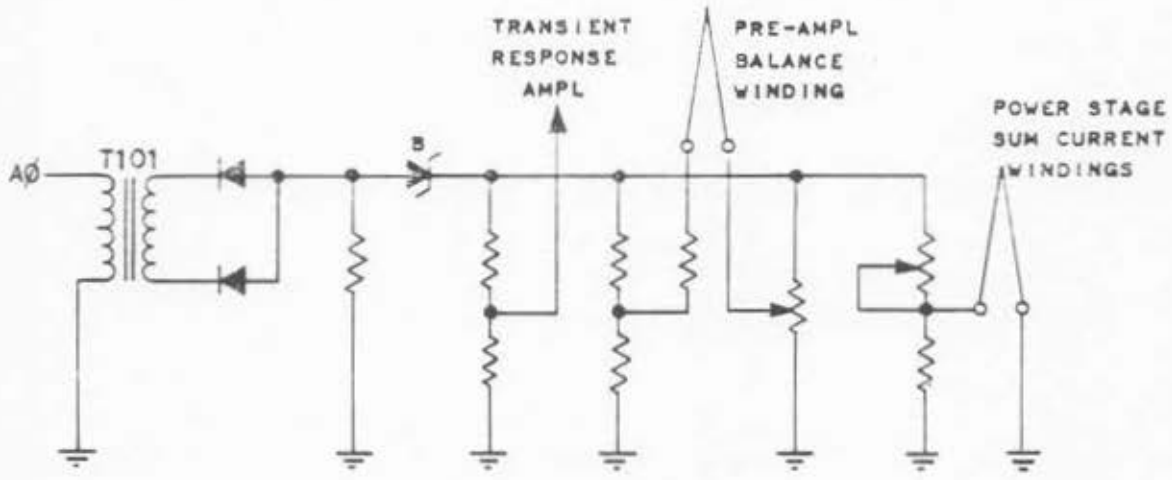
The power stage output drives the load-biasing solenoid in the CSD unit to increase or decrease CSD torque. An increase in torque allows the generator to carry a

larger real load, equalizing the generator loads. A decrease in torque decreases the generator load.



POWER STAGE

The transient response magnetic amplifier controls the response of the magnetic amplifiers to signals from the current transformers. The amplifier prevents the load controller from responding to signals of short duration. The voltage regulator is a full-wave rectifier and voltage divider, using a Zener diode for regulation. The D-C voltages bias the magnetic amplifier windings for proper operation.

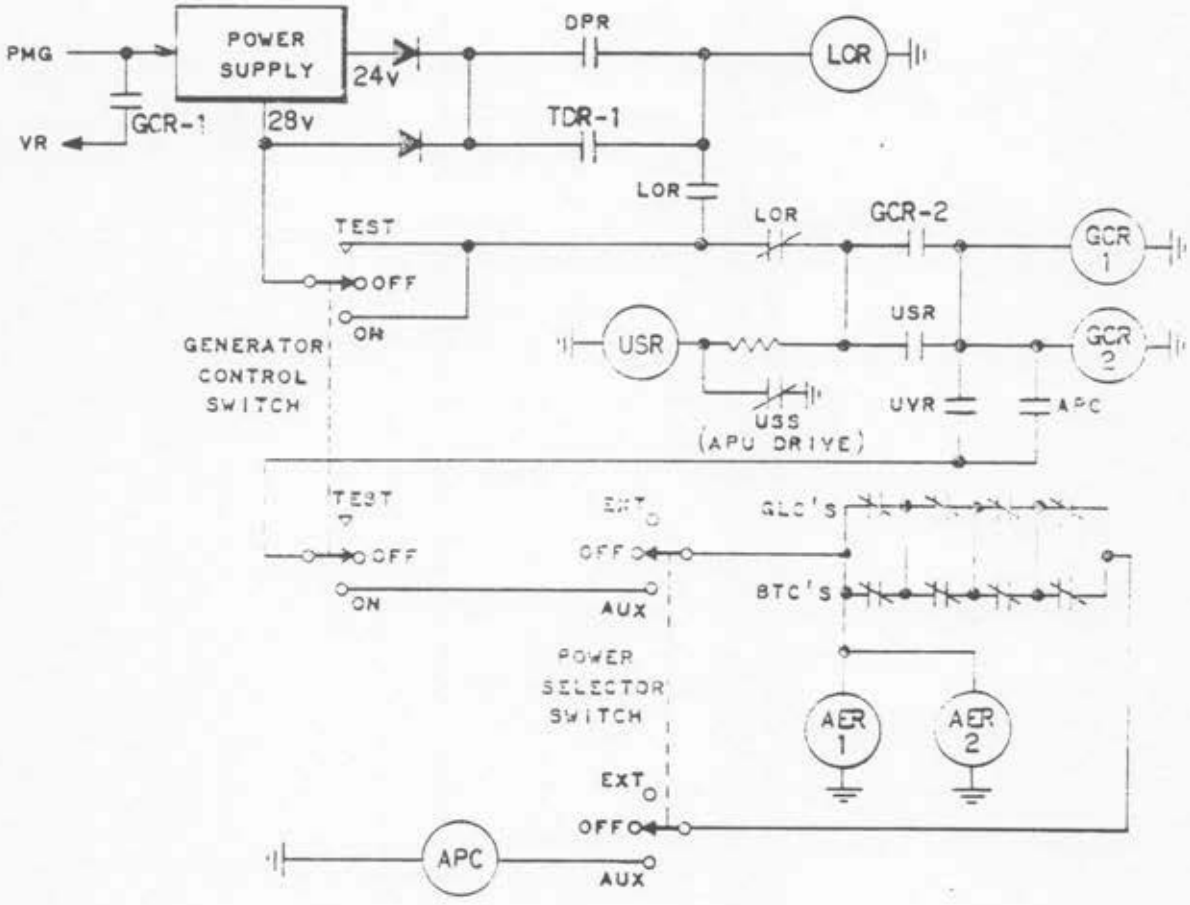


VOLTAGE REGULATOR

The magnetic amplifiers contain many windings to control the saturable reactor core. A control winding is the magnetic amplifier's D-C input winding. A bias winding establishes the operating point of the amplifier by biasing the core. Gate windings have A-C power inputs, and rectifiers to change the A-C to D-C. The gate windings are the output windings of each stage. Feedback and frequency response windings are used for linearity and stability. A sum current winding and balance winding are used to establish the correct output of the amplifiers when the CT input signal is zero.

AUXILIARY GENERATOR SYSTEM (APR GENERATOR)

The fifth A-C power source is driven by the APU to provide three-phase A-C power during ground checkout of the systems. The auxiliary generator cannot be used in flight and does not parallel with any other A-C power source. The



AUX GENERATOR CONTROL CIRCUITS

auxiliary generator system consists of a generator, protection panel, and VR unit. The APU and generator are located in the forward left main wheel well. The generator is identical to the main generators, capable of selectively supplying power to all aircraft buses. An APU-driven fan provides cooling air for the generator. The protection panel and VR unit are located in the electrical equipment rack.

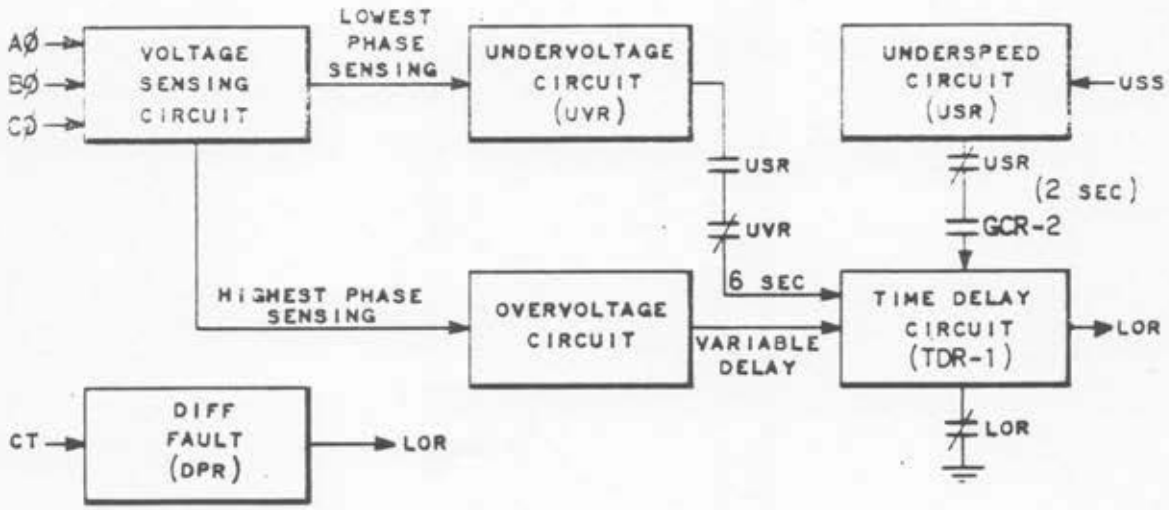
The auxiliary generator is controlled by both the Generator Control and Power Selector switches. If the control switch is "ON" and the power selector is in "AUX," the generator output connects to the main A-C tie bus. The APC is energized to connect the generator output to the bus. With auxiliary power in use, main A-C buses No. 2 and 3 can be energized by positioning the Auto Load Disconnect switches to "OVERRIDE." The "OVERRIDE" position energized the monitor relays. The auxiliary generator loadmeter should be monitored as a precaution against overloading the generator when "OVERRIDE" is used.

VOLTAGE REGULATOR

The voltage regulator automatically maintains the generator three-phase voltage output, 115-volt, AC per phase. The regulator is similar to the main generator regulator but does not contain reactive biasing since the generator does not parallel with the other power sources.

GENERATOR PROTECTION PANEL

The protection panel contains the protection and control circuits of the system. The panel is similar to the main protection panels but contains few circuits and relays since paralleling protection and control are not required. The panel contains a PMG, D-C power supply plus individual phase sensing, undervoltage



AUX GENERATOR PROTECTION CIRCUITS

with fixed time delay, overvoltage with time delay inverse to amplitude, underspeed with fixed time delay, and differential fault protection circuits.

The power supply, individual phase sensing, overvoltage, undervoltage, and underspeed circuits are basically the same as the main generator protection circuits. One TDR is used to control the APC. The TDR times out to energize the LOR, disabling the generator.

The TDR timing is initiated by an undervoltage or underspeed condition. The overvoltage circuit determines the variable delay which is inverse to voltage amplitude and then energizes the TDR. The underspeed switch is controlled by the APU to energize or deenergize the USR. To reset the generator after a fault, position the Generator Control switch to "OFF" then "ON." The switch breaks the holding circuit of the LOR in the "OFF" position.

A differential fault between the generator and APC immediately disables the generator by energizing the LOR. The fault indication is the same as the other faults on the auxiliary generator system, and reset is accomplished by positioning the Generator Control switch to "OFF" then "ON." If the fault still exists, the generator is immediately disabled.

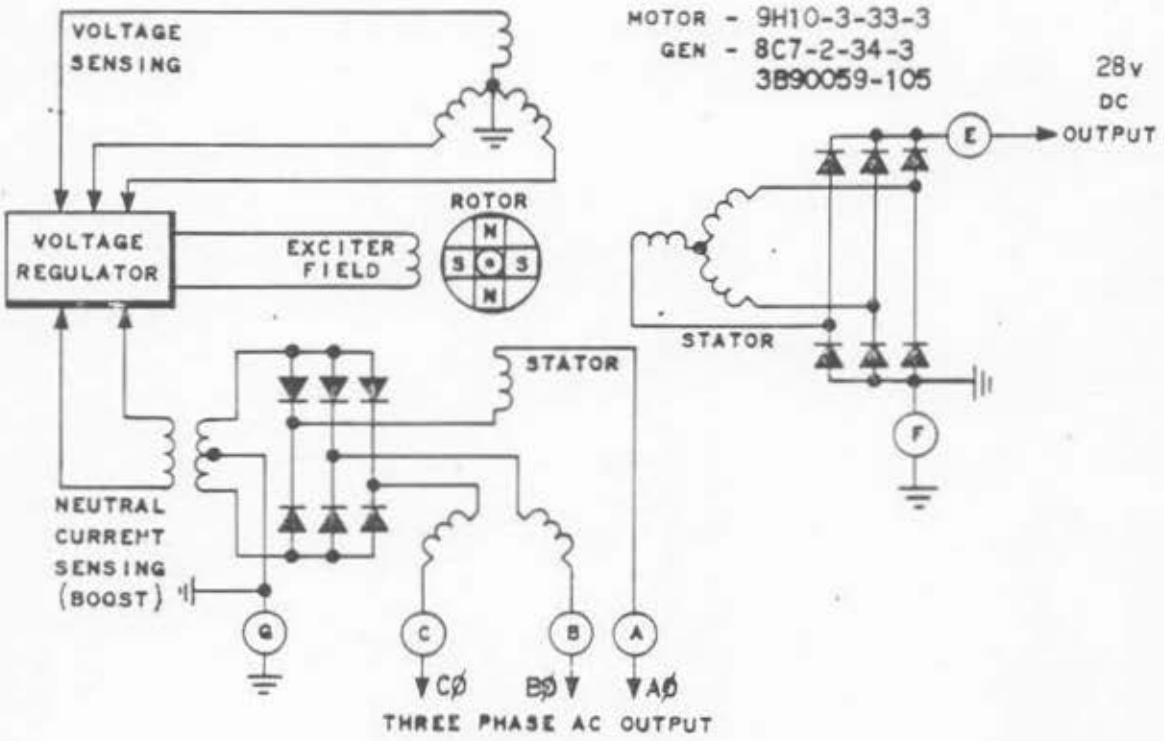
EMERGENCY POWER SYSTEM

The emergency system automatically provides A-C and D-C power if the normal power sources fail. If power to the essential A-C bus No. 1 is lost, the emergency generator automatically operates. Generator output is three-phase, 115/200-volt, AC, at 2 KVA and 28-volt, 20-ampere DC. The generator supplies the emergency and isolated A-C and D-C buses. Emergency power cannot be used to supply the other buses or to charge the battery.

EMERGENCY GENERATOR

The emergency generator is located in hydraulic service center No. 2. A four-pole, Lundell-type generator is used. The continuous A-C power output is 2 KVA. However, the generator is capable of supplying 2.5 KVA for 5 out of 30 minutes. A rotor speed of 12,000 RPM is maintained by a constant-displacement hydraulic motor. Generator output voltage is regulated to 116 volts, AC, by an integral voltage regulator. A fan attached to the rotor provides generator cooling air.

The generator contains a permanent magnet rotor and three sets of stator windings. The rotor magnetic field strength is varied by field excitation current from the voltage regulator. Three sets of stator windings provide the generator outputs. The stators provide a three-phase A-C output, 28-volt D-C output, and three-phase sensing voltage into the voltage regulator.



EMERGENCY GENERATOR

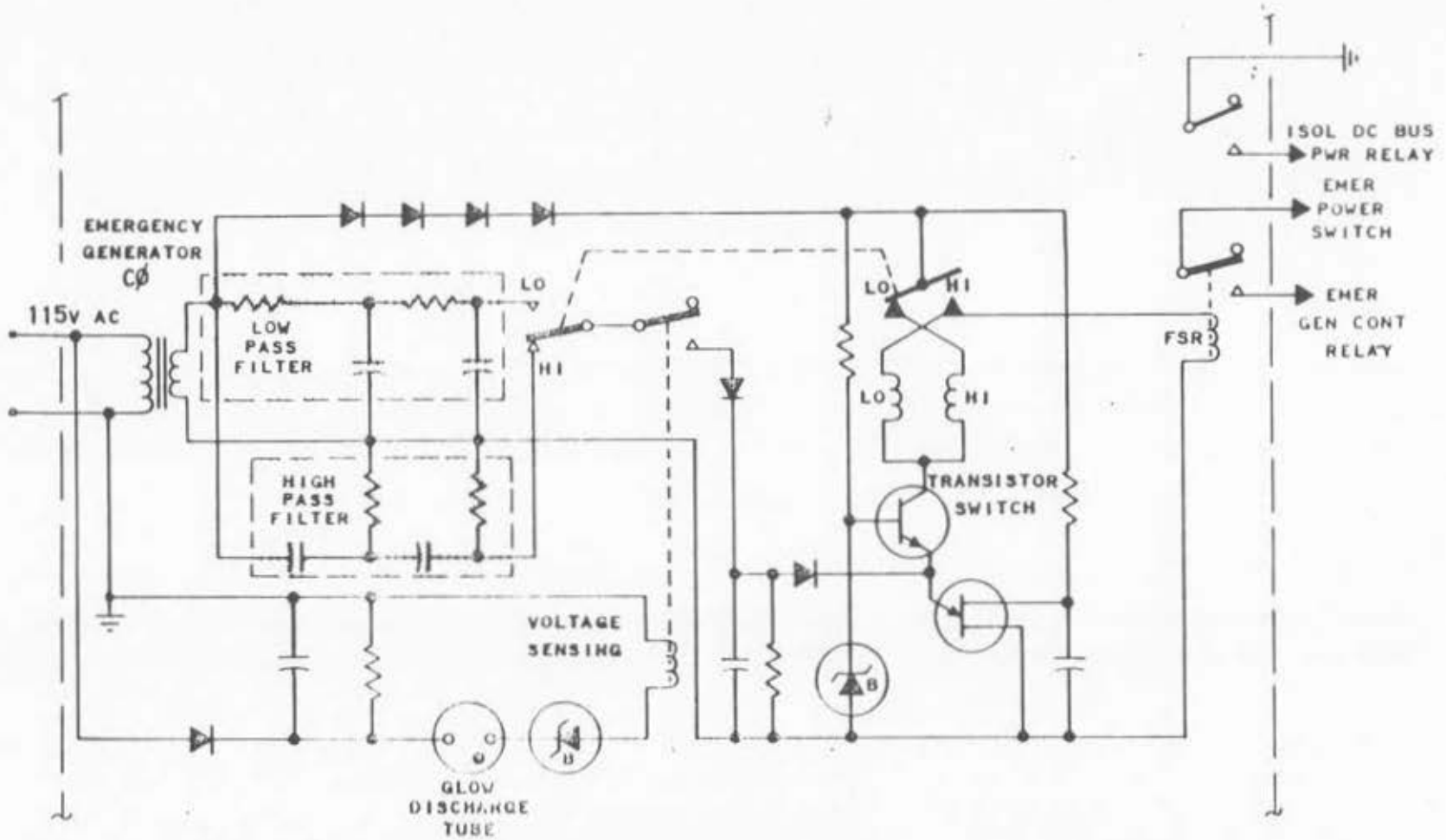
The three-phase A-C output is supplied to the emergency and isolated AC buses when the generator is operating. The neutral wire current of each phase is rectified and supplied into the VR as boost current during an overload.

The three-phase voltage sensing windings provide AC into the voltage regulator. The regulator rectifies the AC to provide CR operating voltage and compares the sensed voltage against a zener diode voltage reference. The resulting signal from the comparison circuit is amplified and supplied to the exciter to regulate generator output voltage.

The third stator voltage is rectified and supplied to the emergency and isolated D-C buses. A full-wave rectifier changes the AC to 28-volt, D-C output. The rotor is the equivalent of a four-pole magnetic rotor driven at 12,000 RPM to provide 400 Hertz A-C output. Without excitation, the residual magnetism would provide approximately 30-volt A-C output. The VR controls the exciter to maintain the output at 116 volts, AC.

FREQUENCY SENSITIVE RELAY

The Frequency Sensitive Relay (FSR) contains a voltage sensing circuit, high-pass low-pass filter, transistor switch, and relay coils. The FSR senses generator



FREQUENCY SENSITIVE RELAY (FSR)

phase C voltage and frequency and is energized when voltage is above 100 volts, AC and the frequency is above 380 Hz. A 3 to 6-second delay is provided in the FSR to prevent relay dropout during a transient voltage or frequency condition.

As generator voltage builds up, the voltage sensing coil is energized. The voltage required to energize the coil is determined by a glow discharge tube and Zener diode in series with the coil. Relay contacts connect the high-pass or low-pass filter signal to the transistor switch. Above 380 Hertz, the high-pass filter signal is rectified, filtered, and supplied to the switch. The positive rectified voltage causes the unijunction transistor and transistor switch to conduct, energizing the HI coil of a polarized relay. The HI relay contacts close to energize the FSR coil which controls the generator system. The low-pass/high-pass filters are switched by the polarized relay and the transistor switch stops conducting. The polarized relay remains in the "HI" position due to the permanent magnet relay armature.

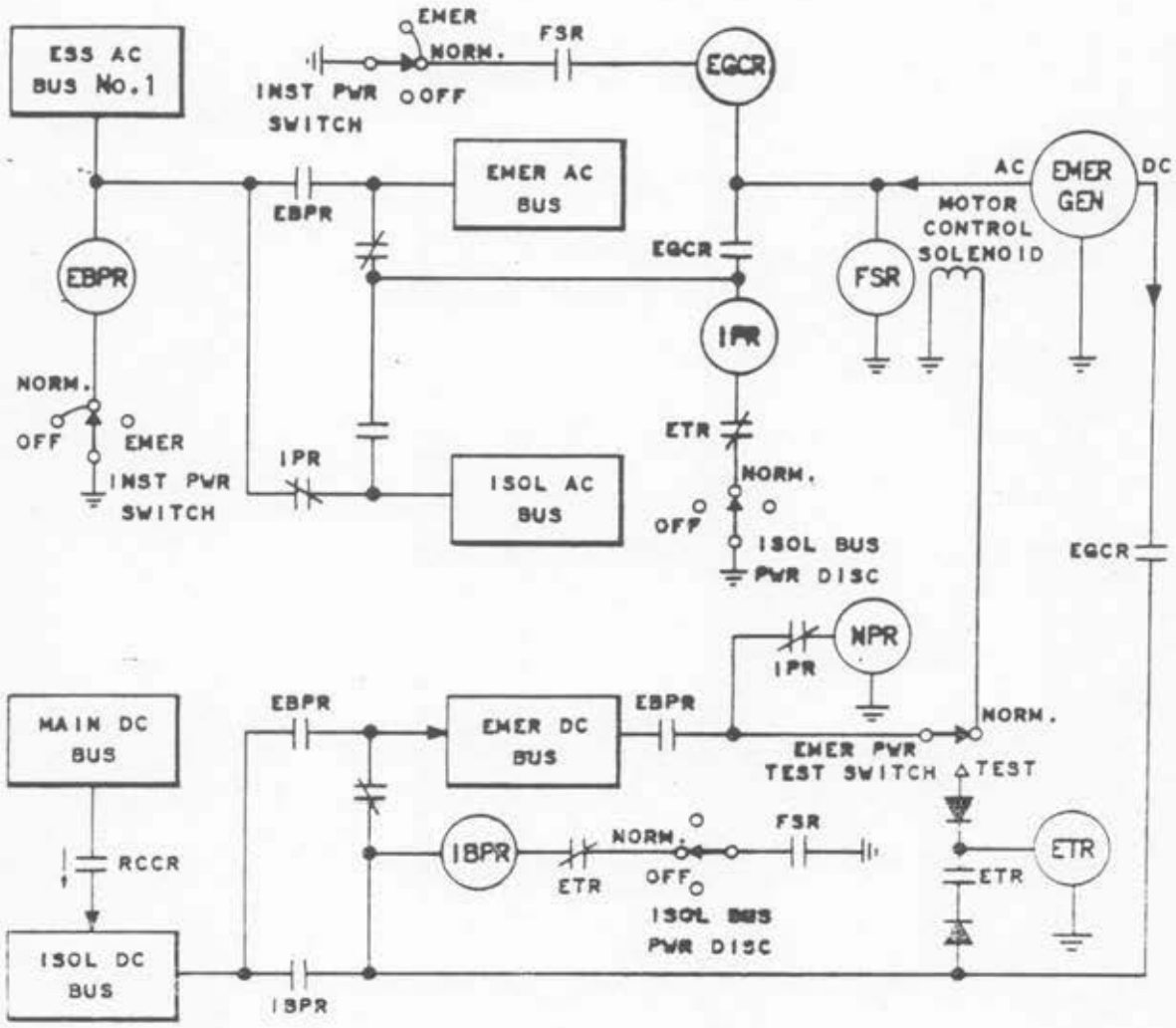
When frequency decreases below 360 Hertz, the low-pass filter output is rectified, filtered, and supplied to the transistor switch. Filter voltage builds up until the transistors conduct, energizing the LO coil of the polarized relay. The relay contacts switch to the LO side, deenergizing the FSR. The FSR contacts remove the generator from the load through the EGCR. The lower frequency of the low pass filter and the filter capacitors provide the 3 to 6-second delay on relay dropout.

EMERGENCY GENERATOR CONTROL

An energized motor-control solenoid prevents hydraulic fluid from driving the hydraulic motor, preventing generator operation. The solenoid is deenergized due to loss of power to essential A-C bus No. 1, or loss of the emergency D-C bus. The deenergized solenoid opens a hydraulic shutoff valve allowing the motor to operate. The solenoid is located below the motor generator.

When power to the essential A-C bus No. 1 fails, the Emergency Bus Power Relay (EBPR) is deenergized. Relay contacts open the circuit to the solenoid and the motor starts. An FSR senses generator output frequency through a low-pass high-pass filter. The FSR is energized when frequency is above 380 Hertz and deenergized below 360 Hertz. The FSR contacts provide a ground to energize the Emergency Generator Control Relay (EGCR), and Isolated DC Bus Power Relay (IBPR)

The energized EGCR connects the A-C and D-C generator outputs to the buses. The emergency buses are supplied through the deenergized EBPR, and the isolated buses are supplied through the energized Isolated A-C Bus Power Relay (IPR) and the Isolated D-C Bus Power Relay (IBPR). The FSR and EGCR



EMERGENCY GENERATOR CONTROL CIRCUITS

are located in the generator control box within hydraulic service center No. 2. The bus power relays are behind the emergency circuit breaker panel in the flight station.

The "EMER" position of the switch deenergizes the EBPR to start the generator. The "OFF" position prevents use of the emergency generator with a load by opening the EGCR circuit but does not prevent generator operation.

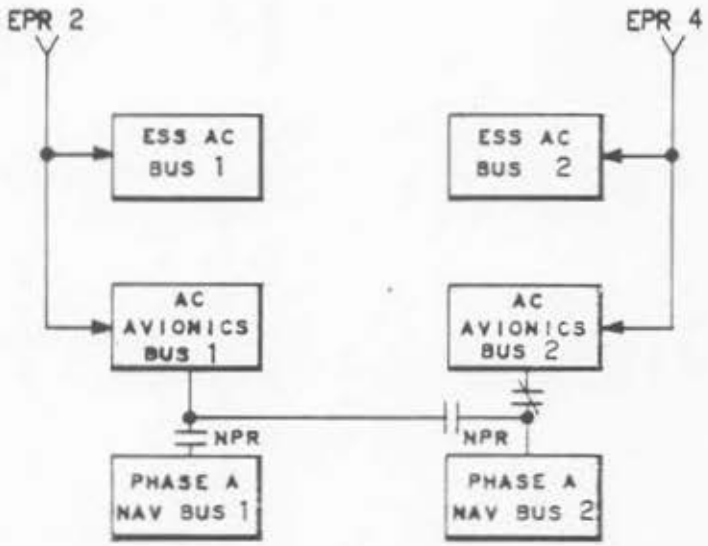
An EMERGENCY POWER test switch, located on the electrical control panel, is used to check the generator without a load. The voltmeter and frequency meter can be used to monitor generator output. The "TEST" position removes

emergency D-C bus power from the solenoid to start the generator. The output of the generator will not connect to the buses in "TEST" since the TEST RELAY opens the IPR and IBPR to the isolated bus. Power from the emergency generator cannot reach the emergency bus due to open contacts of EBPR.

An isolated bus power disconnect switch can be used to disconnect the isolated buses from the emergency generator. The "OFF" position deenergizes the IBR, and IBPR. The relays prevent generator power from reaching the isolated buses, and the emergency buses remain energized from the emergency generator.

NAVIGATION BUSES

The avionic buses are energized from the primary bus power sources. The Phase A navigation buses are normally energized through the Navigation Bus Power Relay (NBR). The NBR is energized from the emergency D-C bus when the normal power sources are operating. The navigation buses are normally supplied power from the A-C avionics bus No. 1.



NAVIGATION BUS POWER SOURCES

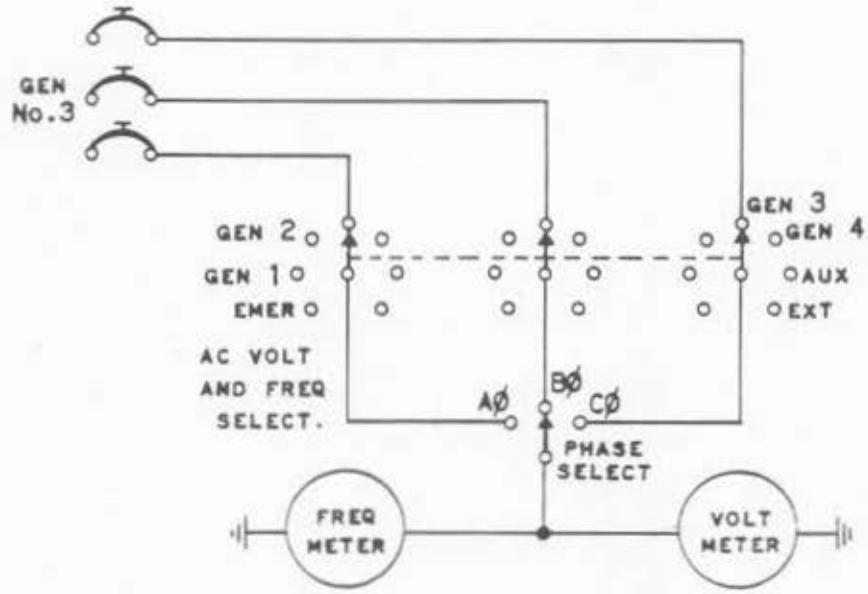
If the emergency generator is operating, the NBR is deenergized. The NBR opens the circuit to the Phase A navigation bus No. 1, and connects Phase A navigation bus No. 2 avionics bus No. 2. The avionics bus No. 2 is supplied from essential A-C bus No. 2 which may still be energized, even though the emergency generator is operating. The emergency generator is controlled by loss of power to essential A-C bus No. 1.

FLIGHT ENGINEER"S ELECTRICAL CONTROL PANEL

The control switches, selectors, and indicators necessary to monitor and maintain control of the electrical power system are on the flight engineer's electrical control panel.

AC METERS

The output frequency and phase voltage of all generators or external A-C power can be monitored on the frequency and volt meter through switch selections.

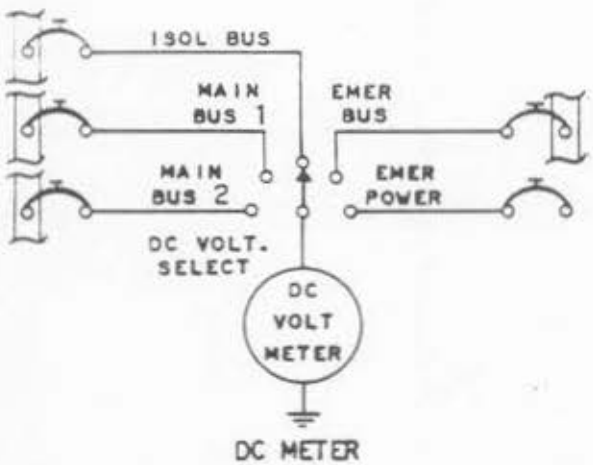


AC METERS

The system to be monitored is selected on the AC VOLT & FREQ SELECT switch and phase on the PHASE SELECT switch. During parallel operation, the voltmeter reading is the voltage of the parallel generators, not the selected generator. Isolated operation, or "TEST" of the generator is used to obtain a single generator indication.

D-C METERS

Voltage of all D-C sources may be checked on the D-C volt meter through the DC VOLT SELECT switch. Battery voltage may be read on the isolated D-C bus when the TR units and emergency generator are not operating. The battery switch must be positioned to "ON," energizing the isolated D-C bus from battery voltage.



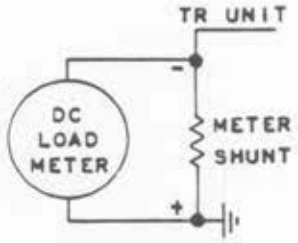
DC METER

Two D-C load meters indicate the percent load on each TR unit. A 100 percent reading is equal to 200 amperes. The reading is provided by a meter shunt in series with the TR unit ground wire.

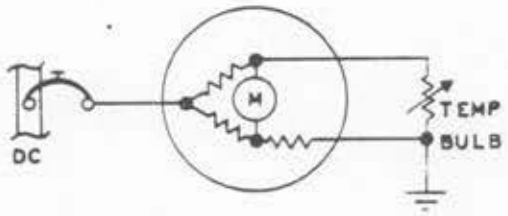
CSD MONITORING

Each CSD unit has a temperature indicator, warning light, and disconnect switch. The indicator

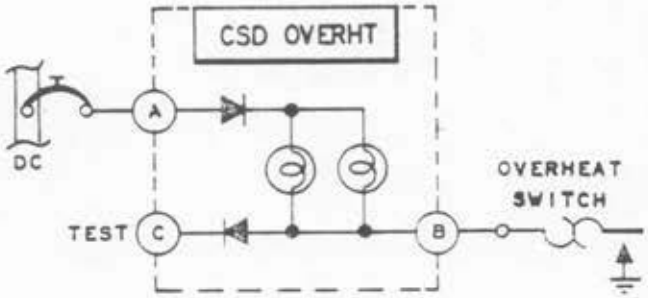
and warning light are controlled by CSD oil temperature. The CSD overheat switch closes above 179° C to illuminate the warning light. The CSD DISC switch controls a solenoid in the CSD unit. If the switch is actuated while D-C power is available, the CSD will be disconnected. The CSD remains disconnected until the manual lever on the CSD is reset.



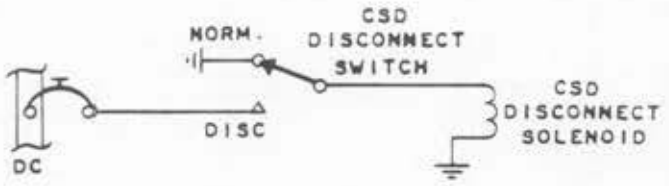
LOADMETER



CSD OIL TEMP



CSD OVERHEAT LIGHT

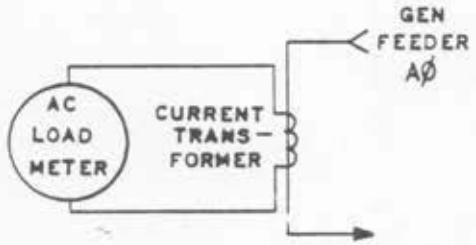


CSD DISCONNECT

GENERATOR MONITORING

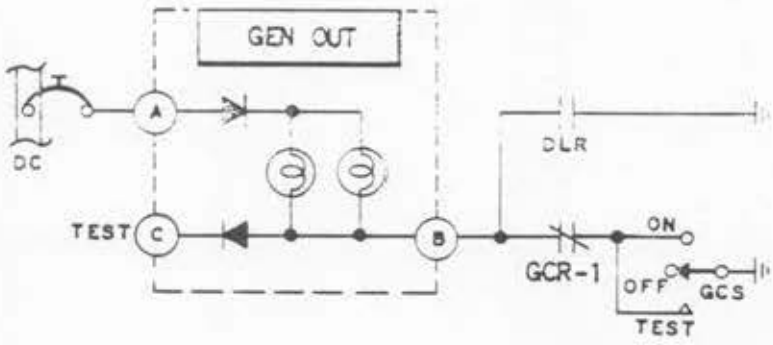
Each main generator and auxiliary generator has a GEN FAIL light, loadmeter, generator OFF light, and control switch. The fail light illuminates due to a mechanical circuit in the generator when the generator bearings fail. The load may be removed from the generator by moving the control switch to "OFF," or the generator can be stopped by disconnecting the CSD. The auxiliary generator can be stopped by turning the APU to "OFF."

The generator loadmeter indicates percent load, with 100 percent equal to 50KVA. During normal parallel operation, the main generator load meters should read the same. The loadmeter reading is provided by a current transformer around the Phase A feeder of the generator.

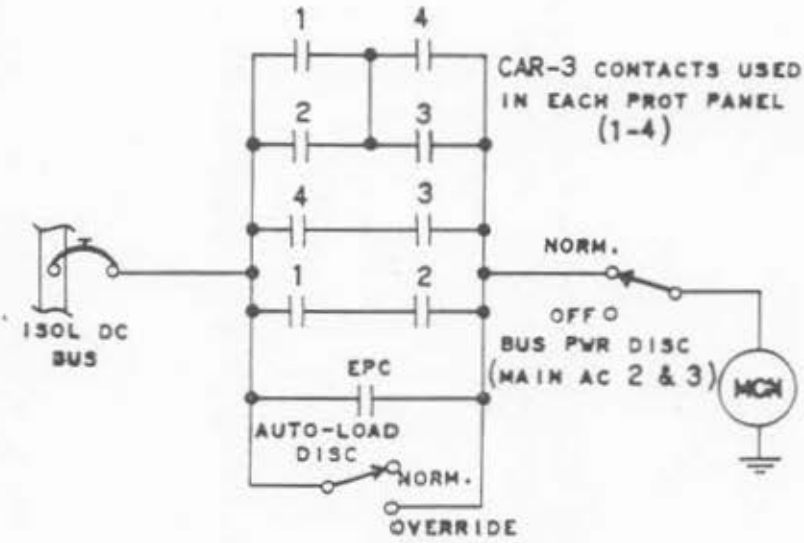


LOADMETER

The generator OUT light illuminates through GCR-1 or DLR contacts when the protection circuits trip the generator. The light is extinguished by placing the control switch in "OFF." If a ground fault exists, the light remains illuminated in "OFF" due to the DLR until reset is accomplished. The auxiliary generator OUT light is extinguished in the "OFF" position of the control switch since the auxiliary generator does not have a DLR. The bus tie OPEN light is identical to the generator OUT light but is controlled by normally closed BTC contacts.



GENERATOR OUT LIGHT



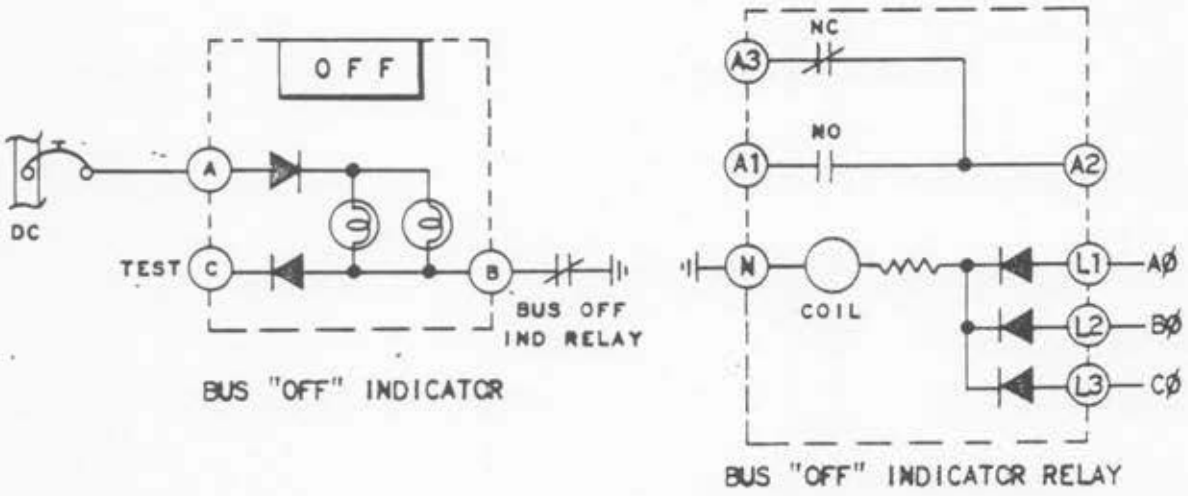
MONITOR RELAY CONTROL

AUTO LOAD DISCONNECT SWITCHES

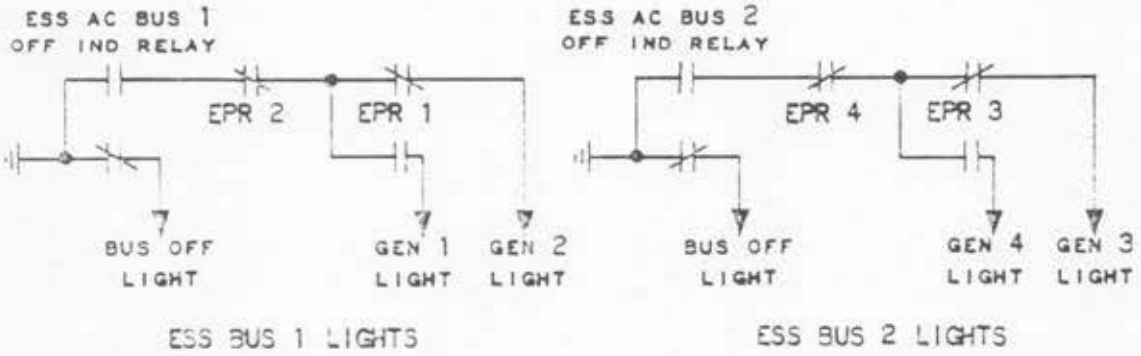
The No. 2 and No. 3 main generator systems have auto load-disconnect switches to permit override of the monitor relays. The relays are normally energized through two series CAR-3 contacts of the protection panels. Two or more main generators in operation close the CAR-3 contacts to energize the relays. External power also energizes the relays through EPC contacts. The auto load disconnect switch is used to bypass the CAR-3 contacts (override) to energize the monitor relays.

BUS WARNING LIGHTS

The A-C bus OFF warning lights are provided for main A-C buses No. 1 and 4, essential A-C buses No. 1 and 2, and isolated A-C bus. The OFF lights are controlled by bus OFF indicator relays which sense the three-phase bus voltage. The relays are energized when bus voltage is normal. Rectifiers change the three-phase bus voltage to DC for the relay coil. When the bus fails or has low voltage (three-phase average below 90 volts AC), the relay is deenergized and the light illuminates. The relays are located in the flight station relay panel below the flight engineer's table.



The essential bus indicator lights are OFF - GEN 1 and GEN 2 for essential bus 1. The essential bus No. 2 lights are OFF - GEN 3 and GEN 4. The OFF light is illuminated through the deenergized bus off indicator relay when the bus source fails. The GEN 1 light is illuminated through the energized bus off indicator relay, deenergized EPR-2 and energized EPR-1. The bus is supplied power from generator No. 1.



The GEN 2 light is illuminated through the deenergized EPR-1. The bus is supplied power from Generator 2. All three lights extinguish when the main A-C tie bus has a power source due to the energized bus off indicator relay and EPR-2. The essential bus No. 2 lights function the same as bus 1 using EPR-3 and EPR-4.

The isolated A-C bus off indicator relay is energized by three-phase A-C voltage from the isolated A-C bus. The relay controls the isolated A-C OFF light. The EMER PWR and ISOL AC BUS light illuminate when the emergency generator is

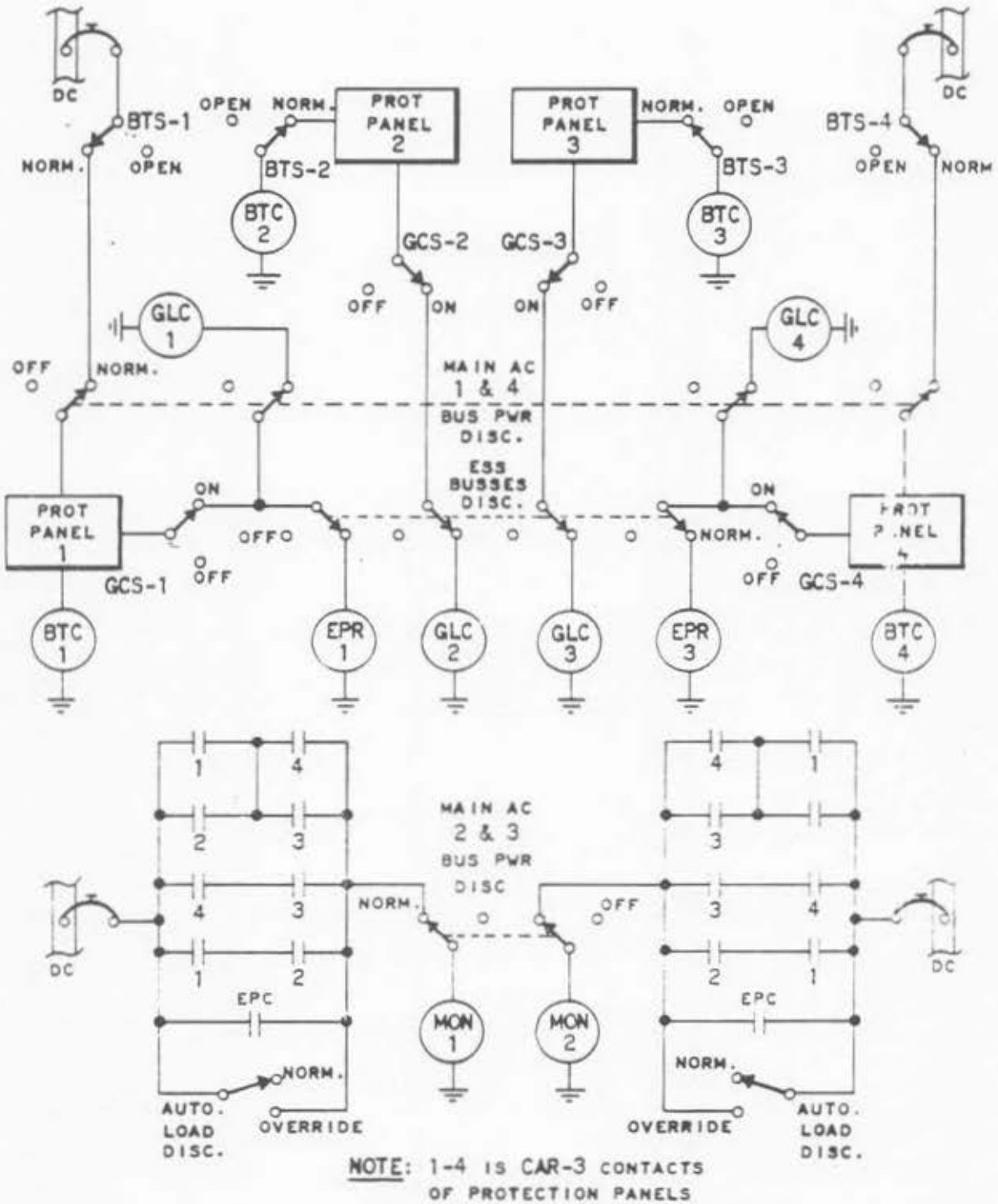
supplying power to the bus. The lights are controlled through the energized IPR. The EMER PWR EMER AC BUS lights illuminate when emergency bus is supplied power from the emergency generator. The lights are controlled through the energized EGCR and deenergized EBPR. An EMER PWR ON light, located on the pilot's instrument panel, also illuminates to indicate emergency power is supplying the emergency A-C bus. The light is in parallel with emergency bus lights.

BUS POWER DISCONNECT SWITCHES

The disconnect switches are provided to remove the bus load quickly in case of a fire or emergency condition. The main A-C buses No. 2 and 3 switch in the "OFF" position opens the monitor relays, disconnecting main A-C buses No. 2 and 3. The main A-C buses No. 1 and 4 switch opens GLC's 1 and 4 and BTC's 1 and 4, disconnecting main A-C buses No. 1 and 4. The essential buses switch opens GLC-2 and GLC-3, deenergizing the essential A-C buses and main A-C tie bus by deenergizing EPR-1 and EPR-3.

The main A-C bus disconnect switches should be "OFF" before the essential buses' disconnect switch is effective in generator parallel operation. The isolated bus switch deenergizes the isolated A-C and D-C power relays (IPR and IBPR).

The switch connects the isolated buses to the normal system by deenergizing the relays. If the normal power source is operating, the switch has no effect and the isolated buses remain energized. The emergency generator must be the only power source before the isolated bus disconnect is effective.



NOTE: 1-4 IS CAR-3 CONTACTS OF PROTECTION PANELS

BUS POWER DISCONNECT