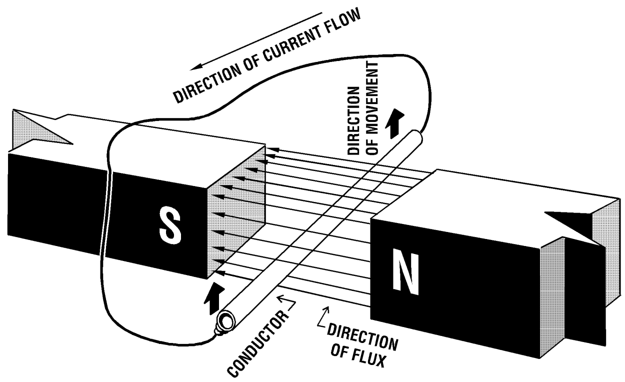
A. A knowledge of basic electrical theory is essential to understanding the operation of the AH-64 AC and DC power generation systems. Current Generation Theory, AC Generator Theory, Generator limiting factors, Frequency Determination of an AC Generator, Phase Determination of an AC Generator, and AH-64A generator output specifications will be discussed.

CURRENT AND VOLTAGE GENERATION THEORY I

ELECTROMAGNETIC INDUCTION



09-94-08

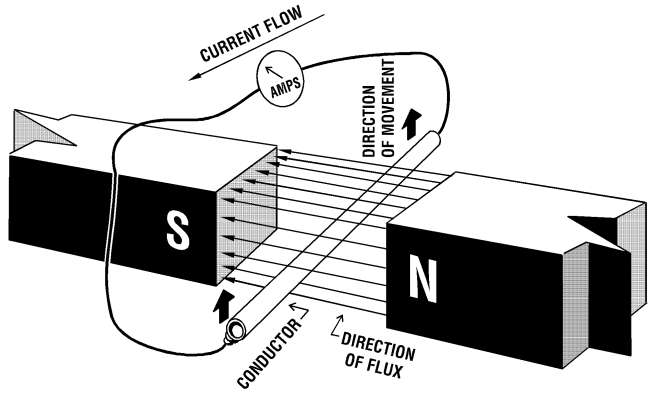
NOTES

1. Current and Voltage Generation Theory

   a. When an electrical conductor (wire) moves at right angles to a magnetic field, electrons are caused to flow in that wire. The generation of electron flow by moving the wire in the presence of a magnetic field is called electromagnetic induction.

CURRENT AND VOLTAGE GENERATION THEORY II

CURRENT MEASUREMENT



09-94-09

NOTES

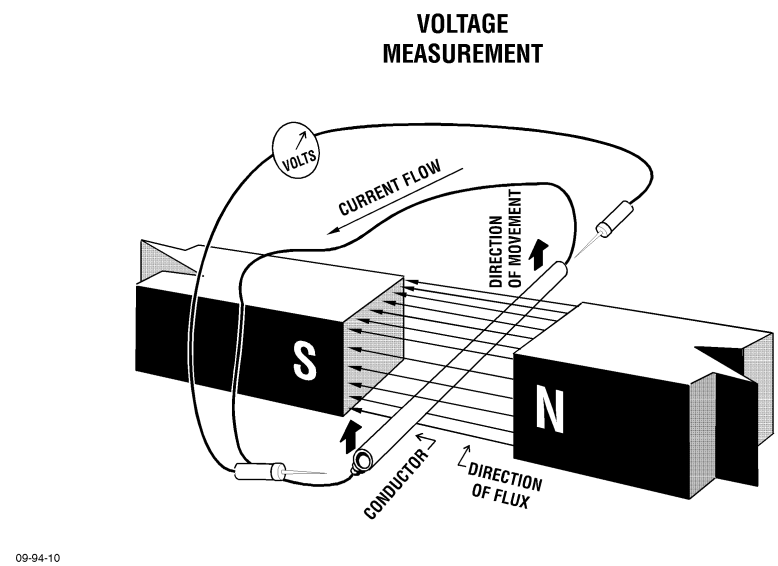
b. The current can be measured by placing an current meter (known as an ammeter) in series with the circuit. The current flowing thru the wire will cause a DC voltage to be created because the wire has a small amount of resistance to current flow, about 16.9 ohms per 1000 feet for 22 gauge copper wire. If the resistance and current are known, the voltage can be determined by the voltage, current, and resistance relationship established by Ohm's Law .

Ohm's Law for DC current

voltage = current x resistance

$E = I \times R$

CURRENT AND VOLTAGE GENERATION THEORY III



NOTES

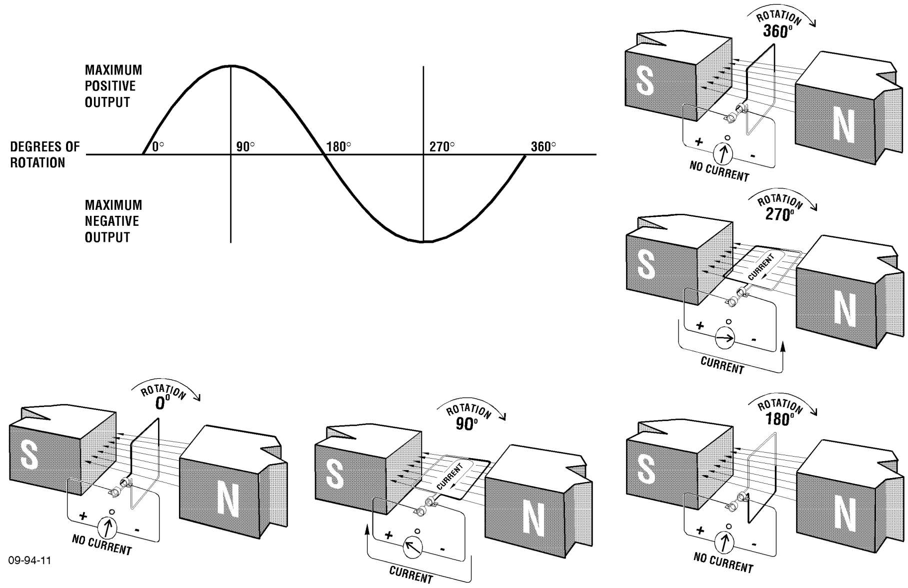
c. The DC voltage can be measured with a voltmeter by attaching it in parallel with the ends of the wire. The current and voltage will exist as long as the wire continues to move through the magnetic field in the same direction. If the wire is moved in the opposite direction, or if the polarity of the magnetic field is reversed (by turning the magnet around), the current will flow in the opposite direction and the voltage will reverse polarity.

d. The amount of current flowing in the wire is directly proportional to the rate of movement and the strength of the magnetic field, and inversely proportional to the resistance of the wire.

e. The amplitude of the DC voltage created is directly proportional to the rate of movement, the strength of the magnetic field, and the quantity of current flowing through the wire.

f. Current can also be made to flow in the wire by moving the magnetic field instead of moving the wire.

AC GENERATOR THEORY SYSTEMS
ROTATING COIL



NOTES

2. AC Generator Theory Systems Rotating Coil

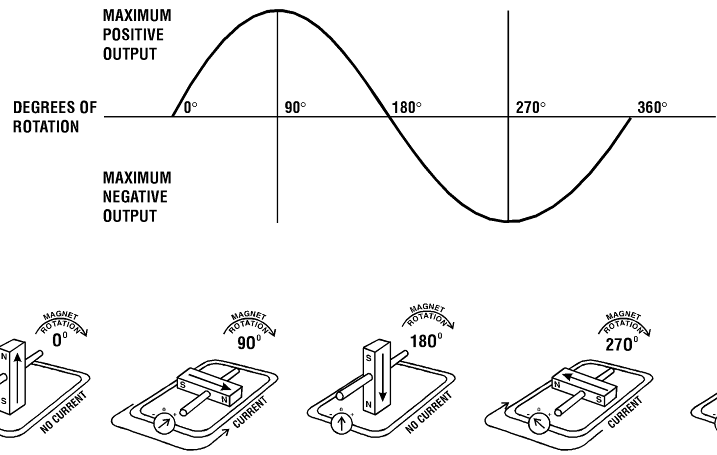
a. Rotating coil

(1) If a coil of wire is mounted on a shaft and rotated inside a magnetic field, an alternating current and an AC voltage will be generated. The current will flow in one direction, stop, reverse direction, stop, and flow in the opposite direction. The current will alternate in this cyclic manner as long as the coil is rotated.

(2) Voltage will be created by the current flowing through the resistance in the wire. As the current in the wire increases, the voltage will increase; and it will alternate from positive, to zero, to negative, to zero, back to positive and will continue to alternate in this cyclic manner as long as the coil is rotated.

(3) The disadvantage to this type of generator is that brushes and slip-rings must be used to connect the current and voltage supplied by the rotating coil to whatever will use it.

AC GENERATOR THEORY
ROTATING MAGNET



09-94-12

NOTES

3. AC Generator Theory-Rotating magnet

a. If a bar magnet is mounted on a shaft and rotated inside a coil of wire, which is at a right angle to the shaft, an alternating current and an AC voltage will be generated. The current will flow in one direction, stop, reverse direction, stop, and flow in the opposite direction. The current will alternate in this cyclic manner as long as the magnet is rotated.

b. The voltage will be created, as before, by the current flowing through the small resistance in the wire. As the current in the wire increases, the voltage will increase; and it will alternate from positive, to zero, to negative, to zero, back to positive and will continue to alternate in this cyclic manner as long as the magnet is rotated.

c. The current and voltage from a rotating magnet-type generator is usable without the need for slip-rings or brushes. This is possible because the coil is stationary and does not rotate, eliminating the need to connect the current through the coil by means of brushes. Brushes operate a high temperatures and are the weak link in a generator. Rotating magnet AC generators are more reliable because the brushes are eliminated in the design. This is the type of generator used on the AH-64A.

GENERATOR LIMITING FACTORS

BRUSH TYPE GENERATORS

- **BRUSH AND SLIP RING HIGH OPERATING TEMPERATURES**
- **GENERATED BY MECHANICAL FRICTION AND CURRENT**
- **SHORT LIFE EXPECTANCY AND UNRELIABILITY**
  BRUSHLESS PERMANENT MAGNET GENERATORS
- **MODERATELY HIGH WINDING TEMPERATURES**
- **GREATER SAFETY MARGIN FOR WINDINGS THAN FOR BRUSHES IN BRUSH TYPE**
- **GREATER RELIABILITY AND EFFICIENCY**

09-94-13

NOTES

4. Generator Limiting Factors

a. Brush type generators

(1) The temperature at which the brush and slip ring assemblies operate is the limiting factor in brush-type rotating coil generators.

(2) Mechanical friction and the heat generated by current flowing through the brushes and slip-rings create very high temperatures.

(3) The results of this characteristic are short life expectancy, unreliability, and degraded performance (lower current and voltage available) under maximum load situations.

(4) The generators used on the AH-64A do not experience these short comings due to the brushless design.

b. Brushless permanent magnet generators

(1) At high demands, the limiting factor for a brushless generator is the temperature of the windings.

(2) The margin of safety for the temperature of the windings is greater than the margin of safety for the temperature of the brushes in a brush-type generator.

(3) The reliability and efficiency of a brushless type generator is, by comparison, greater than the brush-type.

FREQUENCY DETERMINATION OF AN AC GENERATOR

$$\text{FREQUENCY} = \frac{\text{N x RPM}}{60}$$

FREQUENCY IN HERTZ (CYCLES PER SECOND)

N = NUMBER OF N-S POLAR PAIRS

RPM = GENERATOR SHAFT-
REVOLUTIONS PER MINUTE

60 = CHANGES REVOLUTION TIME BASE
FROM MINUTE TO SECONDS

09-94-14

NOTES

5. Frequency Determination of an AC Generator

a. The output frequency of an AC generator is determined by the number of poles of the rotor and the rotational speed which the generator operates with reference to time. A calculation must be done to know the output frequency of a specific AC generator. The frequency can be determined by the formula

$$\text{FREQUENCY} = \frac{\text{N x RPM}}{60}$$

(1) The output frequency, cycles, or number of complete alternations (from zero, to maximum positive, back to zero, to maximum negative, and back to zero) in each second of time, is specified as "hertz" ("cycles per second" is also acceptable).

(2) N = number of N-S polar pairs in the magnetic field.

(a) A standard bar-magnet has two poles, one north and one south. The N and S pole are considered as one polar pair.

(b) Permanent magnets and electromagnets may have more than two poles (an electro-magnetic field is created by current flowing through a field winding as established by basic generator theory).

(c) The AH-64A AC generators use both types, a twelve-pole permanent magnet for excitation and a four-pole electromagnetic field for control of the main generator.

(3) RPM = The number of times a generator shaft rotates 360° (one full turn or revolution) in one minute. The rotation of the shaft establishes the frequency output of the generator.

(4) Divide the product of the terms by 60 to change the time base from minutes to seconds. Rotation rates for mechanical systems are generally specified in minutes. Seconds are used as the time base used for frequency in electrical and electronic systems.

For example

The 4 pole, main rotating field winding in an AH-64A AC generator has 2 polar pairs.

(N = 2).

The accessory gear box turns the AC generators at 12,251 RPM with the engines running the main transmission at 100 % N_R (12,200 RPM with the APU running).

RPM = 12,251

FREQUENCY DETERMINATION OF AN AC GENERATOR

$$\text{FREQUENCY} = \frac{\text{N x RPM}}{60}$$

FREQUENCY IN HERTZ (CYCLES PER SECOND)

N = NUMBER OF N-S POLAR PAIRS

RPM = GENERATOR SHAFT- REVOLUTIONS PER MINUTE

60 = CHANGES REVOLUTION TIME BASE FROM MINUTE TO SECONDS

09-94-14

NOTES

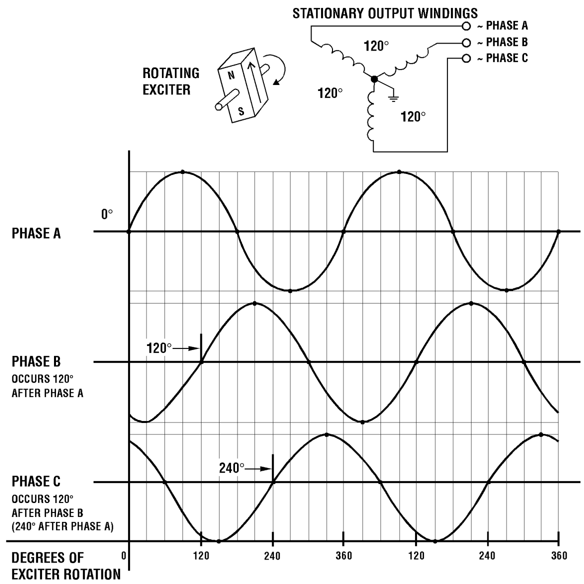
To convert the "minutes" time base in the generator RPM to the "seconds" time base required for frequency determination, divide by 60.

/60

$$408 \text{ hertz} = \frac{2 \times 12{,}251}{60}$$

The normal operating frequency of the generator is 408 hertz, at 100 % N_R.

PHASE DETERMINATION OF AN AC GENERATOR



09-94-15

NOTES

6. Phase Determination of an AC Generator

a. Normal house current is single phase.

b. A 3-phase AC generator has three single-phase outputs, designated phase A, phase B, and phase C.

(1) The current/voltage peaks of each output occurs at different times, due to the three output windings being physically mounted 120º apart. To simplify the discussion, only the positive peaks will be considered.

(a) As the magnetic exciter field rotates past one output winding, that output winding's current/voltage peak occurs.

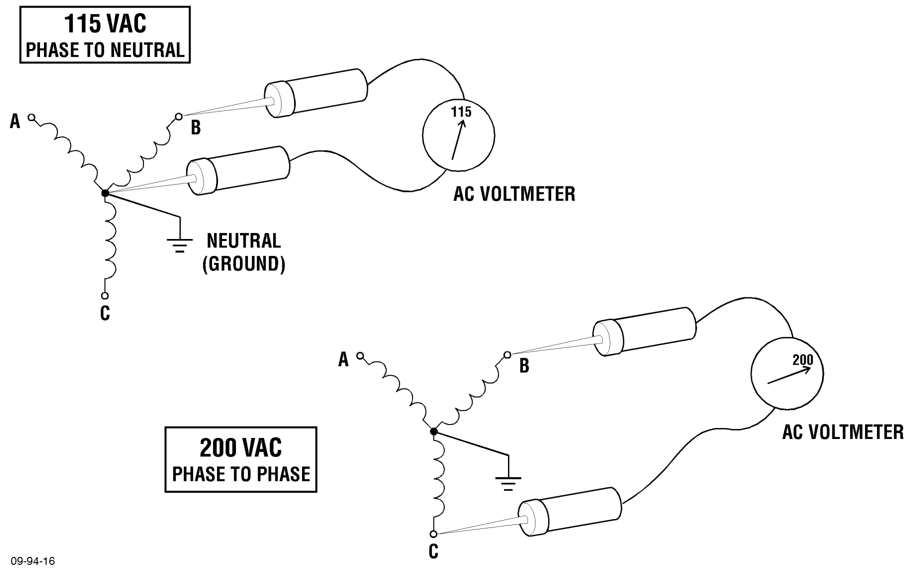
(b) The magnetic exciter field rotates to the next output winding 120º later (120º is 1/3 of a shaft revolution) and its current/voltage peak output occurs.

(c) The magnetic exciter field rotates to the next output winding 120º later (a total of 240º or 2/3 of a shaft revolution) and its current/voltage peak output occurs.

(d) The magnetic exciter field continues to rotate around and returns to the first output winding 120º later (a total of 360º or one full shaft revolution) and its current/voltage peak output occurs again.

(2) The advantages to a three-phase generator are compact packaging, higher total power available, and the ability to convert the 3-phase AC power to DC power efficiently.

AH-64A GENERATOR OUTPUT SPECIFICATION I



NOTES

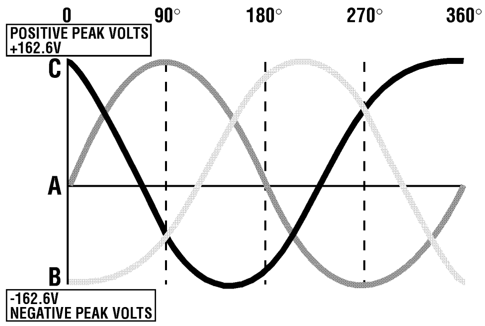
7. AH-64A Generator Output Specification

a. Each AH-64A Generator is a 3-phase, 115/200 VAC, 400 Hz, 35 Kilo Volt Amperes generator.

(1) The 3 output phases occur 120^{o} apart.

(2) 115 VAC is measured from neutral (ground) to the individual phase voltage test point, 200 VAC is measured phase to phase.

AH-64A GENERATOR OUTPUT SPEC II
PHASE TO PHASE RMS VOLTAGE



A	Sine A	Sine (A+240°)	Δ
0	0.000	-0.866	-0.866
30	0.500	-0.500	0.0
60	0.866	-0.000	0.866
90	1.000	+0.500	1.500
120	0.866	+0.866	1.732
150	0.500	+1.000	1.500
180	0.0	+0.866	0.866
210	-0.500	+0.500	0.0
240	-0.866	-0.0	-0.866
270	-1.000	-0.500	-1.5
300	-0.866	-0.866	-1.732
330	-0.500	-1.000	-1.5

115 VAC (RMS VALUE)

PEAK VOLTAGE = 115 VAC X 1.414

PEAK VOLTAGE = ±162.6V

PHASE TO PHASE VOLTAGE = SINE A + SINE (A - 120 DEGREES)

BY CHOOSING PHASE "A" AT ITS PEAK VALUE:

= SINE A (AT 90°) + SINE (A (AT 90°) - 120°)

= 1.000 (162.6 VOLTS) + 0.500 (162.6 VOLTS)

PHASE TO PHASE VOLTAGE = 243.9 VOLTS

09-94-17

NOTES

(a) The computation of phase to phase voltage is the RMS value of sine A + sine (A - 120 DEG). Also, sine A - sine (A + 120º]).

(b) The new peak value of the wave form increases from 162.6 volts to 243.9 volts.

(3) 400 Hz is the frequency of each of the 3-phase outputs.

(a) The Phase A output frequency is 400 Hz.

(b) The Phase B output frequency is 400 Hz and occurs 120º after Phase A.

(c) The Phase C output frequency is 400 Hz and occurs 120º after Phase B (240º after Phase A).

(4) KILO-VOLT-AMPERES RATING

(a) Each AH-64A generator is rated at 35 KVA.

(b) The Kilo-Volt-Amperes rating of a generator is a way of stating how much electrical power a generator can provide.

(c) Electrical power is stated and measured in watts.

1) One Watt is defined as one Volt-Ampere (1 Watt = 1 Volt x 1 Ampere).

2) One thousand Watts is one thousand Volt- Amperes. Different combinations of voltage and current will yield one thousand watts.

a) 1000 Watts = 1 Volt x 1000 Amperes, or

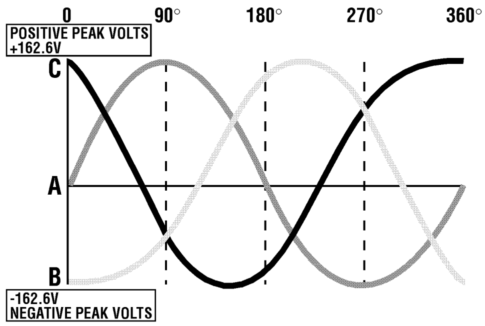
b) 1000 Watts = 10 Volts x 100 Ampere, or

c) 1000 Watts = 100 Volts x 10 Amperes

(d) In the case of the AH-64A generators, the 35 KVA rating is determined by substituting the known values.

1) Each AH-64A generator is rated at 300 amps maximum continuous current at 116.6 volts.

AH-64A GENERATOR OUTPUT SPEC II
PHASE TO PHASE RMS VOLTAGE



A	Sine A	Sine (A+240°)	Δ
0	0.000	-0.866	-0.866
30	0.500	-0.500	0.0
60	0.866	-0.000	0.866
90	1.000	+0.500	1.500
120	0.866	+0.866	1.732
150	0.500	+1.000	1.500
180	0.0	+0.866	0.866
210	-0.500	+0.500	0.0
240	-0.866	-0.0	-0.866
270	-1.000	-0.500	-1.5
300	-0.866	-0.866	-1.732
330	-0.500	-1.000	-1.5

115 VAC (RMS VALUE)

PEAK VOLTAGE = 115 VAC X 1.414

PEAK VOLTAGE = ±162.6V

PHASE TO PHASE VOLTAGE = SINE A + SINE (A - 120 DEGREES)

BY CHOOSING PHASE "A" AT ITS PEAK VALUE:

= SINE A (AT 90°) + SINE (A (AT 90°) - 120°)

= 1.000 (162.6 VOLTS) + 0.500 (162.6 VOLTS)

PHASE TO PHASE VOLTAGE = 243.9 VOLTS

09-94-17

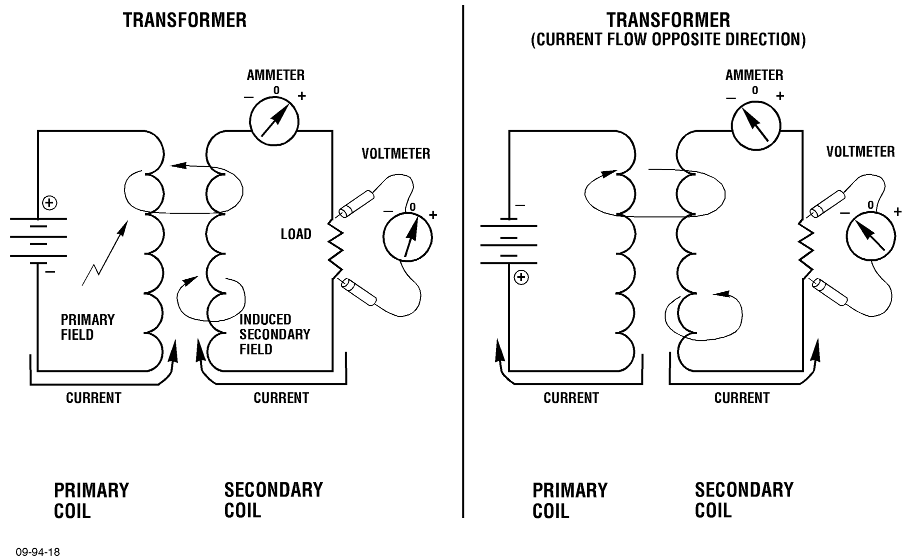
NOTES

2) By substitution into the electrical power formula, Watts = Volts x Amperes.

   a) 300 amps X 116.6 volts = 35 kilo watts

   b) By definition 35 kilo watts = 35 kilo volt-amperes.

TRANSFORMER THEORY



NOTES

8. Transformer Theory

a. A basic transformer consists of two coils of wire. The two coils are called the primary and secondary coils. The two coils are wound in close proximity to one another, in a way which aids the transfer of energy, by transformer action, from one coil to the other. Transformer Action is the interaction of a magnetic field and two or more conductors in close proximity to each other.

b. Transformer operation

(1) Expanding field

(a) If a voltage is applied to the first coil (called the primary coil or winding), a current will flow through it and a magnetic field will be created. As the magnetic field is created and gets stronger, it expands out and surrounds the second coil (called the secondary coil or winding).

(b) As the magnetic field expands out and surrounds the second coil (secondary), a current is induced to flow in it. The current flowing through the resistance of the secondary will create a voltage across it.

(c) Once the current flowing in the primary has reached and continues to flow at its maximum value, the magnetic field stops expanding and stays at its maximum strength.

(d) When the field stops expanding, the current in the secondary drops until it reaches zero. The voltage across the secondary will also drop until it reaches zero.

(2) Collapsing field

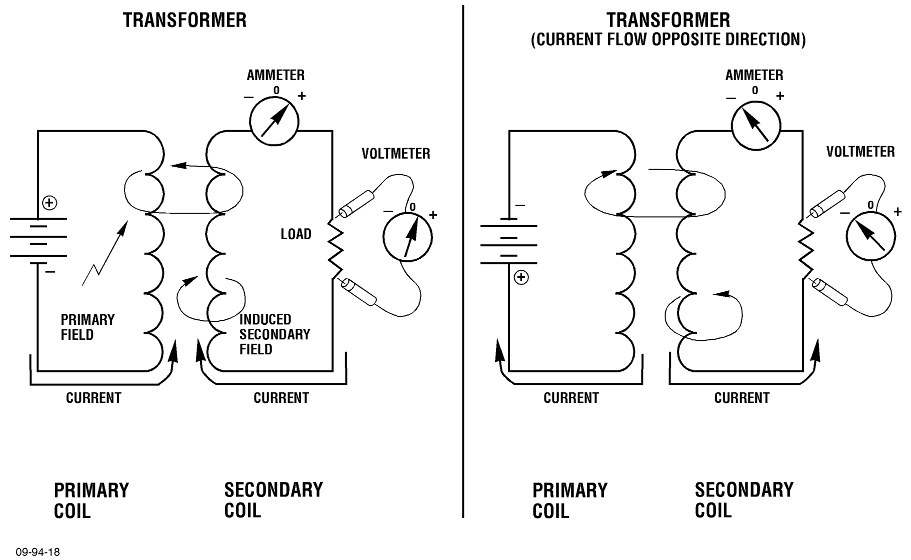
(a) If current flow in the primary is caused to flow in the opposite direction, a magnetic field will be created of the opposite polarity. As the field expands, it surrounds the secondary coil and induces a current to flow in it.

(b) The current flow in the secondary is now in the opposite direction, and a voltage of the opposite polarity is created.

(c) Once the current is flowing in the primary has reached its maximum value, the magnetic field stops expanding and stays at its maximum strength.

(d) When the field stops expanding, the current in the secondary drops until it reaches zero. The voltage across the secondary will also drop until it reaches zero.

TRANSFORMER THEORY



NOTES

(3) Alternating field

(a) If the current in the primary continues to change from one direction to the other, it is said to alternate. An AC current in the primary creates a magnetic field with alternating polarities and a voltage with alternating polarities in the primary. The alternating magnetic field in the primary induces an AC current and voltage in the secondary coil.

(b) The secondary will have a voltage present across it and a current flowing in it ONLY as the magnetic field expands or collapses.

(c) The ability to quickly reverse field polarity and the efficiency of current transfer from the primary to the secondary can be improved by the use of magnetic core materials, such a iron or nickel-cobalt, around which the coils are wound.

(4) Transformers and DC current

(a) Expanding field

1) If the field were created by a DC CURRENT, it would EXPAND ONLY FOR AN INSTANT, as the DC current was INITIALLY caused to flow in the primary coil. Voltage is present across, and current is caused to flow in the secondary only during this time.

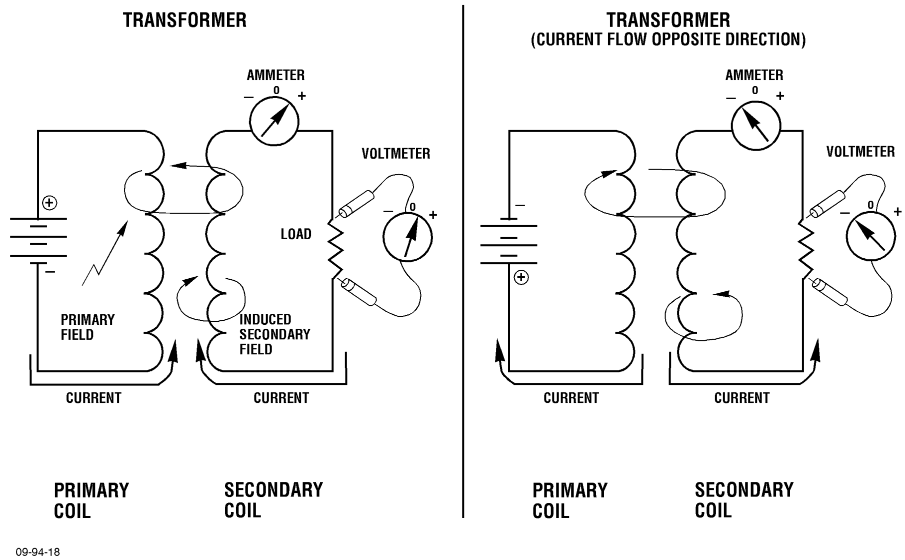
(b) Steady state field

1) The field would then reach a maximum point, and WOULD NOT EXPAND ANY FURTHER as the DC current is stabilized and flowing at it's CONSTANT "direct" rate.

2) The current in, and the voltage across, the secondary winding would become zero at this time BECAUSE THE FIELD HAS STOPPED EXPANDING.

3) As long as the DC current flowing in the primary does not change, there will be no voltage present across, or current flowing in the secondary to provide a source of electrical power for equipment to use.

TRANSFORMER THEORY



NOTES

(c) Collapsing field

1) The field will collapse if the DC current is REMOVED from the primary which will cause voltage of the opposite polarity to be present across the secondary, and current will flow in the opposite direction through the secondary for a very brief instant of time.

(d) Zero field

1) The field will collapse entirely, at which time the current in, and the voltage across, the secondary winding would become zero at this time BECAUSE THE FIELD HAS STOPPED COLLAPSING.

2) There is an initial, very brief, transfer of voltage and current to the secondary when DC current is applied to (or removed from) the primary but it is of no use to systems that require DIRECT, CONTINUOUS CURRENT over long periods of time.

3) TRANSFORMER ACTION, the transferring of voltage and current FROM a primary winding TO a secondary winding, DEPENDS on the FIELD EXPANDING or COLLAPSING, CONTINUALLY, to cause voltage and current to be transferred in USEABLE AMOUNTS to the secondary. This is the reason that there are no "DC" transformers.

c. Transformer Turns Ratio, Current, and voltage relationship

(1) Turns ratio

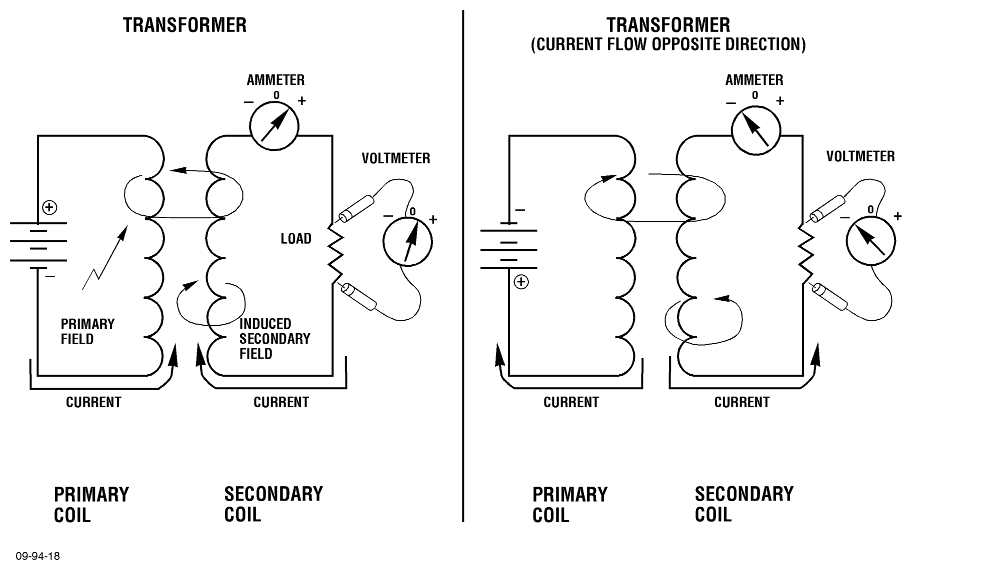
(a) The relationship of the number of turns in the primary coil to the secondary coil is called the turns ratio. There are three basic types of transformer turns ratio relationships.

1) 1:1 (one-to-one) - the number of turns in the primary coil is equal to the number of turns in the secondary coil.

2) Step up transformer - if there are less windings in the primary than in the secondary.

3) Step down transformer - if there are more windings in the secondary than in the primary.

TRANSFORMER THEORY



NOTES

(2) Turns Ratio, Current, and voltage relationship

(a) The number of turns in the secondary to the number of turns in the primary, Np / Ns is the turns ratio.

(b) The voltage across the secondary to the voltage across the primary, Ep / Es, is the voltage ratio.

(c) The current flowing in the PRIMARY the current flowing in the SECONDARY (which is an inverse ratio, Is / Ip, is the current ratio.

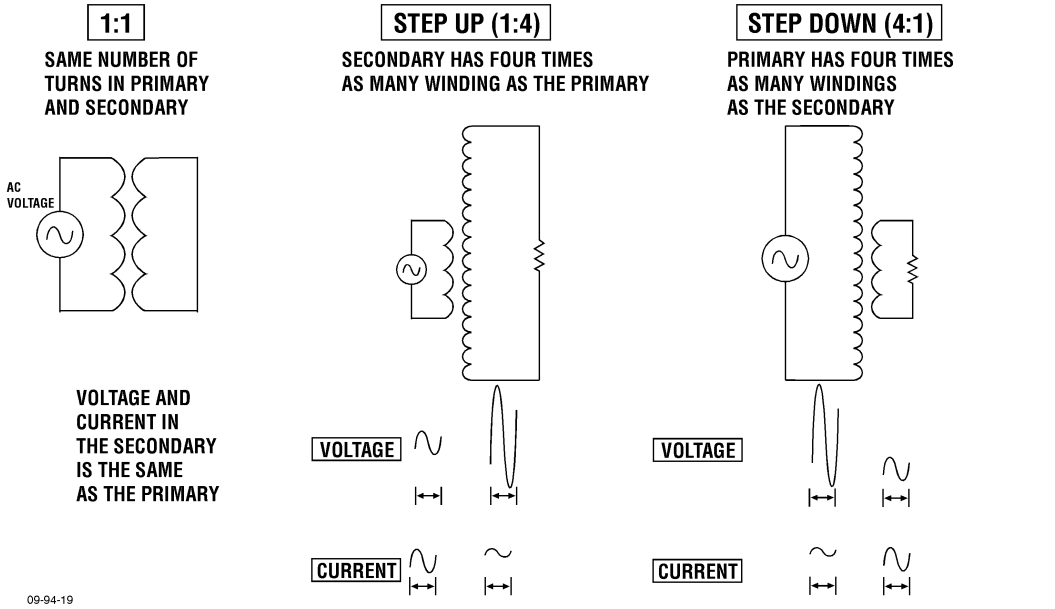
(d) The impedance (AC "resistance") of the secondary to the impedance of the primary, Zp / Zs is the impedance ratio.

(e) The current and voltage induced in the secondary of a transformer can be altered by changing the number of turns of the secondary coil in relation the to the primary coil. For example, if there are fewer turns in the secondary, the secondary voltage will be less, the secondary current will be more, and the impedance will be less.

(3) Turns Ratio, Current, and voltage formula

$$\frac{Np}{Ns} = \frac{Ep}{Es} = \frac{Is}{Ip} = \sqrt{\frac{Zp}{Zs}}$$

1:1 STEP UP AND STEP DOWN TRANSFORMERS



NOTES

(4) 1:1 (one-to-one) transformer

(a) The number of turns in the primary and secondary windings are equal.

(b) A 1:1 transformer is used to transfer an AC signal from one circuit to another without transferring a DC signal along with it.

(5) Step up transformer

(a) Contains more windings in the secondary than in the primary.

1) The secondary voltage will be higher and the current will be lower than in primary.

2) If the turns ratio of the transformer is 1:4 (four times as many windings in the secondary)

a) The voltage across the secondary will be 4 X the primary voltage.

b) The current in the secondary will be 1/4 of the primary current.

3) Automotive ignition coils are step up transformers that convert CHOPPED DC (which acts like AC in transformer operation) to a high energy magnetic field.

(6) Step down transformer

(a) Contains more windings in the primary than in the secondary

1) The secondary voltage will be lower and the current will be higher than in primary.

2) If the turns ratio of the transformer is 4:1 (four times as many windings in the primary)

a) The voltage in the secondary will be 1/4 of the primary voltage.

b) The current in the secondary will be 4 X higher.

1:1 STEP UP AND STEP DOWN TRANSFORMERS

1:1

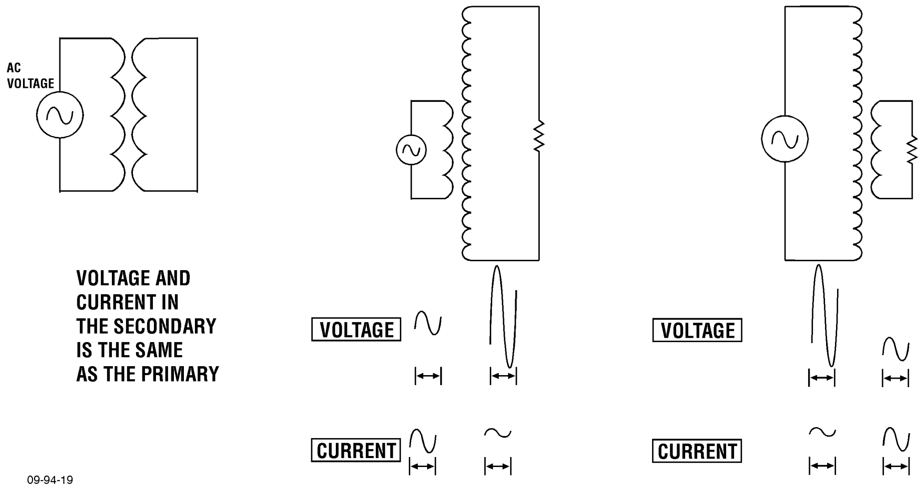
SAME NUMBER OF TURNS IN PRIMARY AND SECONDARY

STEP UP (1:4)

SECONDARY HAS FOUR TIMES AS MANY WINDING AS THE PRIMARY

STEP DOWN (4:1)

PRIMARY HAS FOUR TIMES AS MANY WINDINGS AS THE SECONDARY



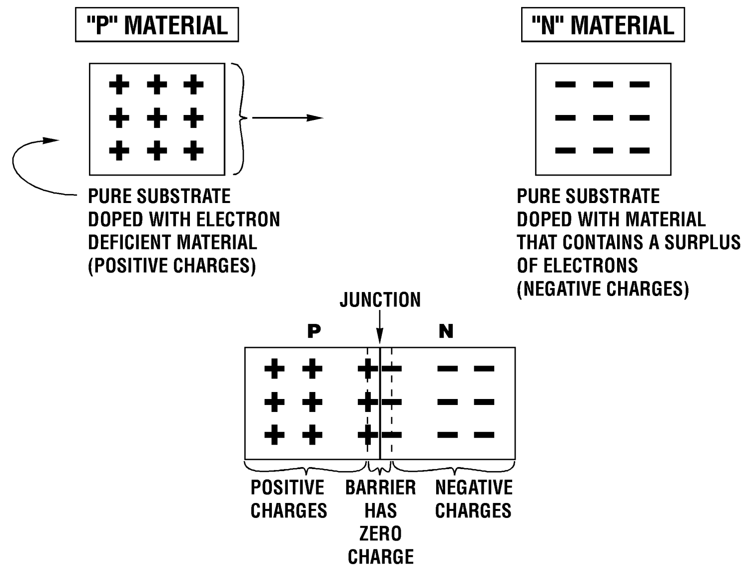
VOLTAGE AND CURRENT IN THE SECONDARY IS THE SAME AS THE PRIMARY

09-94-19

NOTES

(b) The transformer rectifiers for each AH-64A DC electrical system use step down transformers for each AC input phase, to lower the AC input voltage before converting it a DC voltage through the use of rectifiers.

RECTIFIER THEORY I



09-94-20

NOTES

9. Rectifier Theory

a. Many types of electrical circuits and electrical equipment use DC current provided by a DC low voltage source.

b. High AC voltages at low currents can be transferred more efficiently over long distances but are more difficult to use than low voltage DC.

c. Transformers are used to reduce the AC voltage to a lower, more useable level, near the location it will be used.

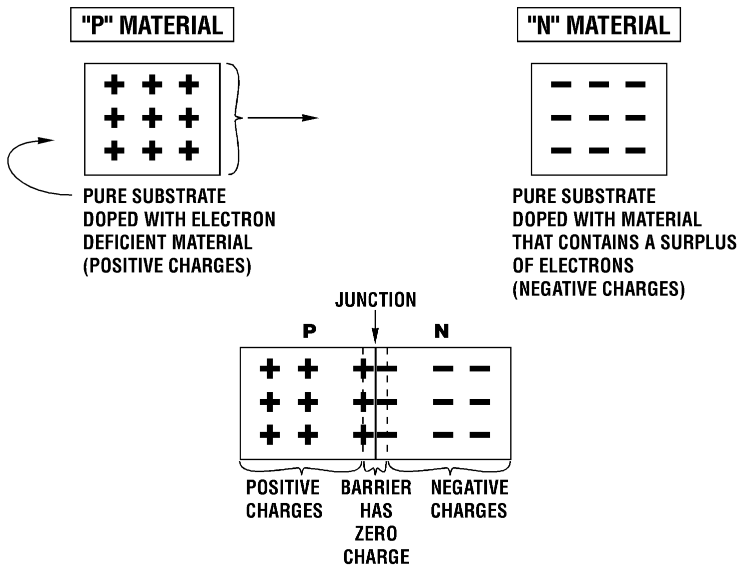
d. Rectifiers are special diodes that are designed to handle high currents.

e. Rectifiers are used in the CONVERSION OF ALTERNATING CURRENT and voltage TO A UNIDIRECTIONAL OR DIRECT CURRENT and voltage. RECTIFIERS ACCOMPLISH THIS BY PERMITTING CURRENT FLOW IN ONE DIRECTION AND NOT IN THE OTHER.

f. A rectifier is a semiconductor device that consists of a two types of materials. They are both made from a very pure substrate material that will allow electrons to flow through them, although poorly, and not as easily as a pure conductor will. Substrate materials usually have four electrons in their outer (valence) shell, which is fewer than the maximum of eight electrons that can stably remain in the outer shell. As a result these material have some resistance to current flow and fall in between a good conductor (copper wire) and a good insulator (glass).

g. To make the substrate material usable, impurities of two different types are introduced in the manufacturing process to yield two different types of treated, or "doped" SEMICONDUCTOR material. One of the impurities typically used has 3 valence electrons and the other common impurity has 5 valence electrons. The net result is that one doped substrate material becomes a semiconductor that has 7 valence electrons, (carries a positive charge, 8 - 7 = + 1) and is called "P" MATERIAL. The other doped substrate material becomes a semiconductor that has 9 valence electrons, carries a negative charge, 8 - 9 = - 1) and is called "N" MATERIAL. The 7 valence electron semiconductor material (P) will tend to gain an electron to reach the stable 8 valence electron (zero charge) configuration. The 9 valence electron semiconductor material (N) will tend to lose an electron to reach the stable 8 valence electron (zero charge) configuration. Both semiconductor materials will tend to either gain or lose an electron, EASILY. Application of a voltage of the proper polarity is sufficient to accomplish the gain or loss. The gain or loss is current flow.

RECTIFIER THEORY I

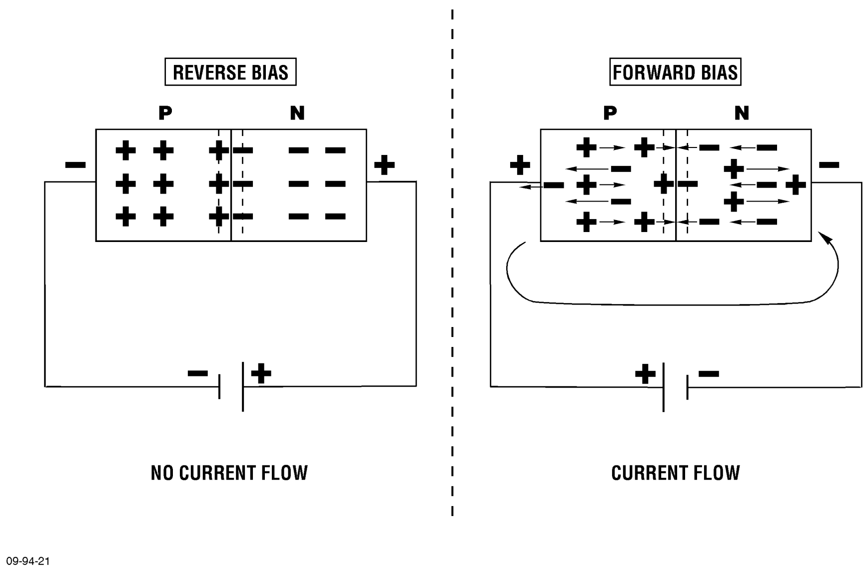


09-94-20

NOTES

h. The P and N material are joined during the manufacturing process and remain two separate types of material. The interface where they are joined is called a junction. When the materials are joined, some of the excess electrons from the N material leave their valence shells and fill the electron deficiency in the valence shells of the some of the P material. This creates a barrier of semiconductor material of neutral or ZERO charge. Only the P and N material in the IMMEDIATE vicinity of the junction forms this barrier. Once the barrier has formed, the combining stops, leaves P material on one side and N material on the other side.

RECTIFIER THEORY II



NOTES

i. If a voltage is applied to the P and N material, with Negative voltage to the P material and the Positive voltage to the N material, the unlike charges of the applied voltage and material attract and move the charges of the P and N material FURTHER AWAY from the junction. There is NO CURRENT FLOW through the junction and the junction is said to be "back" or "reverse" biased.

j. If a voltage is applied to the P and N material, with Positive voltage to the P material and the Negative voltage to the N material, the like charges of the applied voltage and material repel and move the charges of the P and N material toward the junction. If the voltage is raised to a certain point, the charges will cross the junction. The excess electrons from the N material flow across the junction to combine with electron deficient P material. CURRENT FLOWS through the junction and the junction is said to be "forward" biased.

k. Once across the junction, most of the electrons continue to flow through the P material, to the Positive end of the voltage source, through the voltage source, out of the Negative end of the voltage source and to the N material, which is now slightly deficient of electrons due to electron flow through the junction.

l. Current will continue to flow as long as the voltage at the ends of the P material, called the ANODE, and N material, called the CATHODE, is sufficient to keep the junction forward biased.

IMPEDANCE, REACTANCE AND AC CURRENT FLOW

- OHM'S LAW FOR DC CURRENT
  $E = I \times R$
- OHM'S LAW FOR AC CURRENT
  $E = I \times Z$
- IMPEDANCE
  $Z = \sqrt{R^2 + (X_L + X_c)^2}$
- INDUCTIVE REACTANCE
  $X_L = 2\pi fL$
- CAPACITIVE REACTANCE
  $X_c = \frac{1}{2\pi fC}$

09-94-22

NOTES

10. Ohm's Law for DC current applies to alternating current (AC) situations, with a modification.

Ohm's Law for DC current

voltage = current x resistance

$$E = I \times R$$

Becomes

11. Ohm's Law for AC current (with the substitution of the term impedance for resistance).

voltage = current x impedance

$$E = I \times Z$$

a. Impedance (Z) is "resistance" to AC current flow. Impedance takes into account the effects of the rate, or frequency, of the alternating current in a circuit that has Inductive Qualities and/or Capacitive Qualities. INDUCTIVE CIRCUITS RESIST AN INITIAL CHANGE IN CURRENT FLOW. Coils and transformers are inductive components. CAPACITIVE CIRCUITS ALLOW MAXIMUM INITIAL CHANGE IN CURRENT FLOW. Capacitors or circuits that act as capacitors, are capacitive components (the small spaces between the windings of a coil can act as a capacitor in higher frequency circuits).

b. Impedance is the mathematical vector component of Resistance (R), Inductive Reactance X_L (X_L is pronounced X-sub-L), and the Capacitive Reactance X_C (X_C is pronounced X-sub-C). Inductive and capacitive reactance tend to cancel each other out in a circuit. The larger of the two (X_L or X_C) will be the determining factor. When combined vectorially with the Resistance (R) of a circuit they will yield the net "resistance" to AC current flow.

$$Z = \sqrt{R^2 + (X_L - X_C)^2}$$

Impedance = the square root of the quantity
Resistance^2 +
(Inductive Reactance - Capacitive Reactance)^2

Z = Impedance is the mathematical vector component of Resistance (R), Inductive Reactance (X_L), and the Capacitive Reactance (X_C). It represents the "resistance" to AC current flow. The vector is derived by taking the square-root of the terms under the radical signs and observing the proper algebraic order of operation.

IMPEDANCE, REACTANCE AND AC CURRENT FLOW

- OHM'S LAW FOR DC CURRENT
  $E = I \times R$
- OHM'S LAW FOR AC CURRENT
  $E = I \times Z$
- IMPEDANCE
  $Z = \sqrt{R^2 + (X_L + X_c)^2}$
- INDUCTIVE REACTANCE
  $X_L = 2\pi fL$
- CAPACITIVE REACTANCE
  $X_c = \dfrac{1}{2\pi fC}$

09-94-22

NOTES

R^2 = Resistance^2 is the pure resistance to the AC current flow **AS IF** an identical value DC current is flowing through the circuit. The resistance is multiplied times itself to become the R^2 term of the equation.

X_L = Inductive Reactance is the resistance to AC current flow due to the pure inductive qualities of a circuit. Inductive reactance is usually associated with coils and transformers. Inductive reactance can be calculated by using the relationship

$$X_L = 2 \pi f L$$

X_C = Capacitive Reactance is the resistance to AC current flow due to the pure capacitive qualities of a circuit. Capacitive reactance is usually associated with capacitors, although other electronic components can exhibit capacitive reactance under the right circumstances. Capacitive reactance can be calculated by using the relationship

$$X_C = \frac{1}{2 \pi f C}$$

$(\quad)^2$ = The X_L - X_C terms are subtracted before the result is squared.

c. Some circuits are mostly inductive and the impedance (Z) is equal to the inductive reactance. A coil is a device that has inductive properties (inductive circuits resist an initial change in current flow) and is used as the example here.

$$X_L = 2 \pi f L$$

Inductive Reactance = 2 x π x Frequency x Inductance

X_L = Inductive Reactance is the resistance to AC current flow in a coil due to inductive effects. The Inductive Reactance is stated in OHM's.

2π = 2 times PI (2 x 3.14159)

f = The frequency of the AC current that is flowing through the coil (or the voltage across the coil); ie, 400 HZ in the case of the AH-64A AC generator main generator windings.

IMPEDANCE, REACTANCE AND AC CURRENT FLOW

- OHM'S LAW FOR DC CURRENT
  $E = I \times R$
- OHM'S LAW FOR AC CURRENT
  $E = I \times Z$
- IMPEDANCE
  $Z = \sqrt{R^2 + (X_L + X_C)^2}$
- INDUCTIVE REACTANCE
  $XL = 2\pi fL$
- CAPACITIVE REACTANCE
  $X_C = \frac{1}{2\pi fC}$

09-94-22

NOTES

L = The inductance of the coil or transformer is derived by an equation that is dependant on the specific type of inductive device and is not easily calculated or measured in normal troubleshooting circumstances. Some of the variables that control inductance are the shape of the inductor, length, radius, the cross sectional area, and the core material on which the inductor is wound. Many inductors have an inductance value marked on them. "Henrys" are the units that inductance is stated in (usually micro-Henrys, 10^{-6} Henrys, or one-millionth of a Henry).

d. Some circuits are mostly capacitive and the impedance (Z) is equal to the capacitive reactance. A capacitor is a device that has capacitive properties (capacitive circuits allow maximum initial change in current flow) and is used as the example here.

$$X_C = \frac{1}{2 \pi f C}$$

$$\text{Capacitive Reactance} = \frac{1}{2 \times \pi \times \text{Frequency} \times \text{Capacitance}}$$

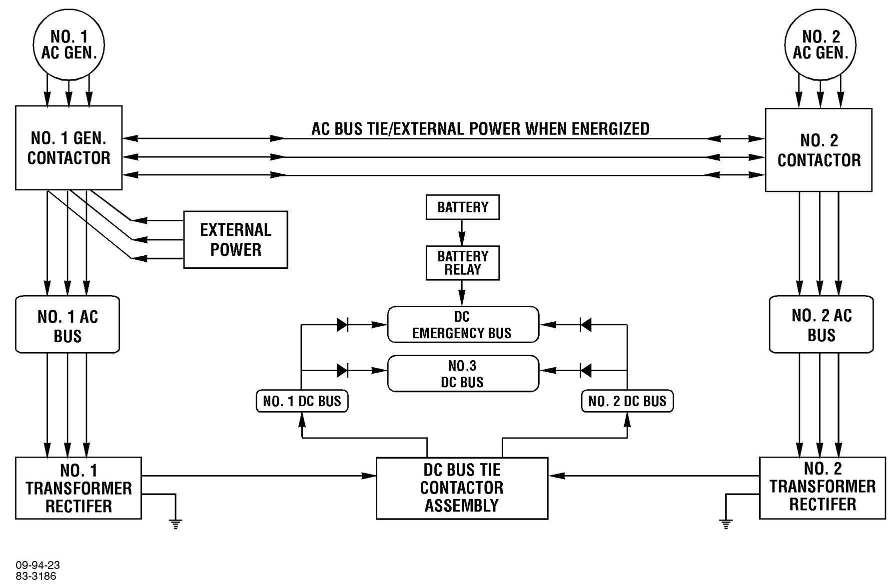
X_C = Capacitance reactance is the resistance to AC current flow of a capacitor due to capacitive effects. The capacitance reactance is stated in OHM's.

2π = 2 times PI (2 x 3.14159)

f = The frequency of the AC current that is flowing to and from the plates of the capacitor.

C = The capacitance of the capacitor is derived by an equation that is dependant on the specific type of capacitor and is not easily calculated or measured in normal troubleshooting circumstances. Some of the variables that control capacitance are the shape of the capacitor, dielectric material, spacing between the plates, and the area of the plates. Many capacitors have the capacitance value marked on them. "Farads" are the units that capacitance is stated in (usually micro-Farads, 10^{-6} Farads, or one-millionth of a Farad).

AH-64A ELECTRICAL SYSTEM



NOTES

WARNING

ELECTRICAL POWER

Electrical power operating or maintenance procedures, practices or conditions, which, if not strictly observed, could result in injury or death to personnel. These WARNINGS must be strictly obeyed by all personnel.

A. AH-64A electrical system features and capabilities.

1. The AC electrical system consists of two separate and redundant systems. In normal operation each AC system supplies approximately 50% of the AC power required by the helicopter.

   a. The generators outputs are connected through the AC generator contactors.

   b. A single operating generator can power AC essential buses 1 and 2 simultaneously.

2. The DC electrical system consists of two separate and redundant systems. In normal operation each transformer/rectifier supplies approximately 50% of the DC power required by the helicopter.

   a. The T/R outputs are routed through a single DC bus tie contactor relay assembly.

   b. A single operating T/R can power DC essential buses 1 and 2 simultaneously.

   c. The DC Essential bus 3 is powered via isolation diodes from each DC essential bus.

3. The DC emergency bus is powered by the transformer rectifiers under normal conditions or by the helicopter battery if both transformer rectifiers (DC essential buses 1 and 2) fail. The DC emergency bus provides DC power to critical systems.

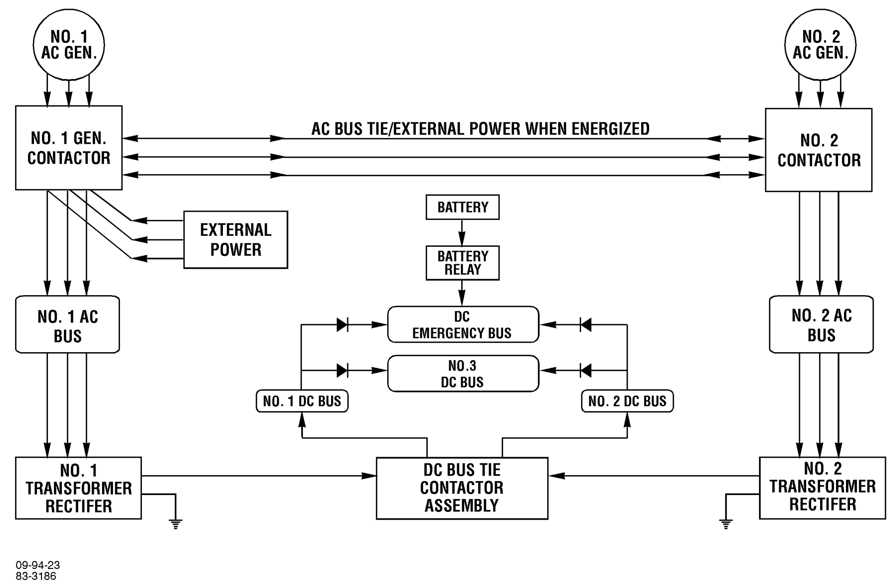
   a. The battery, if operating properly, will assume the load if both generators or both TR's fail.

   b. The battery charger will detect the loss of DC essential bus power and as the voltage falls through 18 VDC, will energize the battery relay which applies battery power to the emergency bus.

4. The external power system provides a means of connecting external AC power to the helicopter during ground operation.

   a. The external AC power source is checked for phase, frequency and amplitude.

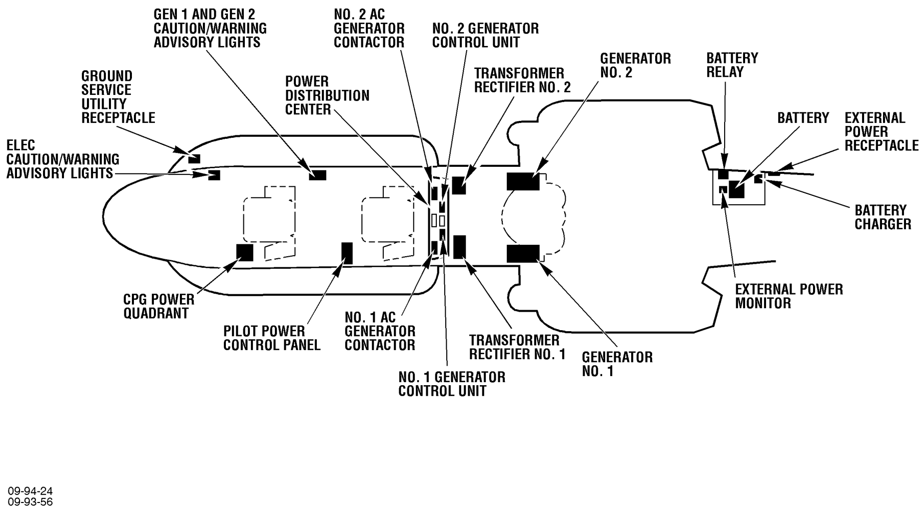
AH-64A ELECTRICAL SYSTEM



NOTES

b. If the power parameters are correct, the external power monitor energizes the external power contactor and 3-phase, 115/200 VAC, 400 Hz power is applied to the helicopter's AC essential bus.

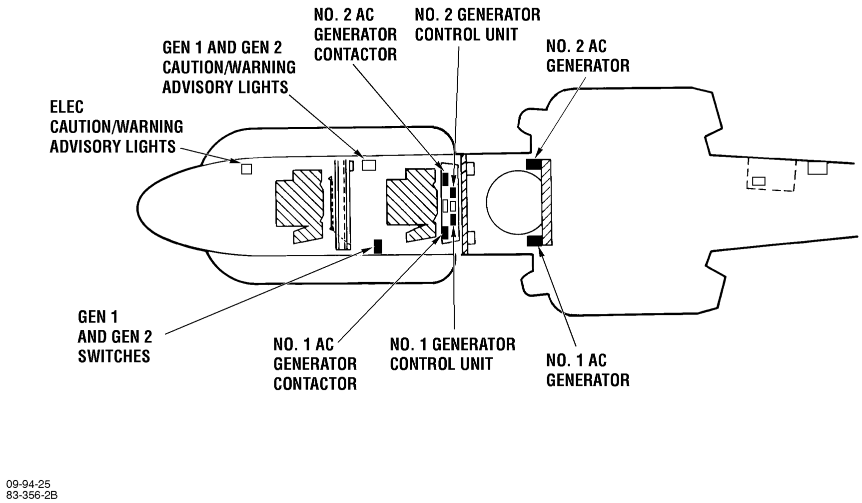
AH64A ELECTRICAL SYSTEMS COMPONENTS



NOTES

5. The Electrical components are located throughout the helicopter, rather than being grouped in one location. This enhances the combat survivability of the electrical systems.

AC ELECTRICAL SYSTEM



NOTES

B. AC electrical power system

1. Generates the AC power necessary to operate the AH-64A helicopter AC and DC electrical systems.

2. Distributes the electrical power through a system of AC contactors and essential buses.

C. Features and capabilities

1. Consists of two identical AC electrical power systems. The systems' AC generators are driven by the main transmission accessory gear box.

   a. Either system is capable of supplying all electrical power requirements. Each normally supplies approximately 50%.

   b. If one system malfunctions, automatic switching ensures continued electrical operation.

2. Each system distributes voltages to the respective AC essential bus.

3. Each AC system monitors itself for faults.

   a. Undervoltage

   b. Overvoltage

   c. Underfrequency (on the ground only)

   d. Overcurrent

D. Major electrical components

1. AC generators

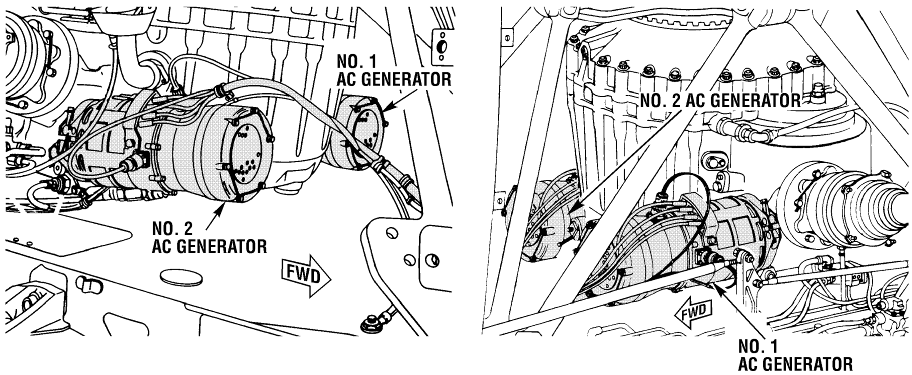
2. Generator control unit (GCUs)

3. AC generator contactors

4. GEN 1 and GEN 2 switches

5. GEN 1 and GEN 2 CAUTION/WARNING/ADVISORY Lights

GENERATOR LOCATIONS



09-93-13
83-143B

NOTES

E. AC generator(s) component purpose, location, description, and operation

1. The generators convert mechanical energy to electrical energy.

2. Provides 3-phase, 115/200 VAC, 400 Hz at 35 Kilo Volt Amperes (KVA) for use by the helicopter systems that require AC electrical power.

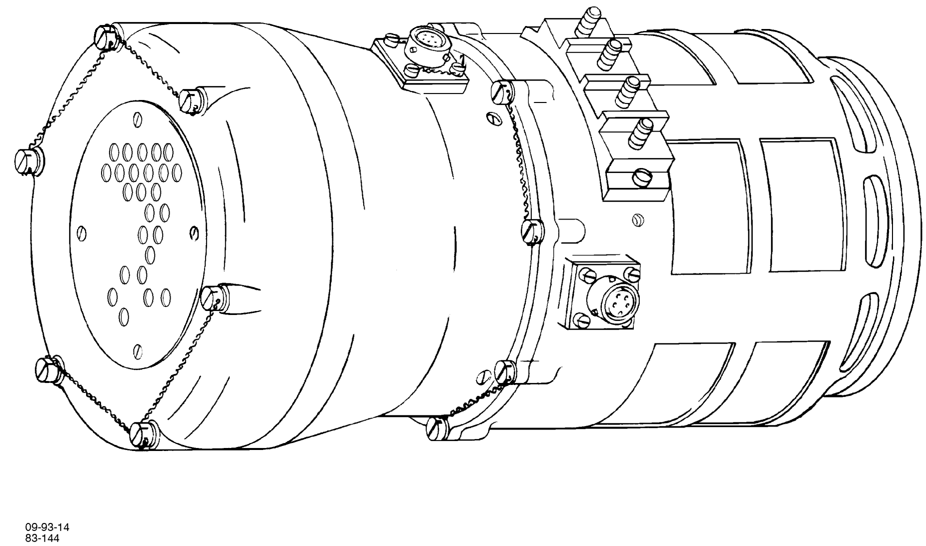
   a. Can supply 35 KVA (100% rated power, 115 VAC, at 304 amps) maximum continuous.

   b. Can supply 53 KVA (150% rated power, 115 VAC, at 457 amps) for 2 minutes.

   c. Can supply 70 KVA (200% rated power, 115 VAC, at 608 amps) for 5 seconds.

3. The AC generators are mounted on the forward left and right sides of the main transmission accessory gearbox AC generator Power Take Offs (PTO's) by Quick Attach Assemblies (QAA's).

AC GENERATOR



NOTES

4. AC generator description

   a. The AC generators are self-excited, brushless, air cooled (self-cooling), permanent magnet generators (PMG's) that utilize prelubricated bearings.

   b. Compact, cylindrical in shape, weighing 45 pounds.

   c. Two quick-disconnect electrical receptacles and four terminal studs for electrical control and power output connections.

   d. Driven through the accessory gearbox of the main transmission by the APU or main engine(s) at 12,200 or 12,251 rpm respectively.

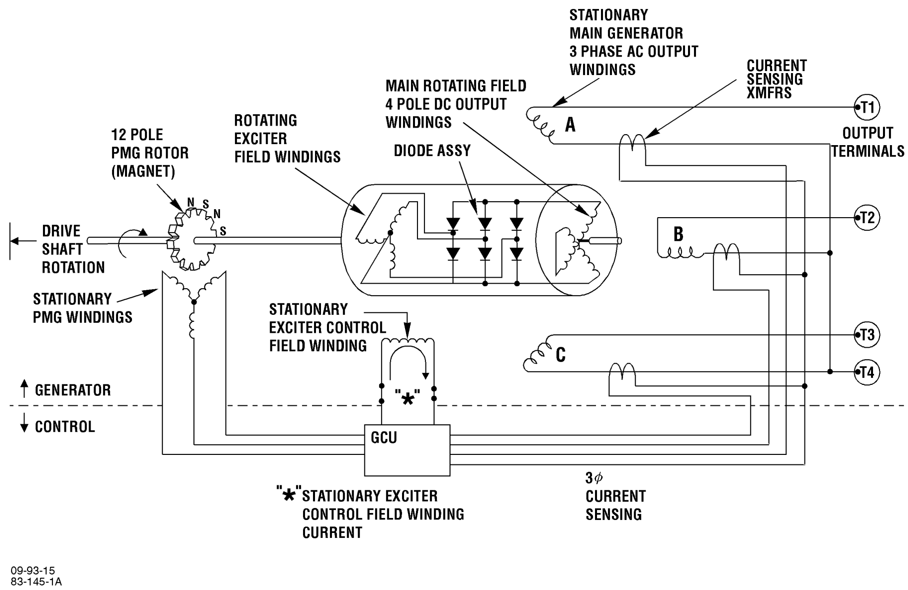
   e. Three main internal sections

      (1) Permanent magnet generator (PMG)

      (2) Rotating Exciter

      (3) Main generator

AC GENERATOR BLOCK DIAGRAM



NOTES

5. AC Generator Electrical Operation

a. Permanent magnet generator (PMG)

(1) Provides the source of excitation energy for the AC generator.

(2) Permanent magnet generator (PMG) circuit

(a) Rotating permanent magnet assembly

1) Twelve-pole permanent magnet, consisting of six N-S polar pairs and their respective six magnetic fields.

2) Attached to the generator shaft and rotates anytime the accessory geartrain is being rotated by the APU or main engines.

3) Rotating the permanent magnet assembly causes the magnetic fields to rotate.

(b) Stationary PMG windings

1) Provides the means to collect and utilize the energy contained in the rotating magnetic fields.

2) Three-phase "Y" configuration windings, spaced 120° apart.

3) Are stationary-mounted to, and electrically isolated from, the generator case.

4) Positioned in close proximity to the rotating permanent magnet assembly.

(3) PMG Operation

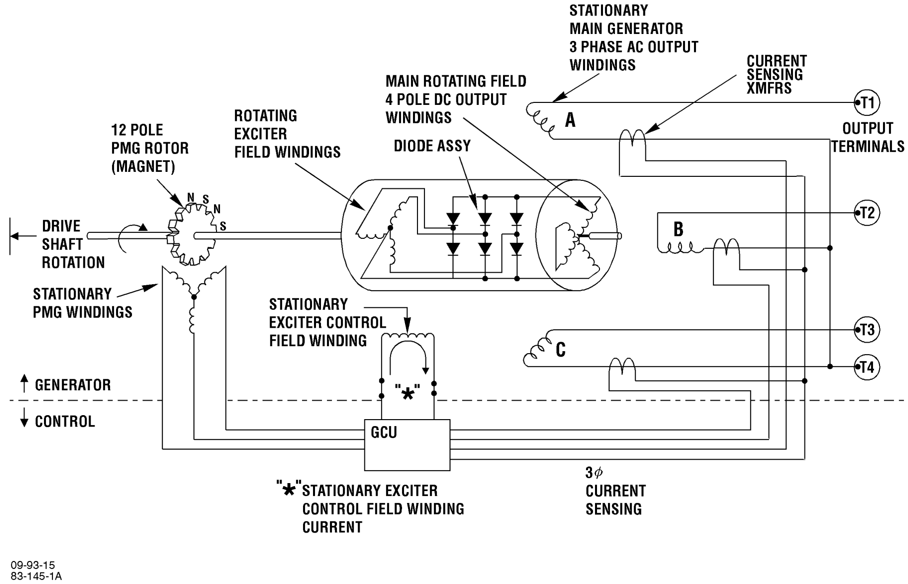
(a) The twelve-pole permanent magnet assembly is rotated by the AC generator shaft.

(b) This causes the six magnetic fields to rotate in close proximity to the stationary PMG windings.

(c) Current is caused to flow in the 3-phase windings due to the principles established in generator theory.

1) As the six magnetic fields rotate past each of the three windings, current will flow in one direction, stop, and then flow in the other direction as the polarity of the magnetic fields change.

AC GENERATOR BLOCK DIAGRAM



NOTES

2) Current flowing in alternate directions through the impedance (resistance to AC current flow) of each of the windings will cause 22 VAC, 1200 Hz, to be present across each of the 3-phase stationary PMG windings. The voltage is developed due to the principles established by generator theory and Ohms Law, $E = IR$.

(d) The 3-phase voltages are applied to the Generator Control Unit (GCU) and are rectified to a 28 VDC.

b. Stationary exciter control field winding

(1) Provides the excitation energy for the rotating exciter.

(2) The Generator Control Unit controls the stationary exciter control field winding current.

(a) Generator Control Unit

1) AC voltage regulator circuit

2) Generator Control Relay (GCR)

(b) AC generator, stationary exciter control field winding

1) Provides the means to control the rotating exciter.

2) Is single winding mounted to, and electrically isolated from, the generator case.

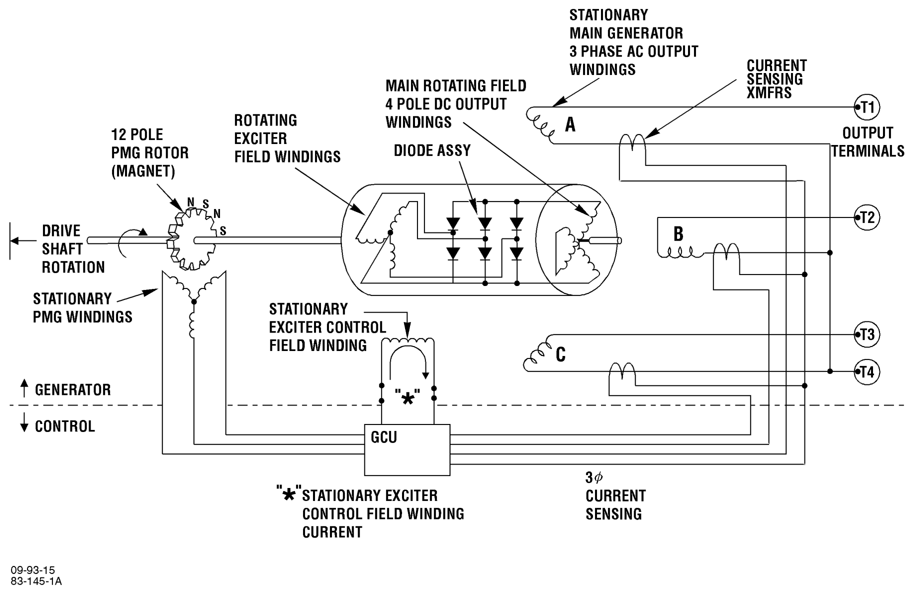
a) Positioned in close proximity to the rotating exciter assembly.

(c) Stationary exciter control field winding operation

1) As determined by the GCU, a controlled current is caused to flow in the Stationary exciter control field winding, which creates a controlled magnetic field, according to the principles of generator theory.

2) The controlled stationary exciter controlled magnetic field is used to control the rotating exciter (and ultimately the AC generator output).

AC GENERATOR BLOCK DIAGRAM



NOTES

c. Rotating Exciter

(1) Is attached to the generator shaft and serves as the rotating exciter field for the stationary main generator windings.

(2) Rotating exciter circuit

(a) The stationary exciter control field winding controls the rotating exciter.

(b) Rotating exciter field, 3-phase AC, input windings

1) Three-phase "Y" configuration windings

2) Spaced 120° apart

(c) Rectifier diodes

(d) Main rotating field, 4-pole, DC output windings

(3) Rotating exciter operation

(a) The stationary exciter control winding current, which is controlled and supplied by the GCU, creates a stationary, controlled, magnetic field.

(b) As the rotating exciter is turned by the generator shaft, controlled AC current is caused to flow in the 3-phase AC, input windings due to the principles established in generator theory.

(c) The controlled, 3-phase AC current is rectified by diodes to provide controlled DC current.

(d) The controlled DC current flows in the main rotating field, 4-pole, DC output windings.

(e) The controlled DC current creates controlled, 4-pole rotating magnetic fields to excite the main generator windings.

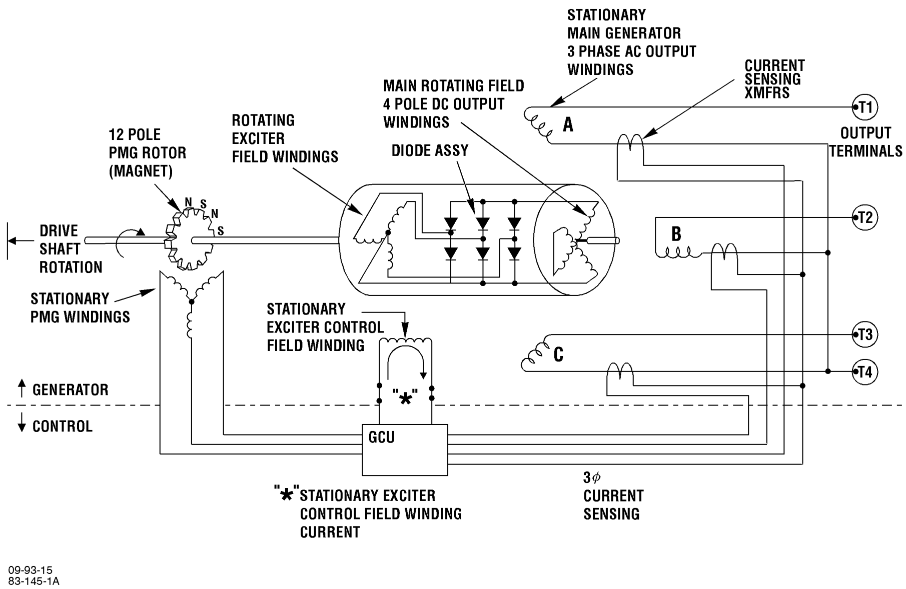
d. Main Generator

(1) Produces the 3-phase, 115 VAC, 400 Hz, 35 KVA output for use by the helicopter systems.

(2) Main Generator Circuit

(a) The exciter main rotating field, 4-pole, DC output windings control the main generator.

AC GENERATOR BLOCK DIAGRAM



NOTES

(b) Stationary, main generator, 3-phase output windings

(c) 3-phase current sensing windings

(3) Main generator operation

(a) The controlled, 4-pole rotating magnetic fields from the main rotating field, 4-pole, DC output windings rotate in close proximity to the stationary, main generator, 3-phase output windings.

(b) Controlled, 3-phase AC current is caused to flow in the Stationary, main generator, 3-phase output windings due to the principles established in generator theory.

(c) The 3-phase, 115 VAC, 400 Hz main generator output voltage is created by the controlled current flowing through the impedance (resistance to AC current flow) of each of the stationary, main generator, 3-phase output windings. The voltage is developed due to the principles established by generator theory and Ohms Law, $E = IR$.

(4) Each of the AC generator 3-phase output voltages and currents are monitored for control/protection by the GCU.

(a) The current sensing transformers inductively couple the 3-phase AC generator current output to the GCU.

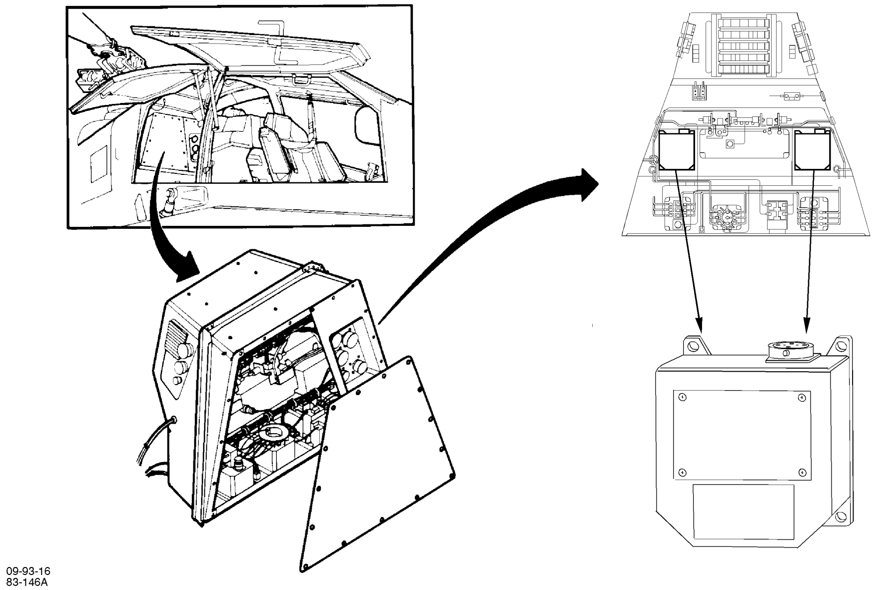
(5) The AC generator 3-phase outputs are connected to the AC generator contactor for use by the helicopter systems.

(6) Four terminal studs (Tl, T2, T3 and T4) are the generator output connection points.

(a) T4 is AC neutral and is grounded.

(b) Tl, T2, and T3 are the main generator output terminals (phase A, B, and C). During normal operation there is 115 VAC at each terminal with respect to neutral (ground).

GCU LOCATION



NOTES

F. Generator Control Unit(s) (GCU) component purpose, location, description, and operation

1. The purpose of the GCUs

a. There is one GCU for each AC generator. They are mounted behind the pilot crewstation in the electrical power distribution center.

b. Controls the operation and regulation of the generator 3-phase outputs by providing controlled current to the AC generator STATIONARY EXCITER CONTROL FIELD WINDING.

c. Regulates the AC generator 3-phase, 115/200 VAC, 400 Hz output voltage to within " 2%.

d. Supplies AC generator contactor (coil A) control voltage to the generator 1 (2) switch if the generator is operating properly. This allows the AC generator contactor to energize when the switch is placed in the GEN position.

e. Provides AC generator protection if any of the following conditions occur.

(1) Overvoltage

(2) Undervoltage

(3) Overcurrent

(4) Underfrequency (on the ground only)

2. Description

a. The GCU is a solid state LRU with a single quick-disconnect receptacle for electrical connection.

b. The LRU major components are

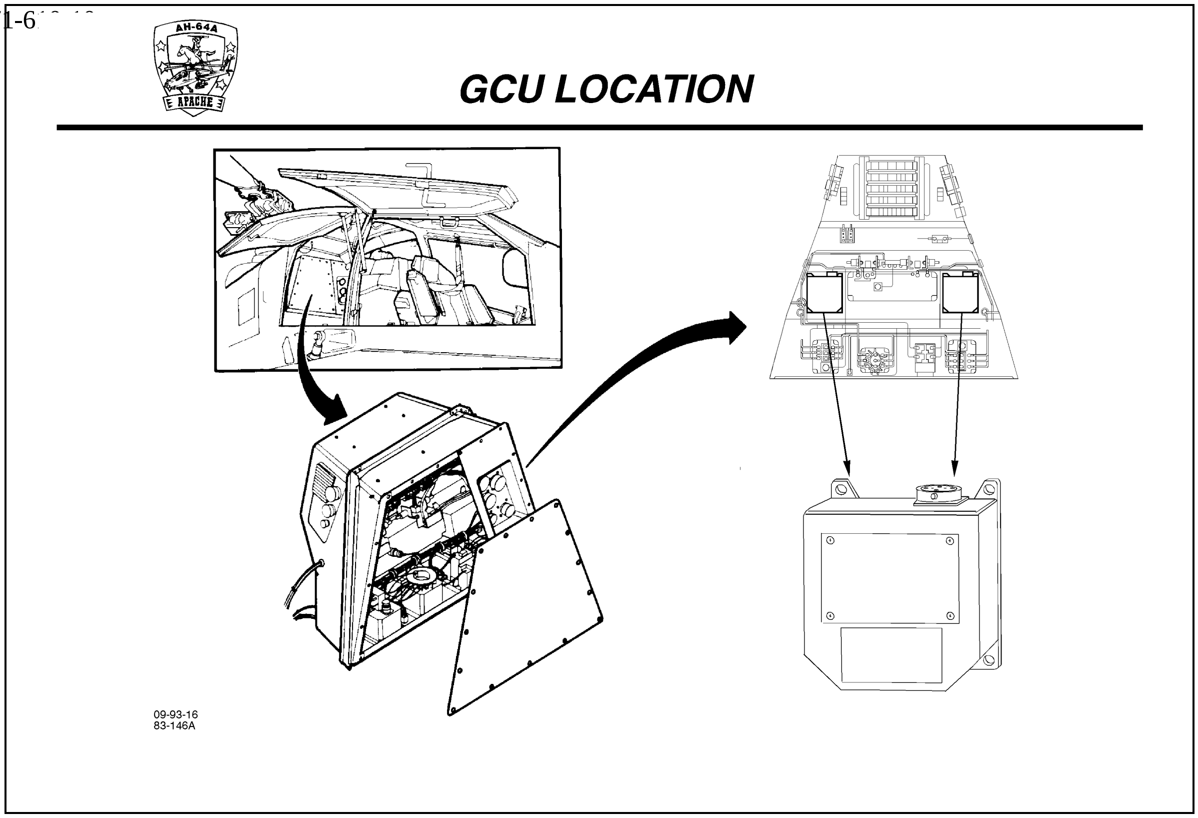
(1) Two printed wiring boards

(2) Three hermetically sealed relays

(3) Assembly enclosed in a metal case

c. Major GCU circuits

(1) PMG rectifier and DC voltage regulator



NOTES

(2) Fault detection circuits

(a) AC voltage regulator

(b) Overcurrent detector

(c) Overvoltage circuit

(d) Undervoltage circuit

(e) Underfrequency monitoring circuit

(3) Fault summing logic

(4) Generator Control Relay (GCR)

(5) Contactor Control Rely (CCR)

(6) TEST relay

GCU CAPABILITIES I

- RECTIFIES PMG 3 - PHASE VOLTAGE
- REGULATES THE RECTIFIED VOLTAGE
- CONNECTS AC VOLTAGE REGULATOR
- CONTROLS THE STATIONARY EXCITER CONTROL FIELD WINDING
- PROVIDES ENERGIZING VOLTAGE FOR THE AC CONTACTOR

09-94-27

NOTES

3. GCU capabilities

   a. Rectifies the AC generator-PMG 3-phase, 22 VAC output to 28 VDC, as the supply voltage for the GCU regulator, Generator Control Relay (GCR), Contactor Control Relay (CCR), and the AC generator contactor (via the AC generator control switch).

   b. REGULATES the rectified, PMG 28 VDC, to REGULATED 22 VDC, as the supply voltage for the GCU fault detection and fault summing logic circuits.

   c. Connects the AC voltage regulator to the AC generator STATIONARY EXCITER CONTROL FIELD WINDING if no AC generator faults exist and the AC generator switch is in the GEN or TEST positions.

   d. Controls the AC generator STATIONARY EXCITER CONTROL FIELD WINDING CURRENT to maintain a constant three-phase, 115/200 VAC, 400 Hz output.

   e. Provides energizing voltage for the AC generator contactor (coil A) if no AC generator faults exist and the AC generator switch is in the GEN position.

GCU CAPABILITIES II

- MONITORS AC GENERATOR CURRENT
- DE-ENERGIZES THE AC CONTACTOR IN THE EVENT OF AC GENERATOR FAILURE
- ISOLATES A FAULTY AC GENERATOR
- ILLUMINATES THE GEN CAUTION LIGHT

09-94-28

NOTES

f. Monitors the AC generator current sensing transformers and compensates for generator overcurrent conditions by reducing the AC generator STATIONARY EXCITER CONTROL FIELD WINDING CURRENT, which in turn reduces AC generator output voltage.

g. De-energizes the AC generator and disconnects it from the AC essential bus in the event of an undervoltage of between 95 and 105 VAC of between 3.5 to 5.0 seconds duration, or an overvoltage of 125 VAC between any phase and ground for more than 5 seconds.

h. De-energizes the AC generator and disconnects it from the AC essential bus, if the output frequency decreases to 380 to 370 Hz for 1 to 3 seconds, during ground operation only.

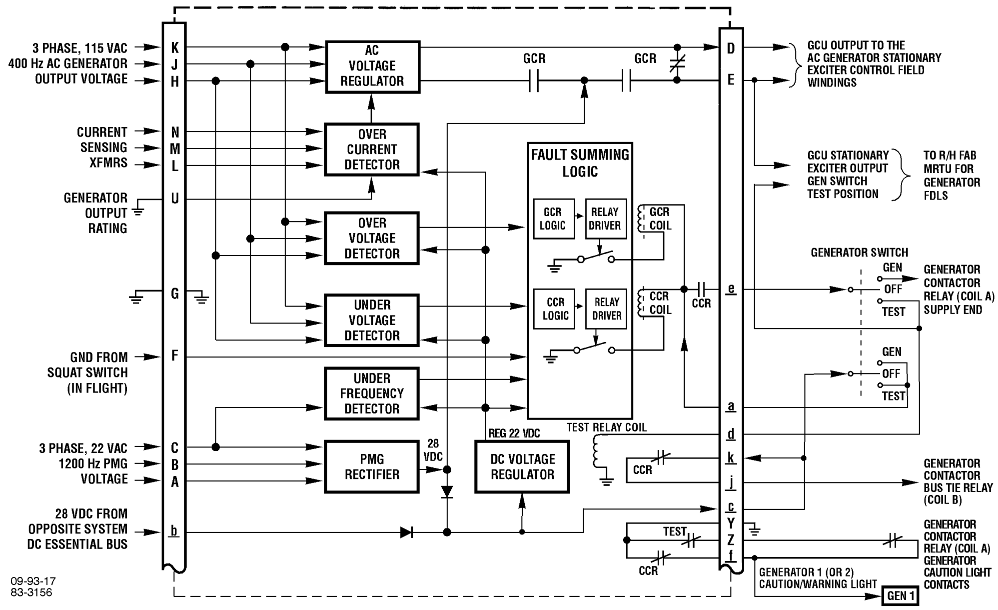
i. Isolates a faulty generator by de-energizing the respective AC generator contactor (coil A). The generator is latched in the off condition and will not automatically come back on-line if the fault clears itself. The generator must be "reset" from the pilot crewstation before it will come back on-line.

j. Illuminates the respective GEN caution light, until reset or repaired. The GEN fail light will illuminate if

(1) An AC generator or GCU failure occurs. The GCU will cause the light to illuminate if either of these failures occur.

(2) An AC generator contactor (coil A) failure occurs.

GENERATOR CONTROL UNIT BLOCK DIAGRAM



NOTES

4. GCU major circuit description

a. PMG rectifier - is a full wave diode bridge that rectifies the PMG 3-phase, 22 VAC, 1200 HZ output to provide "Rectified PMG DC voltage" (28 VDC) as the supply voltage for the GCU DC voltage regulator, GCR and CCR relays, and the AC generator contactor.

b. DC voltage regulator - regulates the rectified, PMG 28 VDC, to 22 VDC. The REGULATED 22 VDC is used as the supply voltage for the GCU fault detection and fault summing logic circuits.

c. AC voltage regulator - monitors, controls and regulates the AC generator 3-phase output voltages, by varying the AC generator STATIONARY EXCITER FIELD WINDING CONTROL CURRENT.

d. Overcurrent detector - each of the three 115 VAC phases of the AC generator is monitored for overcurrent.

(1) The current sensors in the AC generator are monitored by the overcurrent detector circuit (an over current would be caused by a decrease in the resistance, due to damage, of a circuit that the AC generator is supplying current and voltage to. From Ohm's Law, $E = IR$; transposed for current, $I = E/R$; it can be determined that if the resistance decreases, the current will increase).

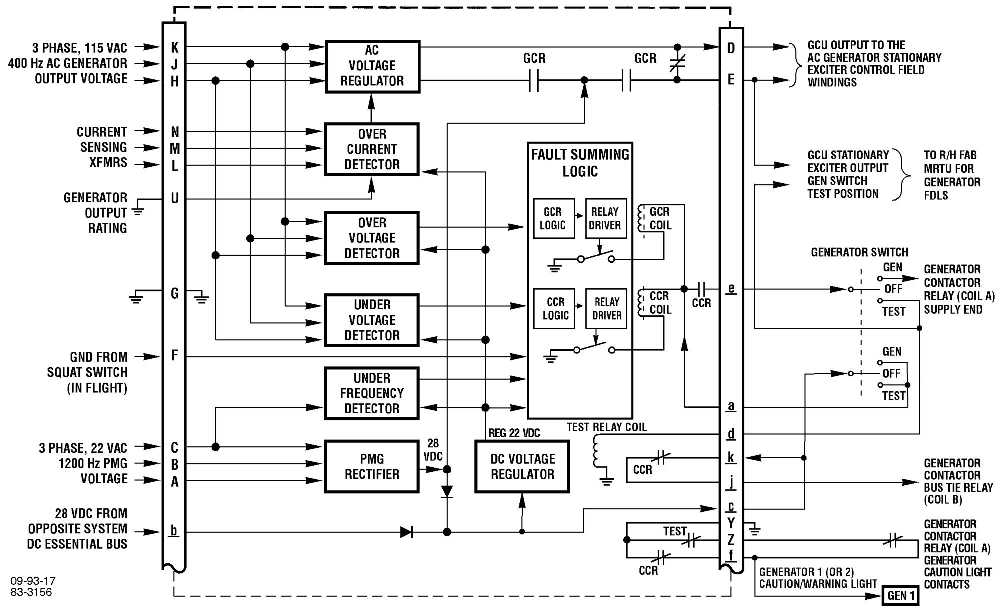
(2) Output of the overcurrent detector circuit is combined with the AC voltage regulator output and reduces the AC generator STATIONARY EXCITER CONTROL WINDING CURRENT to the AC generator if an overcurrent is detected.

(3) Reduction in the AC generator STATIONARY EXCITER CONTROL WINDING CURRENT reduces the current in the rotating exciter and the main generator windings, the result is that the AC generator output voltage is lowered (folded back). The AC generator output voltage foldback will cause the AC GENERATOR to supply LESS CURRENT to the HELICOPTER SYSTEMS and maintain the TOTAL AC GENERATOR OUTPUT AT OR BELOW THE MAXIMUM 35 KVA RATING OF THE GENERATOR.

(a) The reduction in the AC generator output voltage lowers the output current that the AC generator will have to supply to the helicopter systems (established by Ohm's Law, $E = IR$).

(b) If the resistance of the helicopter systems are assumed to be constant (though lower than it should be compared to a normal operating condition). Transposed for current, Ohm's Law becomes $I = E/R$. By examination, if the resistance is held constant, as the voltage (E) is decreased, the current (I) will also decrease.

GENERATOR CONTROL UNIT BLOCK DIAGRAM



NOTES

(c) The concern is to not exceed the 35 KVA total power that the AC generator has to supply.

(d) Since power, P, is the product of voltage and current, P = I x E, reducing current by reducing the voltage will tend to keep the power at or below the rated 35 KVA value.

(e) If the resistance continues to drop (as it may due to a potentially serious bus fault; ie, one or more phases directly shorted to airframe ground by combat or other severe, types of damage), the AC generator output voltage will continue to be lowered until the under voltage fault detection circuit trips and the AC generator output is disconnected from the AC essential bus.

(4) The undervoltage fault detection circuit trips if the AC generator output voltage drops below 100 to 110 VAC for 3.5 to 5 seconds. This causes the AC generator contactor to disconnect the AC generator from the AC essential bus.

(5) The current limiting is programmable and is set for the value required by the AH-64A AC electrical systems.

e. Overvoltage circuit - tests the main generator output for overvoltage. A sample of the three phase, 115 VAC, 400 Hz outputs is rectified and compared to a standard DC voltage reference zener diode.

(1) Overvoltage is in accordance with the overvoltage curve of MIL-G-21480A and can ignore transients according to that specification.

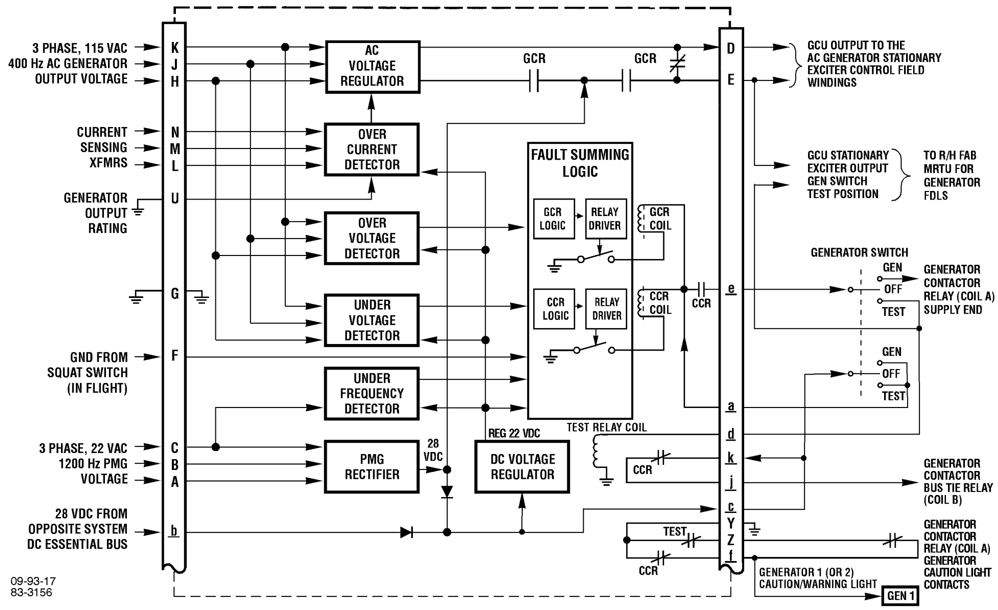
(a) The voltage can rise to 125 VAC, if it lasts less than 5 seconds.

1) The voltage can rise to 130 VAC, if it lasts less than 500 milliseconds

2) The voltage can rise to 165 VAC, if it lasts less than 65 milliseconds. The output is applied to the switching logic.

f. Undervoltage circuit - tests the AC generator 3-phase output for undervoltage. A sample of the 3-phase, 115 VAC, 400 Hz output is half-wave rectified and compared to the same standard DC voltage reference zener diode that the overvoltage circuit utilizes. The undervoltage circuit is operational during AC generator output voltage fold-back operation. The undervoltage detector's output is disarmed by underfrequency through the switching logic. This prevents the GCU from attempting to increase the AC generator output during an underfrequency condition. The reason for this is due to the decreasing AC generator RPM involved during engine shut down (without the APU operating) or APU spool-down from a failure or

GENERATOR CONTROL UNIT BLOCK DIAGRAM



NOTES

commanded shutdown. The inductive reactance of the AC generator winding will decrease, this can be determined by examination of the inductive reactance formula

$$X_L = 2 \pi f L$$

If the frequency (f) decreases, then the inductive reactance, (X_L) also decreases. If the inductive reactance (AC resistance) decreases, then the current will increase. Under this type of condition, if the GCU were to provide maximum current to the AC generator STATIONARY EXCITER CONTROL FIELD WINDING, the current in the AC generator stationary main generator output windings may increase rapidly enough to damage the generator. For the same reason., many of the electrical and electronic components on the AH-64A are susceptible to damage from a low or underfrequency supply voltage.

g. Underfrequency monitoring circuit - phase C of the PMG AC output voltage is tested for minimum correct frequency and detects a fault if the main generator output frequency falls below 370 Hz for 1 to 3 seconds. This equates to a reduction in the PMG frequency from 1200 to 1100 Hz. The output of the final stage of the underfrequency circuit is disabled by an electronic ground signal from the squat switch relay, when the helicopter is in flight. This will prevent the loss of AC electrical power resulting from a reduction in main rotor RPM. Normally, an underfrequency condition caused by main rotor droop is not sufficient to cause equipment damage.

(1) Main transmission gearing establishes the rotational speed of the main rotor system to the rpm of the accessory gear box that drives the AC generator. The mechanical rpm of the AC generator establishes the electrical output frequency.

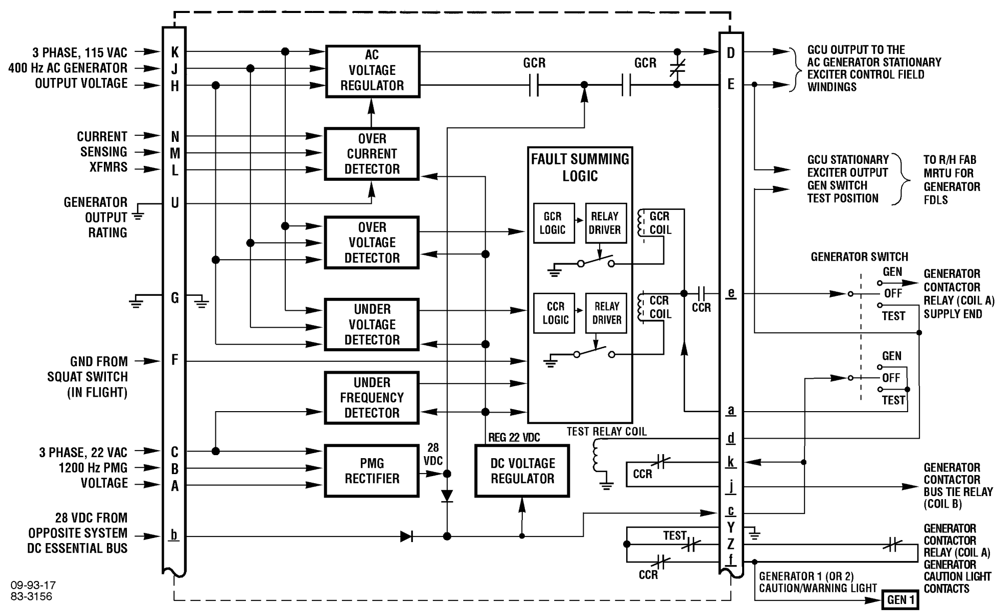
(2) Externally applied AC power is monitored by the External Power System, and protects the helicopter AC powered systems against an over-frequency condition from a defective GPU or AGPU. This feature is independent from the GCU's underfrequency monitoring circuits.

h. Fault summing logic

(1) Fault summing logic circuit - the GCU fault summing logic circuit is a diode and resistor matrix that uses combinations of fault detection circuit inputs in order to control the on-line or off-line status of the AC generator.

(a) During initial power up, the fault summing logic circuit energizes the GCR relay and allows the AC generator to operate off-line. This allows the fault detection circuits to check the parameters prior to placing the AC generator on line.

GENERATOR CONTROL UNIT BLOCK DIAGRAM



NOTES

(b) If the parameters are correct, the fault summing logic circuit energizes the Contactor Control Relay (CCR).

(c) The CCR in turn energizes the AC generator contactor (coil A) via the AC generator switch, connecting the AC generator output to the AC essential bus.

(d) If any of the AC generator parameters go outside tolerance, the fault summing logic circuit will remove the grounds from the GCR and the CCR, the AC generator contactor (coil A) will de-energize, taking the AC generator off line and causing the AC generator to stop producing an output.

(e) Safety and minimum damage feature. If, for any reason the generator does not come on the line within 1 second, this circuit will automatically trip the GCU (GCR) to de-energize the AC generator and disconnect it from the AC essential bus.

i. Generator Control Relay (GCR)

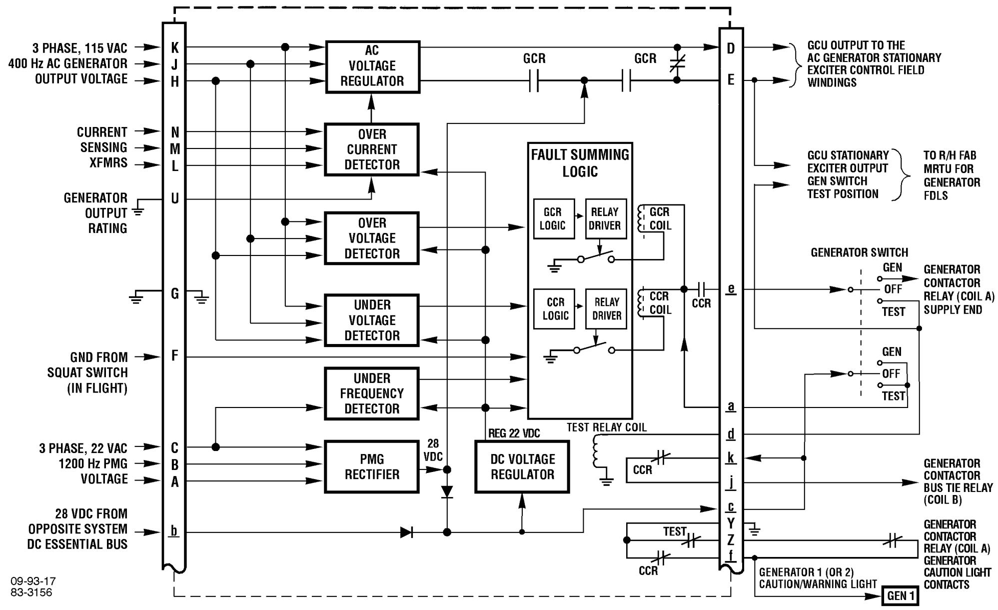
(1) Controls the application of the AC voltage regulator output to the AC generator STATIONARY EXCITER CONTROL FIELD WINDING. This enables or disables the AC generator to produce the three-phase, 115/200 VAC, 400 Hz output.

(2) The GCR energizes when the AC generator switch is placed in the GEN or TEST positions.

(a) RECTIFIED PMG DC VOLTAGE (28 VDC), and 28 VDC from the opposite system's DC essential bus, are applied to the supply end of the GCR relay coil, through the AC generator control switch in the GEN and TEST positions.

(b) The fault detection and fault summing logic circuits were reset by the AC generator switch when it was in the OFF/RESET position. When the AC generator switch is placed in the GEN position a ground is provided to the control end of the GCR coil by the fault summing logic circuit causing the AC generator to operate. The AC generator parameters are checked for faults. If no faults exist, the fault detection and fault summing logic circuits maintain the ground at the control end of the GCR. No AC generator faults may occur during AC generator operation in order for the ground to remain at the control end of the GCR coil. Each fault incident must be reset by cycling the AC generator switch to OFF/RESET and then back to GEN. Additionally, the parameter creating the fault must be corrected, by resetting the AC generator or through maintenance action.

GENERATOR CONTROL UNIT BLOCK DIAGRAM



NOTES

(3) When energized, the GCR

(a) Disconnects the short across the AC generator STATIONARY EXCITER CONTROL FIELD WINDINGS.

(b) Connects the RECTIFIED PMG DC VOLTAGE (28 VDC) voltage to

1) The AC voltage regulator circuit (as supply voltage) and allows it to function.

2) The supply end of the STATIONARY EXCITER CONTROL FIELD WINDING.

(c) Allows the output of the operating AC voltage regulator to control the DC current through the control end of the STATIONARY EXCITER CONTROL FIELD WINDING.

(4) When de-energized

(a) RECTIFIED PMG DC VOLTAGE (28 VDC) is removed from the supply end of the STATIONARY EXCITER CONTROL FIELD WINDING.

(b) Removes the AC voltage regulator output from the control end of the STATIONARY EXCITER CONTROL FIELD WINDING.

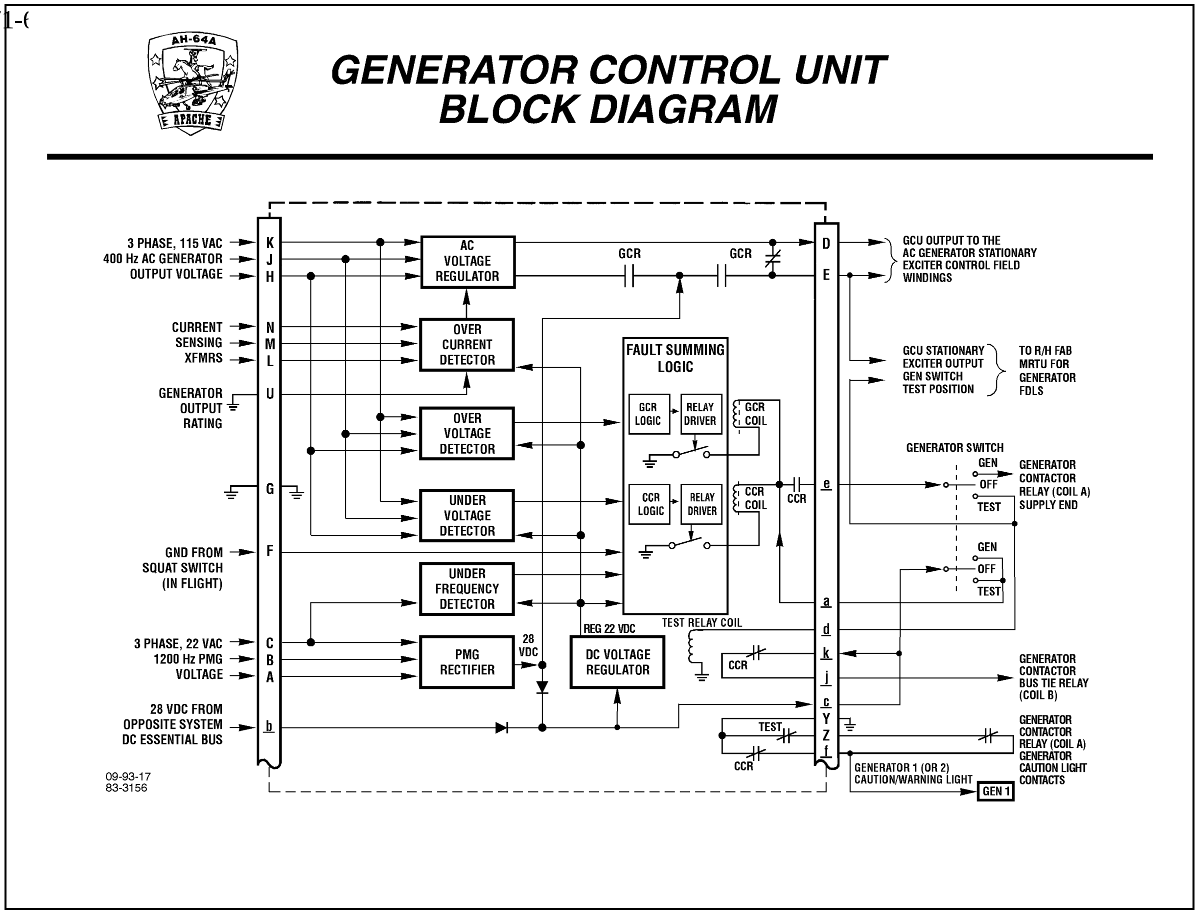
(c) Connects a short across the AC generator STATIONARY EXCITER CONTROL FIELD WINDING to remove the control field from the generator. This stops the rotating exciter current and the main generator output.

j. Contactor Control Relay (CCR)

(1) Controls RECTIFIED PMG DC VOLTAGE (28 VDC) to the generator switch for control of the AC generator contactor (coil A). This enables the three-phase, 115/200 VAC, 400 Hz output of the AC generator to be connected to the helicopter systems.

(2) The CCR energizes when the generator switch is placed in the GEN position.

(a) RECTIFIED PMG DC VOLTAGE (28 VDC), and 28 VDC from the opposite system's DC essential bus, are applied to the supply end of the CCR relay coil, through the AC generator control switch in the GEN position only.


AH-64A
APACHE
GENERATOR CONTROL UNIT
BLOCK DIAGRAM
3 PHASE, 115 VAC
400 Hz AC GENERATOR
OUTPUT VOLTAGE
CURRENT
SENSING
XFMRS
GENERATOR
OUTPUT
RATING
GND FROM
SQUAT SWITCH
(IN FLIGHT)
3 PHASE, 22 VAC
1200 Hz PMG
VOLTAGE
28 VDC FROM
OPPOSITE SYSTEM
DC ESSENTIAL BUS
AC
VOLTAGE
REGULATOR
OVER
CURRENT
DETECTOR
OVER
VOLTAGE
DETECTOR
UNDER
VOLTAGE
DETECTOR
UNDER
FREQUENCY
DETECTOR
PMG
RECTIFIER
28
VDC
REG 22 VDC
DC VOLTAGE
REGULATOR
FAULT SUMMING
LOGIC
GCR
LOGIC
RELAY
DRIVER
GCR
COIL
CCR
LOGIC
RELAY
DRIVER
CCR
COIL
GCR
CCR
TEST RELAY COIL
TEST
GCU OUTPUT TO THE
AC GENERATOR STATIONARY
EXCITER CONTROL FIELD
WINDINGS
GCU STATIONARY
EXCITER OUTPUT
GEN SWITCH
TEST POSITION
TO R/H FAB
MRTU FOR
GENERATOR
FDLS
GENERATOR SWITCH
GEN
OFF
TEST
GENERATOR
CONTACTOR
RELAY (COIL A)
SUPPLY END
GENERATOR
CONTACTOR
BUS TIE RELAY
(COIL B)
GENERATOR
CONTACTOR
RELAY (COIL A)
GENERATOR
CAUTION LIGHT
CONTACTS
GENERATOR 1 (OR 2)
CAUTION/WARNING LIGHT
GEN 1
09-93-17
83-3156

NOTES

(b) The fault detection and fault summing logic circuits were reset by the AC generator switch when it was in the OFF/RESET position. If no generator faults exist, the fault detection and fault summing logic circuits provide a ground to the control end of the CCR coil. No AC generator faults may occur in order for the ground to remain at the control end of the CCR coil. Each fault incident must be reset by cycling the AC generator switch to OFF/RESET and then back to GEN. Additionally, the parameter creating the fault must be corrected, by resetting the AC generator or through maintenance action.

(3) When the CCR is energized

(a) RECTIFIED PMG DC VOLTAGE (28 VDC) is applied to the AC generator contactor (coil A) via the generator switch in the GEN position only.

(b) RECTIFIED PMG DC VOLTAGE (28 VDC) is disconnected from the bus tie relay (coil B) of the AC generator contactor.

(c) The ground for the GEN caution light is removed, extinguishing it.

(d) The ground to the anti-cycling input of the switching logic is interrupted.

(4) When the CCR de-energizes

(a) RECTIFIED PMG DC VOLTAGE (28 VDC) is removed from the AC generator contactor (coil A), causing it to de-energize.

(b) RECTIFIED PMG DC VOLTAGE (28 VDC) is applied to the bus tie relay (coil B).

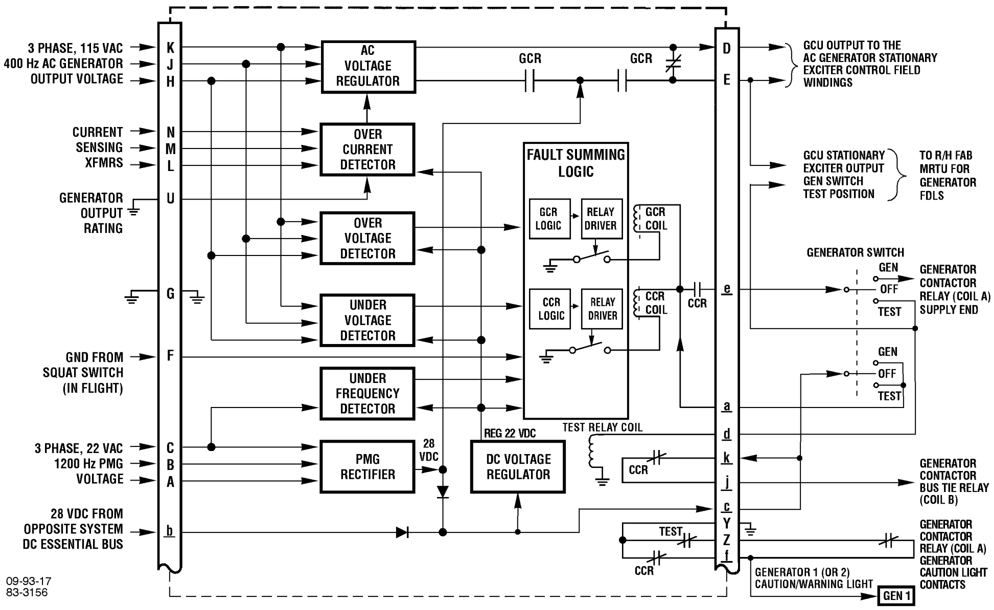
(c) The ground for the GEN caution light is connected, causing it to illuminate.

k. Test relay

(1) Allows the AC generator output to be tested without connecting it's output to the helicopter AC essential bus.

(a) Is energized by RECTIFIED PMG DC VOLTAGE (28 VDC) when the generator switch is held in the TEST position.

GENERATOR CONTROL UNIT BLOCK DIAGRAM

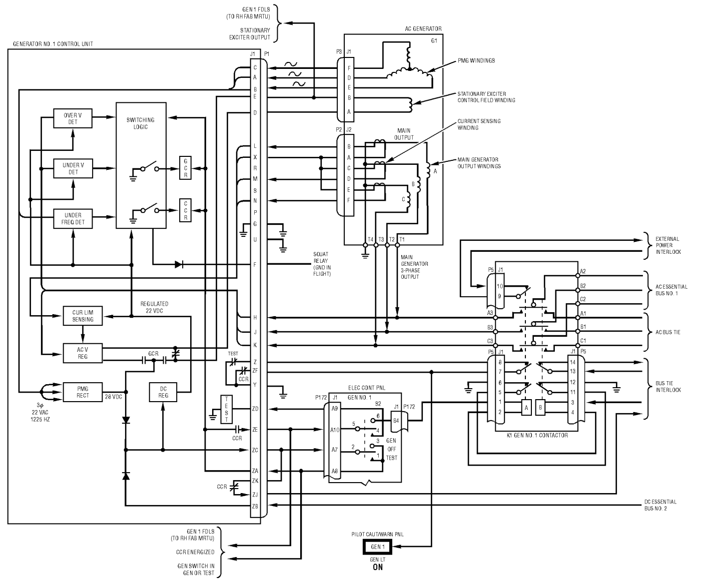


NOTES

(b) When energized, the open contacts of the test relay will extinguish the GEN caution light.

(c) When de-energized, the normally-closed contacts of the test relay will extinguish the GEN caution light.

AC GENERATOR OPERATION, AC GENERATOR OFF



09-94-30

NOTES

G. AC generator operation, initial conditions

1. Helicopter battery power is applied.

2. APU or engine(s) operating.

3. Accessory gearbox, AC generator power takeoff running.

4. The AC generator shaft is rotating.

5. The "helicopter is on the ground" signal is at the GCU J1, pin F.

6. The AC generator "GEN" switch is in the OFF/RESET position.

7. The GEN caution light is illuminated.

H. AC generator operation, AC generator off (GEN switch in the OFF/RESET position)

1. AC generator PMG operation

a. The AC generator shaft is rotated by the accessory gearbox AC generator power take off through a frangible coupling by the APU at 12,200 RPM or the main engines at 12,251 RPM.

b. Once the generator shaft is rotating, the PMG magnet rotates in close proximity to the stationary PMG windings.

c. The rotating magnetic fields of the PMG magnet cause current to flow in the PMG, 3-phase stationary windings.

d. The current flowing in the windings creates the PMG, 3-phase, 22 AC voltage across the windings.

e. The 3-phase voltage from the AC generator stationary PMG windings is applied to J1, pins D, E, F, of the AC generator.

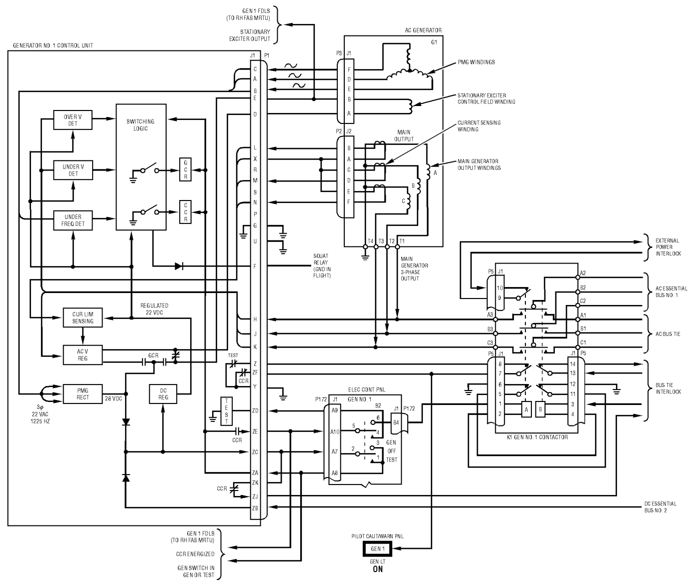
2. GCU PMG rectifier

a. The PMG, 3-phase, 22 VAC from the AC generator P3, pins D, E, F, is applied to the Generator Control Unit (GCU), P1, pins A, B, C.

b. The PMG, 3-phase, 22 VAC from J1, pins A, B, C, is applied to the PMG rectifier circuit which converts the 3-phase, 22 VAC to a RECTIFIED PMG DC VOLTAGE (28 VDC).

c. The RECTIFIED PMG DC VOLTAGE (28 VDC) is applied to an isolation diode.

AC GENERATOR OPERATION, AC GENERATOR OFF



09-94-30

NOTES

3. AC generator switch, AC generator control

   a. The RECTIFIED PMG DC VOLTAGE (28 VDC) is applied through the isolation diode to J1, pin c.

   b. The RECTIFIED PMG DC VOLTAGE (28 VDC) from J1, pin c, is applied to the lower section of the AC generator switch, common terminal. The RECTIFIED PMG DC VOLTAGE (28 VDC) is not connected across the open contacts of the AC generator switch in the OFF/RESET position.

   c. The AC generator contactor (coil A) remains de-energized.

4. GCU DC voltage regulator

   a. The RECTIFIED PMG DC VOLTAGE (28 VDC) is also applied to the DC VOLTAGE REGULATOR via an isolation diode.

   b. If operating, 28 VDC from the DC essential bus of the opposite system is applied to P1, pin b.

   c. The opposite system's 28 VDC from J1, pin b, is applied to the DC VOLTAGE REGULATOR via another isolation diode. The 28VDC serves as backup power for the AC generator PMG or GCU PMG circuits and bus tie voltage, in case of a failure.

   d. The RECTIFIED PMG DC VOLTAGE (28 VDC) is REGULATED to a close tolerance 22 VDC by the DC VOLTAGE REGULATOR and is applied to fault detection and fault summing logic circuits as the REGULATED 22 VDC supply voltage.

5. GCU fault detection and fault summing logic

   a. The AC generator output, from the main generator windings, is applied to terminals T1, T2, T3, and T4.

   b. The AC generator output from terminals T1, T2, T3, and T4, is applied to the AC generator terminals A3, B3, and C3 of the AC generator contactor.

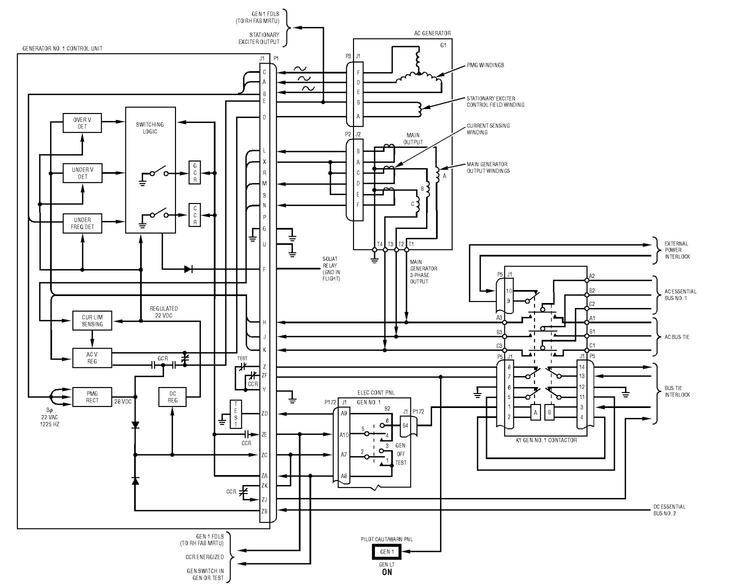
   c. The AC generator output from the AC generator contactor terminal A3, B3, and C3, is also applied to P1, pins H, J, and K of the GCU.

   d. AC generator output from J1, pins H, J, and K is applied to the overvoltage, undervoltage, and underfrequency (on the ground only) fault detection circuits of the GCU.

   e. The AC generator current sensing output, from the current sensing transformer windings, is applied to J2, pins A, B, C, D, E, and F.

   f. The AC generator current sensing output from P2, pins A, C, and E is connected together and applied to P1, pin X, of the GCU.

AC GENERATOR OPERATION, AC GENERATOR OFF



09-94-30

NOTES

g. The AC generator current sensing output from P2, pins B, D, and F is applied to P1, pins L, M, and N, of the GCU.

h. AC generator current sensing output from J1, pins L, M, and N is applied to the overcurrent fault detection circuit of the GCU.

i. The fault detection and fault summing logic circuits operate and check the AC generator operating parameters for faults.

j. The AC generator is not producing an output and the fault detection circuits will find "fault" due to the Undervoltage and Underfrequency (on the ground only) condition of the AC generator. The fault summing logic circuits will not provide a ground to the control end of the GCR and CCR relays and they remain de-energized.

6. GCU control of the AC generator stationary exciter control field winding

a. The GCU and CCR relays are in the de-energized state because the AC generator switch is in the OFF/RESET position.

b. The normally-closed (stationary exciter control field winding) contacts are connected across the AC generator stationary exciter control field winding to short it out, through J1/P1, pins D and E of the GCU and P3/J1, pins A and B of the AC generator. This prevents the generator from creating an output, due to residual magnetism in the stationary exciter control field winding core.

c. The stationary exciter control field winding, via J/P1 pin E, is monitored by FD/LS for the exciter output of the GCU.

d. Additionally, the RECTIFIED PMG DC VOLTAGE (28 VDC) is applied to the normally-open (stationary exciter control field winding) contacts of the GCU relay, preventing the AC voltage regulator circuit from operating.

7. Bus tie control

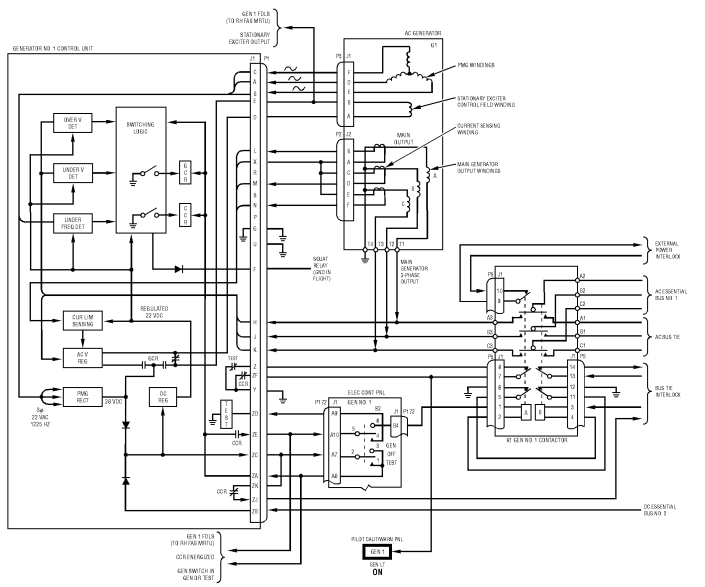
a. The RECTIFIED PMG DC VOLTAGE (28 VDC) from The RECTIFIED PMG DC VOLTAGE (28 VDC) from P1, pin c, is also applied to the GCU P1, pin k.

b. The RECTIFIED PMG DC VOLTAGE (28 VDC) from J1, pin k, is applied to the normally-closed (coil B) contacts of the CCR.

c. The normally-closed (coil B) contacts of the CCR connects RECTIFIED PMG DC VOLTAGE (28 VDC) to J1, pin j.

d. The RECTIFIED PMG DC VOLTAGE (28 VDC) from P1, pin j, is applied to the bus tie relay (coil B) for possible AC bus tie operation.

AC GENERATOR OPERATION, AC GENERATOR OFF



09-94-30

NOTES

8. GEN caution light control

a. The GEN caution light is powered by the DC emergency bus and is controlled by the GCU via the AC generator contactor (coil A) or directly by the GCU during AC generator TEST. In the OFF/RESET condition, both control circuits provide a ground and cause the GEN caution light to illuminate. The two circuit paths are the

(1) CCR, GEN caution light contacts

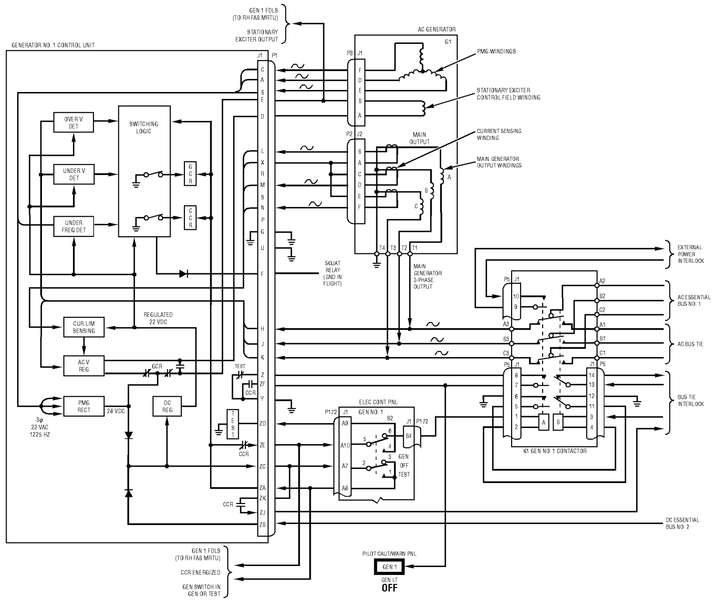
Ground is applied to P1, pin Y, of the GCU. From J1, pin Y, the ground is connected through the normally-closed (GEN caution light) contacts of the CCR, to J1/P1, pin f, and out of the GCU to the GEN caution light.

(2) TEST contacts and AC generator contactor

Ground is applied to P1, pin Y, of the GCU. From J1, pin Y, the ground is connected through the normally-closed contacts of the TEST relay to J1/P1, pin z, and out of the GCU, connected through the normally-closed (GEN caution light) contacts of the AC generator contactor, to the GEN caution light.

(3) With ground present at the GEN caution light, it illuminates.

AC GENERATOR OPERATION, AC GENERATOR ON



09-94-31

NOTES

I. AC generator operation, AC generator on (GEN switch in the GEN position)

1. AC generator switch, AC generator control

a. Placing the AC generator switch to the GEN position connects the RECTIFIED PMG DC VOLTAGE (28 VDC) across the lower section of the AC generator switch, from the common terminal, to the GEN terminal.

b. The RECTIFIED PMG DC VOLTAGE (28 VDC) from the lower section of the AC generator switch, GEN terminal, is applied back to the GCU P1, pin a.

c. The RECTIFIED PMG DC VOLTAGE (28 VDC) from J1, pin a, is applied to the supply end of the GCR and CCR relays, to the normally-open (coil A) contacts of the CCR relay.

2. GCU voltage regulator

a. The DC VOLTAGE REGULATOR is already operating and supplying REGULATED 22 VDC to fault detection and fault summing logic circuits.

3. GCU fault detection and fault summing logic

a. The fault summing logic circuit detects that the RECTIFIED PMG DC VOLTAGE (28 VDC) has been applied by the AC generator switch, which causes the fault summing logic circuit to apply a ground to the control end of the GCR.

4. GCU control of the AC generator stationary exciter control field winding

a. The GCR relay energizes, CHANGING THE STATE OF THE NORMALLY-OPEN CONTACTS, TO CLOSED; AND THE NORMALLY-CLOSED CONTACTS TO OPEN.

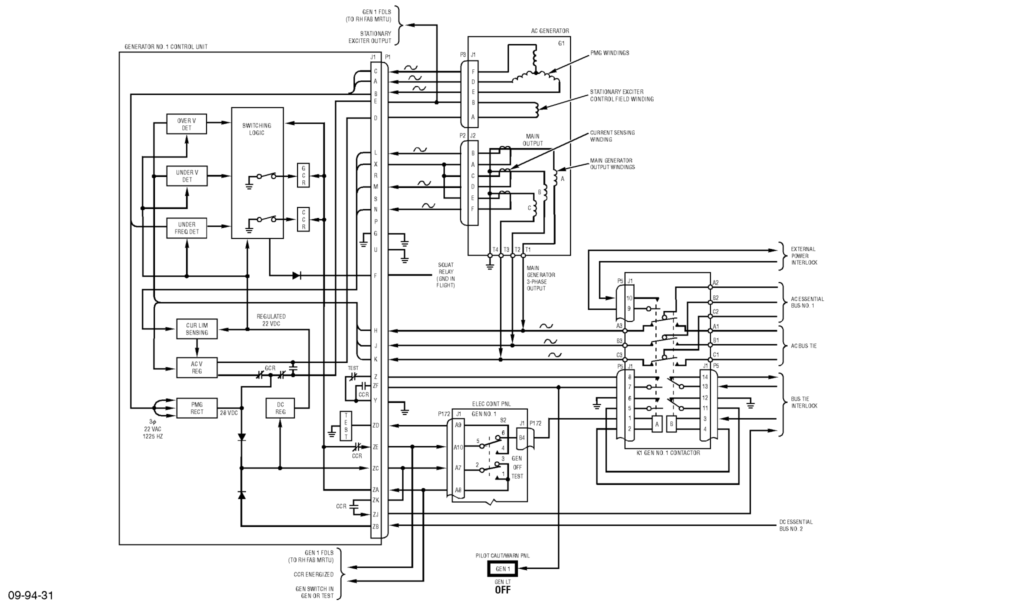
b. The open (stationary exciter control field winding) contacts of the GCR, remove the short from across the winding via J1/P1, pins D and E of the GCU and P3/J1, pins A and B of the AC generator.

c. The closed CCR (AC voltage regulator output) contacts connect one output of the AC voltage regulator output to the AC generator stationary exciter control field winding via J1/P1, pin E, of the GCU and P3/J1, pin B, of the AC generator.

d. The other output of the AC voltage regulator is not controlled by the CCR and is connected directly to the AC generator stationary exciter control field winding via J1, Pin D, of the GCU and P3/J1 pin A of the AC generator.

e. The stationary exciter control field winding, via J/P1 pin E, is monitored by FD/LS for the exciter output of the GCU.

AC GENERATOR OPERATION, AC GENERATOR ON



NOTES

f. The AC generator then develops a 3-phase, 115/200 VAC, 400 Hz output.

5. GCU fault detection and fault summing logic

a. The fault detection and fault summing logic circuits are operating and check the AC generator output for faults.

(1) Overvoltage

(2) Undervoltage

(3) Overcurrent

(4) Underfrequency (on the ground only)

b. If no faults are detected, the fault detection and fault summing logic circuits provides a ground to the control end of the CCR relay. RECTIFIED PMG DC VOLTAGE (28 VDC) is already connected to the supply end of the CCR relay, from the lower section of the AC generator switch.

c. CCR relay energizes, CHANGING THE STATE OF THE NORMALLY-OPEN CONTACTS, TO CLOSED; AND THE NORMALLY-CLOSED CONTACTS TO OPEN.

6. Bus tie control

a. The open (coil B) contacts of the CCR removes the RECTIFIED PMG DC VOLTAGE (28 VDC) from J1/P1, pin j, and the AC generator contactor bus tie relay (coil B). This prevents the AC generator contactor bus tie relay (coil B) from energizing whenever the AC generator contactor, generator contactor relay (coil A) is energized.

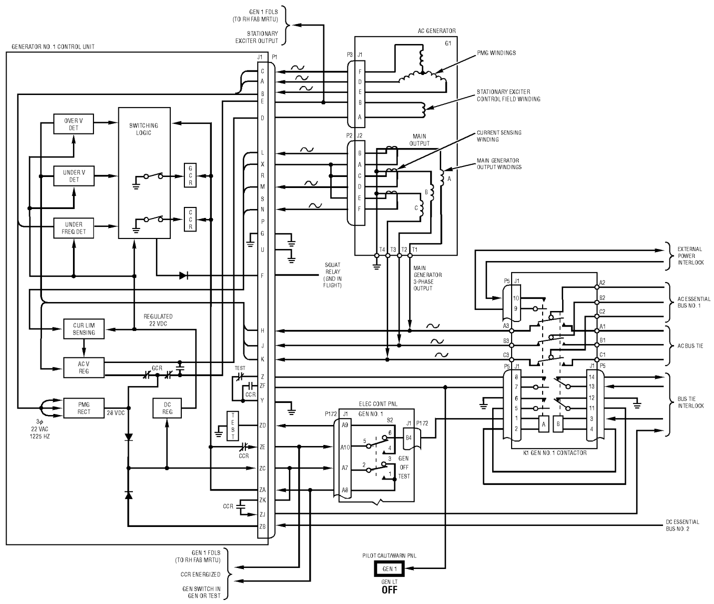
7. AC generator switch, AC generator contactor control

a. The closed (coil A) contacts of the CCR apply RECTIFIED PMG DC VOLTAGE (28 VDC) to J1, pin e.

b. The RECTIFIED PMG DC VOLTAGE (28 VDC) from P1, pin e, is applied to the upper section of the AC generator switch, common terminal, and connected through the closed switch contacts to the GEN terminal.

c. The RECTIFIED PMG DC VOLTAGE (28 VDC) from the AC generator switch, GEN terminal, is applied to P5/J1 pin 1 of the AC generator contactor and the generator contactor relay (coil A) energizes, closes the AC generator contacts and connects 3-phase, 115 VAC, 400 Hz to the respective AC essential bus.

AC GENERATOR OPERATION, AC GENERATOR ON



09-94-31

NOTES

8. GEN caution light control

   a. The GEN caution light is powered by the DC emergency bus and is controlled by the GCU via the AC generator contactor or directly by the GCU during AC generator TEST. In the GEN ON condition, both control circuits are open and remove the ground from the GEN caution light and cause it to extinguish. The two circuit paths are

      (1) CCR, GEN caution light contacts

      Ground is applied to P1, pin Y, of the GCU. From J1, pin Y, the ground is connected to the open (GEN caution light) contacts of the CCR, which disconnects the ground from J1/P1, pin f, and the GEN caution light.

      (2) TEST contacts and AC generator contactor

      Ground is applied to P1, pin Y, of the GCU. From J1, pin Y, the ground is connected through the normally-closed contacts of the TEST relay, applied to J1/P1, pin z, and out of the GCU and is applied to the open AC generator contactor (GEN caution light) contacts, which disconnects the GEN caution light.

      (3) With ground disconnected from the GEN caution light, it extinguishes.

9. The "helicopter is on the ground" signal

   a. The K4-1/2 squat relay is de-energized when the helicopter is on the ground.

   b. Ground is applied to the normally-open contacts of K4-1/2 terminal D1.

   c. Ground is disconnected from K4-1/2 terminal D2.

   d. Ground is removed from the GCU J1, pin F, and the underfrequency fault detection circuit provides AC generator underfrequency fault protection when the helicopter is on the ground.

10. The "helicopter is in the air" signal

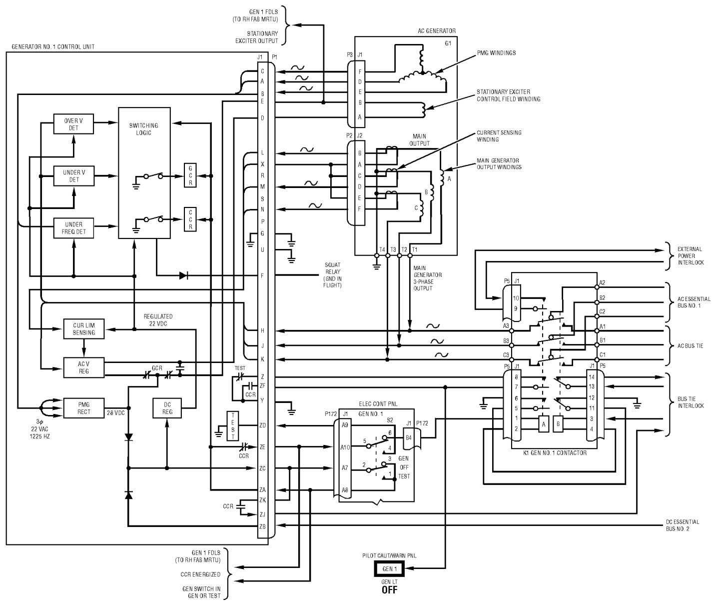
   a. The K4-1/2 squat relay is energized when the helicopter is in the air.

   b. Ground is applied to the closed contacts of K4-1/2 terminal D1.

   c. Ground is connected across the closed contacts of K4-1/2 to terminal D2.

   d. Ground from K4-1/2 to terminal D2 is applied to the GCU P1, pin F.

AC GENERATOR OPERATION, AC GENERATOR ON

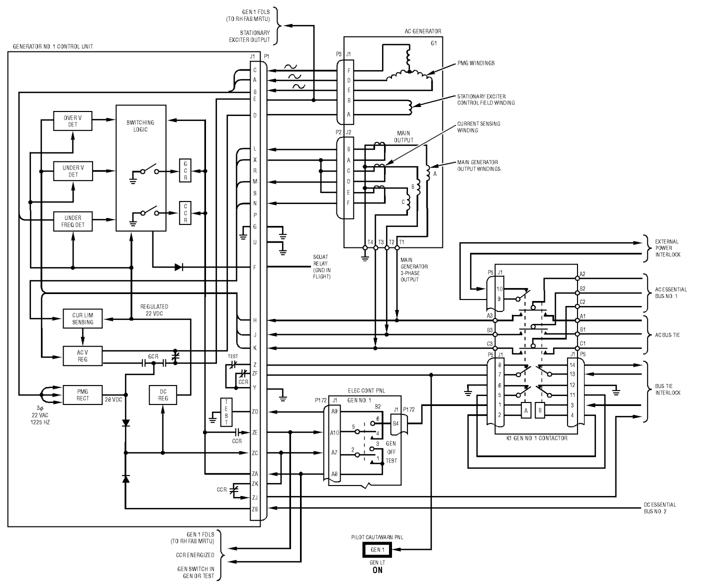


09-94-31

NOTES

e. Ground from GCU J1, pin F, is applied to the underfrequency fault detection circuit and disables the AC generator underfrequency fault protection when the helicopter is in the air.

AC GENERATOR OPERATION, AC GENERATOR OFF



09-94-30

NOTES

J. AC generator operation, AC generator off (GEN switch in the OFF/RESET position)

1. AC generator switch, AC generator control

a. Placing the AC generator control switch in the OFF/RESET position removes the RECTIFIED PMG DC VOLTAGE (28 VDC) from the upper section of the AC generator switch, GEN terminal, and the AC generator contactor, generator contactor relay (coil A) de-energizes. This removes the 3-phase, 115/200 VAC, 400 Hz power from the AC essential bus.

b. Placing the AC generator control switch in the OFF/RESET position also removes RECTIFIED PMG DC VOLTAGE (28 VDC) from the lower section of the AC generator switch, GEN terminal.

c. Removing the RECTIFIED PMG DC VOLTAGE (28 VDC) from the lower section of the AC generator switch, GEN terminal, also removes it from P1, pin a.

2. GCU control of the AC generator stationary exciter control field winding

a. Removing the RECTIFIED PMG DC VOLTAGE (28 VDC) from J1, pin a also removes it from the supply end of the GCR and CCR causing them to de-energize.

b. The GCR and CCR relays both de-energize, CHANGING THE STATE OF THE CONTACTS TO THEIR ORIGINAL NORMALLY-CLOSED AND NORMALLY-OPEN CONDITIONS.

c. The normally-open (stationary exciter control field winding) contacts of the GCU relay remove RECTIFIED PMG DC VOLTAGE (28 VDC) from the AC voltage regulator circuit and it stops operating. Additionally, the normally-closed (stationary exciter control field winding) contacts are connected across the AC generator stationary exciter control field winding to short it out, via J1, pins D and E and P3/J1, pins A and B of the AC generator.

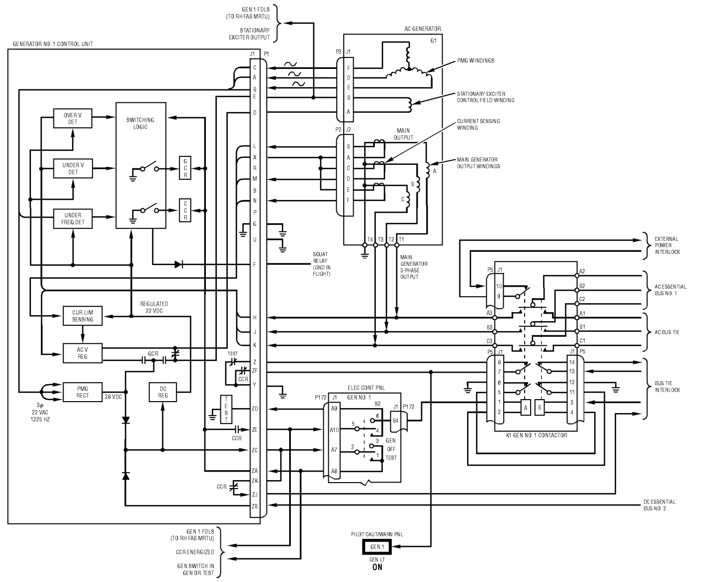
d. The stationary exciter control field winding, via J/P1 pin E, is monitored by FD/LS for the exciter output of the GCU.

e. The AC generator STOPS DEVELOPING the 3-phase, 115/200 VAC, 400 Hz output.

3. Bus tie control

a. The closed (coil B) contacts of the CCR connects the RECTIFIED PMG DC VOLTAGE (28 VDC) across to J1, pin j, and the AC generator contactor bus tie relay (coil B). This allows for possible bus tie connection.

AC GENERATOR OPERATION, AC GENERATOR OFF



09-94-30

NOTES

4. GCU voltage regulator and GCU fault detection and fault summing logic

   a. The DC VOLTAGE REGULATOR and the fault detection and fault summing logic circuits continue to operate and check the AC generator operating parameters for faults.

   b. The AC generator is not producing an output and the fault detection circuits will find "fault" due to the Undervoltage and Underfrequency (on the ground only) condition of the AC generator. The fault summing logic circuits will remove the ground from the control end of the GCR and CCR relays and they remain de-energized.

5. GEN caution light control

   a. The GEN caution light is powered by the DC emergency bus and is controlled by the GCU via the AC generator contactor or directly by the GCU during AC generator TEST. In OFF/RESET condition, both control circuits provide a ground and cause the GEN caution light to illuminate. The two circuit paths are the

      (1) CCR, GEN caution light contacts.

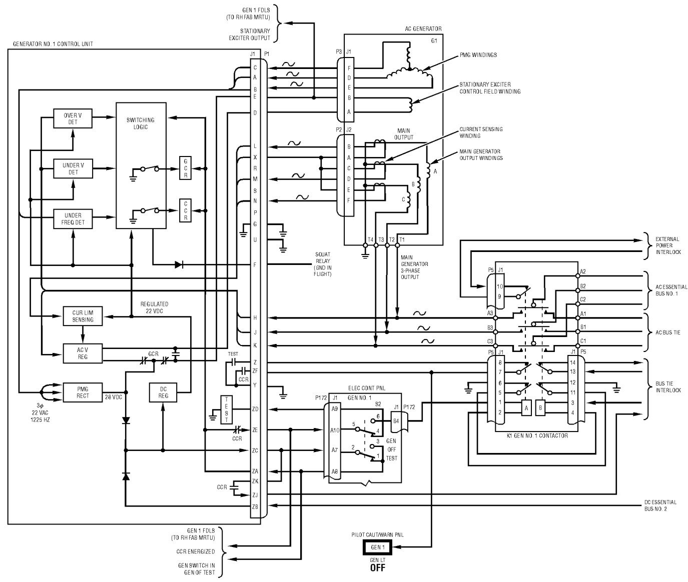
      Ground is applied to J1, pin Y, of the GCU. From J1, pin Y, the ground is connected through the normally-closed (GEN caution light) contacts of the CCR, to J1, pin f, and out of the GCU to the GEN caution light.

      (2) TEST contacts and AC generator contactor.

      Ground is applied to J1, pin Y, of the GCU. From J1, pin Y, the ground is connected through the normally-closed contacts of the TEST relay, applied to J1, pin z, routed out of the GCU, connected through the normally-closed AC generator contactor (GEN caution light) contacts and to the GEN caution light.

      (3) With ground present at the GEN caution light, it illuminates.

AC GENERATOR OPERATION, AC GENERATOR TEST



09-94-32

NOTES

K. AC generator operation, AC generator test (GEN switch in the TEST position)

1. AC generator switch, AC generator control

a. Placing the AC generator switch to the TEST position connects the RECTIFIED PMG DC VOLTAGE (28 VDC) across the lower section of the AC generator switch, common terminal, to the TEST terminal.

b. The RECTIFIED PMG DC VOLTAGE (28 VDC) from the lower section of the AC generator switch, TEST terminal, is applied back to the GCU J1, pin a.

c. The RECTIFIED PMG DC VOLTAGE (28 VDC) from J1, pin a, is applied to the supply end of the GCR and CCR relays, to the normally-open (coil A) contacts of the CCR relay and to the fault detection and fault summing logic circuits.

2. GCU voltage regulator and GCU fault detection and fault summing logic

a. The DC VOLTAGE REGULATOR is already operating and supplying REGULATED 22 VDC to fault detection and fault summing logic circuits.

b. The fault summing logic circuit detects that the RECTIFIED PMG DC VOLTAGE (28 VDC) has been applied by the AC generator switch, the fault summing logic circuit then applies a ground to the control end of the GCR.

3. GCU control of the AC generator stationary exciter control field winding

a. The GCR relay energizes, CHANGING THE STATE OF THE NORMALLY-OPEN CONTACTS, TO CLOSED; AND THE NORMALLY-CLOSED CONTACTS TO OPEN.

b. The open (stationary exciter control field winding) contacts of the GCR, remove the short from across the winding via J1/P1, pins D and E of the GCU and P3/J1, pins A and B of the AC generator.

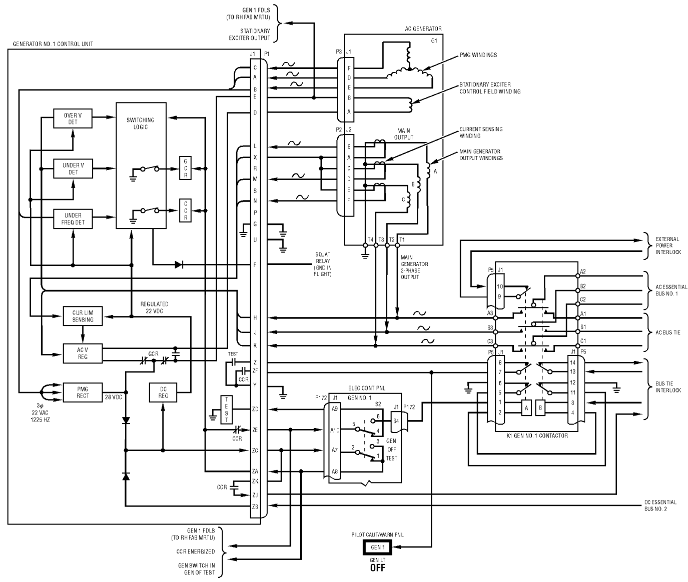
c. The closed CCR (AC voltage regulator output) contacts connect one output of the AC voltage regulator output to the AC generator stationary exciter control field winding via J1/P1, pin E, of the GCU and P3/J1, pin B, of the AC generator.

d. The stationary exciter control field winding, via J/P1 pin E, is monitored by FD/LS for the exciter output of the GCU.

e. The other output of the AC voltage regulator is not controlled by the CCR and is connected directly to the AC generator stationary exciter control field winding via J1, Pin D, of the GCU and P3/J1 pin A of the AC generator.

f. The AC generator then develops a 3-phase, 115/200 VAC, 400 Hz output.

AC GENERATOR OPERATION, AC GENERATOR TEST



09-94-32

NOTES

4. GCU fault detection and fault summing logic

   a. The fault detection and fault summing logic circuits are operating and check the AC generator output for faults.

      (1) Overvoltage

      (2) Undervoltage

      (3) Overcurrent

      (4) Underfrequency (on the ground only)

   b. If no faults are detected, the fault detection and fault summing logic circuits provides a ground to the control end of the CCR relay. RECTIFIED PMG DC VOLTAGE (28 VDC) is already connected to the supply end of the CCR relay, from the lower section of the AC generator switch.

   c. CCR relay energizes, CHANGING THE STATE OF THE NORMALLY-OPEN CONTACTS, TO CLOSED; AND THE NORMALLY-CLOSED CONTACTS TO OPEN.

5. GEN caution light control

   a. The open (GEN caution light) contacts of the CCR disconnects the ground from J1, pin f, and the GEN caution light. The light is still grounded by the de-energized contacts of the AC generator contactor and the TEST relay. The light remains illuminated until the TEST relay energizes.

6. Bus tie control

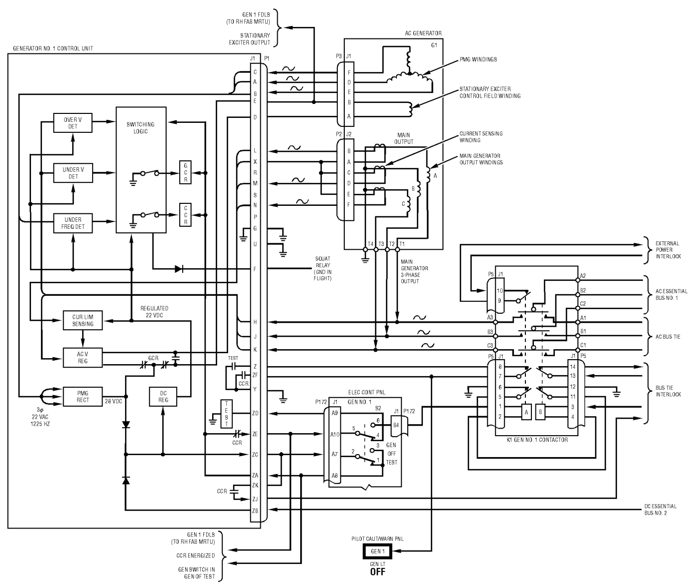
   a. The open (coil B) contacts of the CCR removes the RECTIFIED PMG DC VOLTAGE (28 VDC) from J1, pin j, and the AC generator contactor bus tie relay (coil B). This prevents the AC generator contactor bus tie relay (coil B) from energizing whenever the AC generator contactor, generator contactor relay (coil A) is energized.

7. AC generator switch, AC generator contactor control

   a. The closed (coil A) contacts of the CCR connect RECTIFIED PMG DC VOLTAGE (28 VDC) to J1, pin e. The RECTIFIED PMG DC VOLTAGE (28 VDC) is applied from J1, pin e, to the upper section of the AC generator switch, common terminal, and then across the closed switch contacts to the TEST terminal.

      (1) With the switch is in the TEST position, no RECTIFIED PMG DC VOLTAGE (28 VDC) is connected to the GEN terminal of the switch, preventing the AC generator contactor (coil A) from energizing.

AC GENERATOR OPERATION, AC GENERATOR TEST



09-94-32

NOTES

(2) The de-energized AC generator contactor (coil A) prevents the AC generator 3-phase, 115/200 VAC, 400 Hz output from being connected to the AC essential bus.

b. The RECTIFIED PMG DC VOLTAGE (28 VDC) is applied from the AC generator switch, TEST terminal to J1, pin d.

c. The RECTIFIED PMG DC VOLTAGE (28 VDC) is applied from J1, pin d, to the supply end of the TEST relay coil, the control end is connected to ground.

d. The TEST relay energizes, opening the normally-closed contacts.

8. GEN caution light control

a. The GEN caution light is powered by the DC emergency bus and is controlled by the GCU via the AC generator contactor or directly by the GCU during AC generator TEST. In the TEST condition, both control circuits are open and removes the ground from the GEN caution light causing it to extinguish. There are two circuit paths.

(1) Ground is applied to J1, pin Y, of the GCU. From P1, pin Y, the ground is connected to the open contacts of the TEST relay.

(2) The open contacts of the TEST relay remove ground from J1/P1, pin z, and the normally-closed AC generator contactor (GEN caution light) contacts. The CCR (GEN caution light) contacts are already open.

(3) The GEN caution light extinguishes.

b. The GEN caution light will remain extinguished, provided

(1) The switch is held in the TEST position.

(2) No faults occur.

9. AC generator switch, AC generator contactor control

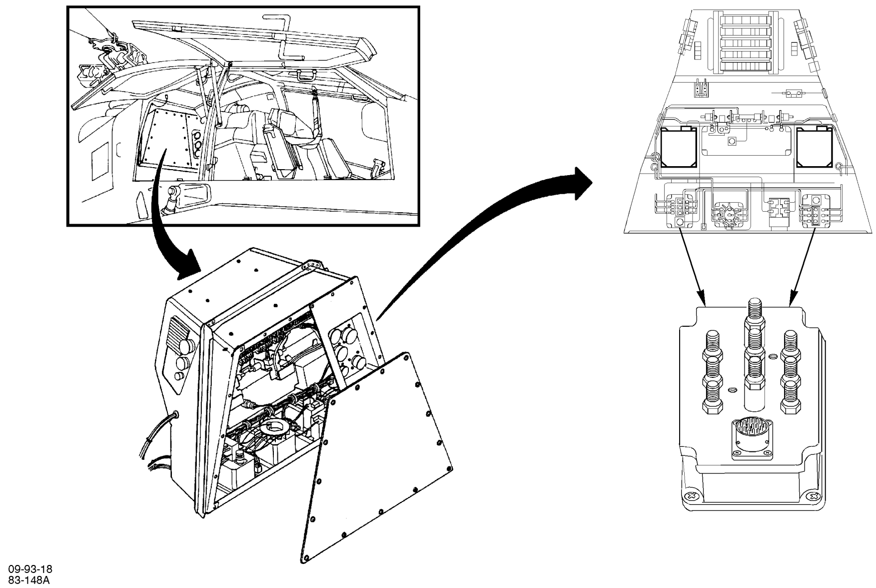
a. Placing the AC generator switch back to the OFF/RESET position will cause

(1) The TEST relay to de-energize, illuminating the GEN caution light.

(2) The GCR and CCR to de-energize, stopping the AC generator 3-phase, 115/200 VAC, 400 Hz output.

(3) The fault detection and fault summing logic circuits to continue operating in preparation for AC generator "on line" or "test" operation.

AC CONTACTOR LOCATION



NOTES

L. AC generator contactor(s) component purpose, location, description, and operation

1. The AC generator contactors are located inside the electrical power distribution center, which is behind the pilot crewstation seat. The contactors are mounted on the inside, bottom of the electrical power center, No. 1 AC contactor is on the left and the No. 2 AC contactor is on the right.

2. Purpose

a. Connects each AC generator's 3-phase output to it's respective AC essential bus, when both AC generators are operating.

b. Isolates the No. 1 AC essential bus from the No. 2 AC essential bus (and the AC generator's outputs) during normal operation with both AC generators providing power to their respective bus.

(1) They isolate the buses to keep as much of the electrical power system operating in the event of combat or other serious damage.

(2) The buses and generators are also isolated because the individual AC generator outputs are not synchronized (voltage maximums of both AC generators occurring at the same time).

(a) This simplifies AH-64A maintenance actions because the AC generators input shafts do not have to be timed in relation to one another when they are installed.

(b) The individual AC generator GCU control requirements are less complex as well. A system that has "paralleled" generators requires additional circuitry to control the individual generators.

(3) Equipment damage could result if both AC generators outputs were connected together.

(4) The AC generator contactor controls part of the GEN caution light circuit.

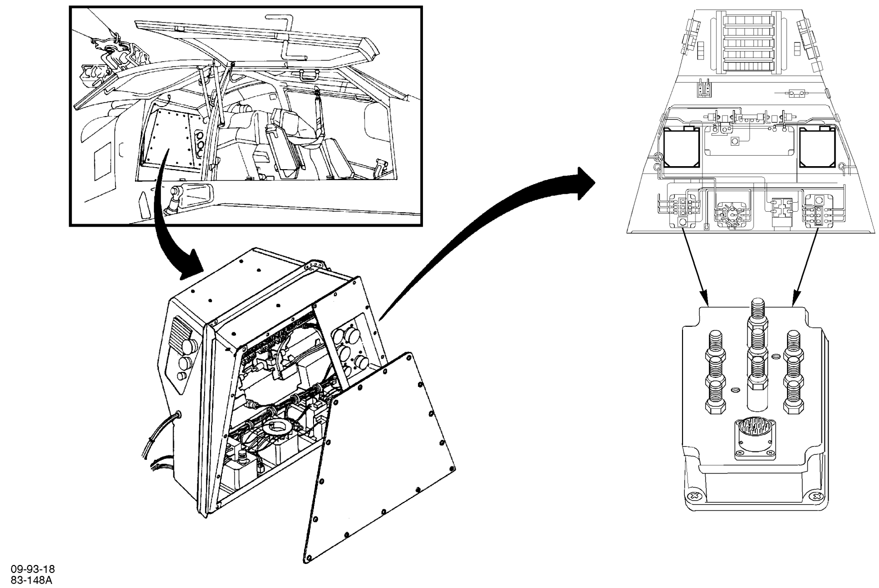
(5) Provides bus tie operation, enabling both AC essential buses to be powered by one AC generator.

(a) The bus tie operation will occur if

1) Only one AC generator switch has been placed in the GEN position. This is manual bus tie operation.

2) Initially, both AC generators are operating normally and a then a failure occurs in one of them. Automatic bus tie operation will occur.

AC CONTACTOR LOCATION



NOTES

3) External power is applied.

(6) Prevents application of external power if either AC generator is operating.

(7) During external power operation, the AC contactors provide bus tie operation, enabling both AC essential busses to be powered from the single external power source.

(8) During external power operation, the AC contactors prevent the connection of either AC generator's 3-phase output to the AC essential buses. The outputs of the external power source and the AC generators are not synchronized (voltage maximums of both AC generators occurring at the same time). Equipment damage could result if the external power source and the AC generator's outputs were connected to the same bus.

3. AC generator contactor mechanical description

a. An electro-mechanical LRU, with nine terminal studs, for AC generator or external power 3-phase connections to the AC essential bus, and one quick-disconnect receptacle for control connections.

b. Contains two independently controlled relays

(1) The generator contactor relay (coil A). Do not confuse the Generator CONTACTOR Relay (coil A) in the AC contactor with the Generator CONTROL Relay in the GCU.

(2) The bus tie relay (coil B).

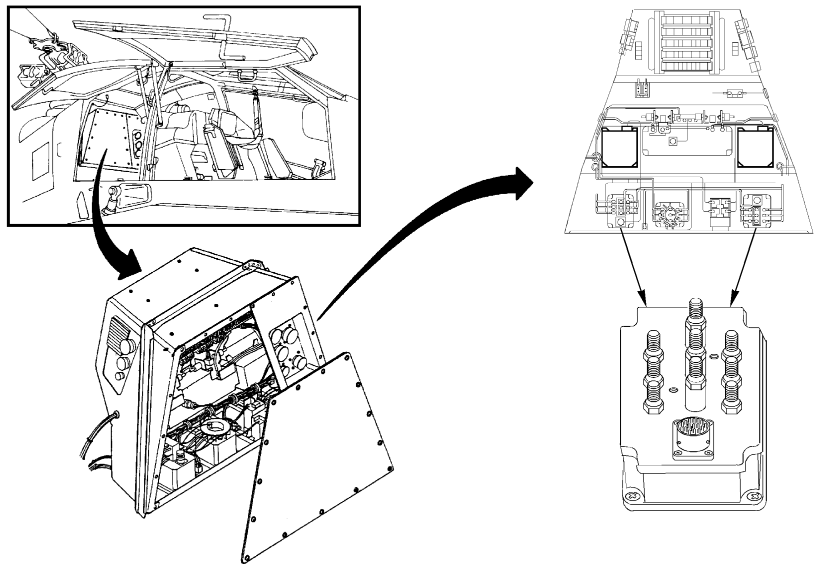
c. Both relays have double pole (one terminal set is common to both), double throw, rocker-type, high current, contact sets (connected to the nine terminal studs).

(1) The contact sets are used for connecting the AC generator or the external power source, 3-phase, 115/200 VAC, 400 Hz outputs to the AC essential bus for direct bus feed or bus tie operation.

(2) The contacts are connected to the input terminals, output terminals, and the bus tie terminals. There are three individual rockers that are used to connect the 3-phase inputs to the 3-phase outputs or 3-phase bus tie contacts.

(3) The three rockers are electrically isolated and mechanically connected to the A and B coils. There is one rocker for each phase. All three rockers are moved simultaneously when activated by the A or B coils. Both coils operate independently and are not energized at the same time.

AC CONTACTOR LOCATION



09-93-18
83-148A

NOTES

(4) For simplicity, the operation of only one rocker is discussed.

(a) The output terminal is connected to the center of the rocker.

(b) The input terminal is connected to the generator contactor relay contacts.

(c) The bus tie terminal is connected to the bus tie (coil B) contacts.

(5) By controlling the coil A and coil B relays

(a) When coil A and coil B are both de-energized, the input terminal is not connected to either the output or bus tie terminal.

(b) When coil A is energized (coil B de-energized), the input (AC generator) terminal is connected to the output (AC essential bus) terminal, the bus tie terminal is open.

(c) When coil B is energized (coil A de-energized), the bus tie terminal is connected to the output (AC essential bus) terminal, the input (AC generator) terminal is open.

d. The Generator contactor relay also has three double pole, single throw, low current, contact sets that operate by standard relay principles. The contact sets are used for

(1) External power interlock.

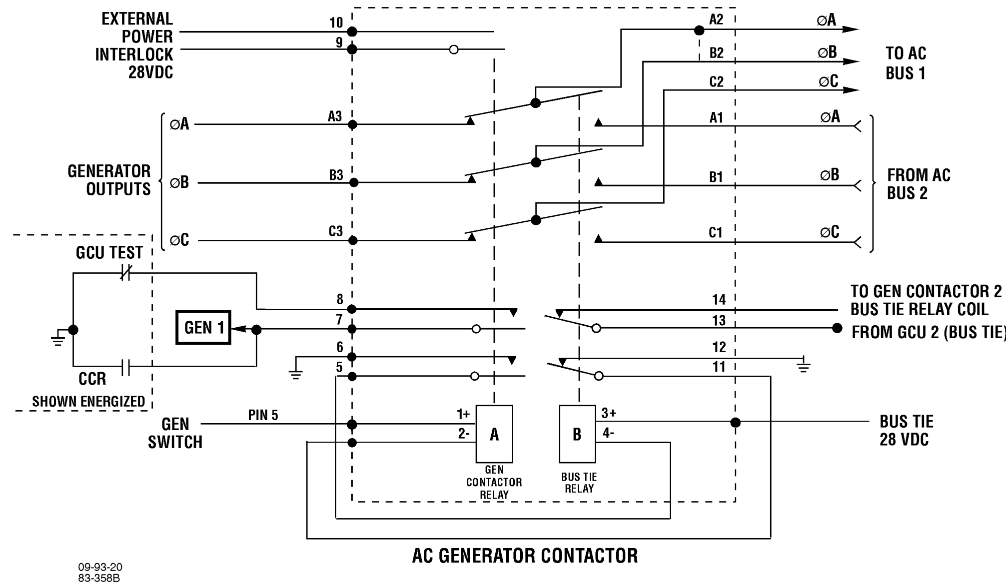
(2) Bus tie interlock (No. 1 and No. 2 systems differ slightly).

(3) GEN caution light control.

e. The bus tie relay also has two double pole, single throw, low current, contact sets that are used for

(1) Bus tie interlock (No. 1 and No. 2 systems differ slightly).

AC CONTACTOR SIMPLIFIED FUNCTIONAL DIAGRAM GENERATOR CONTACTOR RELAY ENERGIZED



NOTES

4. AC generator contactor electrical description

a. Generator contactor relay (coil A)

(1) Controls application of the AC generator's three-phase, 115/200 VAC, 400 Hz output to the AC essential bus and prevents the outputs of the two AC generators from being connected together.

(2) The generator contactor relay (coil A) energizes when the AC generator switch is placed in the GEN position, the AC generator is operating properly, no external power is applied to the helicopter.

(a) RECTIFIED PMG DC VOLTAGE (28 VDC), or 28 VDC from the opposite system's DC essential bus, is applied to the supply end of the generator contactor relay (coil A), through the AC generator control switch in the GEN position.

(b) Ground is connected to the control end of the generator contactor relay (coil A) by the normally closed (coil A) contacts of the bus tie relay.

(3) Generator contactor relay (coil A), when energized

(a) Connects the AC generator's output to the AC generator contactor's output terminals, the AC essential bus, and to the bus tie terminals of the other system's bus tie relay. AC generator power is APPLIED.

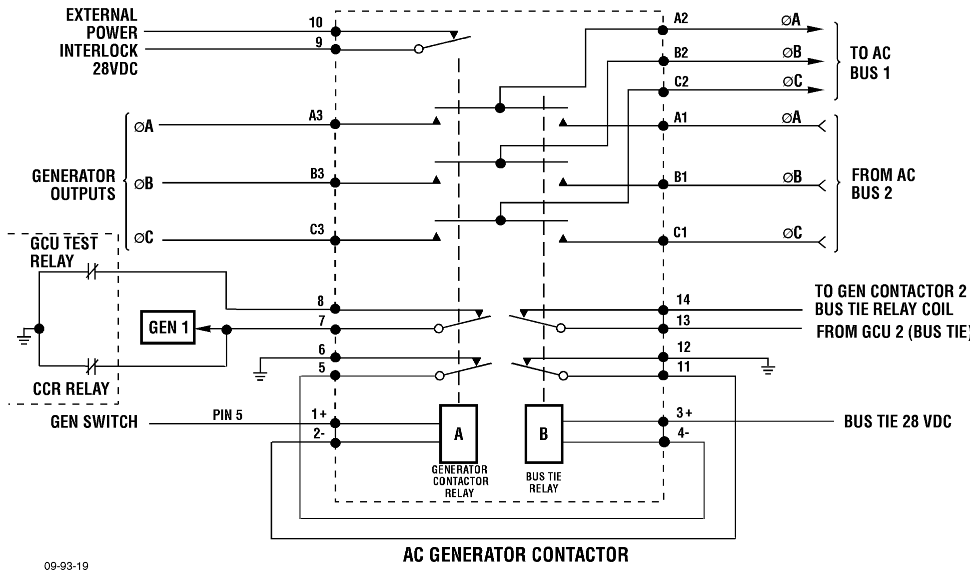
(b) Opens

1) Part of the external power interlock, preventing application of external power.

2) The bus tie interlock ground to the control end of the bus tie relay (coil B), preventing the bus tie relay (coil B) from energizing while the generator contactor relay is energized.

3) Part of the GEN caution light circuit, allows the light to extinguish, the CCR (GEN caution light) contacts are also open when the AC generator is operating and the GEN switch is in the GEN position.

AC CONTACTOR SIMPLIFIED FUNCTIONAL DIAGRAM DE-ENERGIZED



NOTES

(4) The generator contactor relay (coil A) de-energizes when the AC generator switch is placed in the OFF/REST position or an AC generator fault occurs.

(a) RECTIFIED PMG DC VOLTAGE (28 VDC), and 28 VDC from the opposite system's DC essential bus, are removed from the supply end of the generator contactor relay (coil A), by the AC generator control switch in the OFF/RESET position or by the GCU's CCR if an AC generator fault occurs.

(b) Ground remains connected to the control end of the generator contactor relay (coil A) by the normally closed (coil A) contacts of the bus tie relay.

(5) Generator contactor relay (coil A), when de-energized

(a) Disconnects the AC generator's output from the AC generator contactor's output terminals, the AC essential bus, and from the bus tie terminals of the other system's bus tie relay. AC generator power is REMOVED.

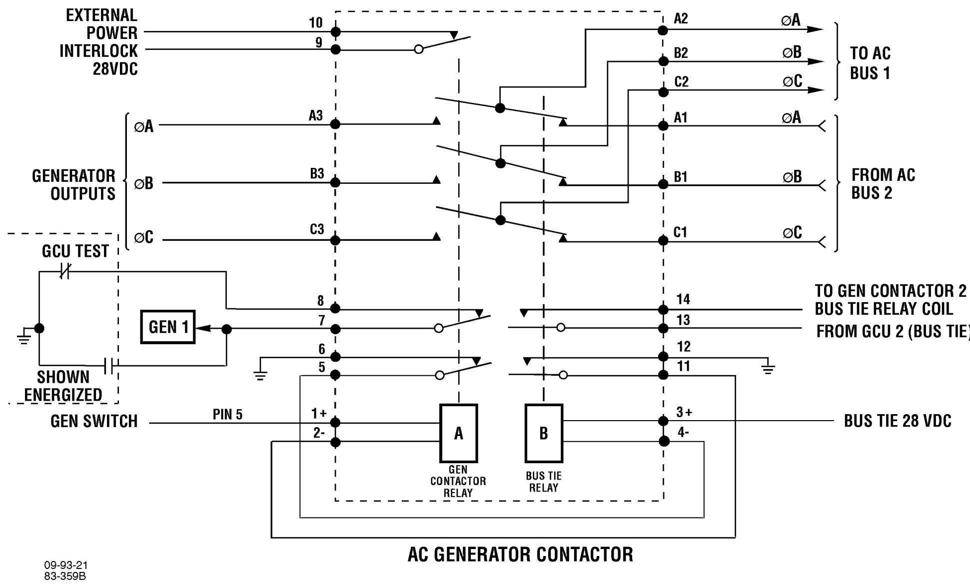
(b) Closes

1) Part of the external power interlock, allowing application of external power if the other interlocks are closed as well.

2) The bus tie interlock ground to the control end of the bus tie relay (coil B), allowing it to energize during bus tie operation.

3) Part of the GEN caution light circuit, causing it to illuminate.

AC CONTACTOR SIMPLIFIED FUNCTIONAL DIAGRAM BUS TIE RELAY ENERGIZED



NOTES

b. Bus tie relay (coil B)

(1) Allows both AC essential buses to be powered by one AC generator. Part of the bus tie circuit is also used for three-phase, 115/200 VAC, 400 Hz external power operation of the helicopter.

(2) The bus tie relay (coil B) energizes when the opposite system's AC generator switch is placed in the GEN position and it's AC generator is operating properly, or when both switches are in GEN position and only the opposite system's AC generator is operating properly.

(a) 28 VDC from the opposite system's DC essential bus is applied to the supply end of the bus tie relay (coil B). RECTIFIED PMG DC VOLTAGE (28 VDC) may not be available if an AC generator fault exists.

1) No. 1 system's bus tie relay (coil B) supply end is also controlled by the normally-closed (coil B) contacts of the external power contactor.

2) No. 2 system's bus tie relay (coil B) supply end is also controlled by the normally-closed (coil B) contacts of the No. 1 system's bus tie relay.

(b) Ground is connected to the control end of the bus tie relay (coil B) by the normally-closed (coil B) contacts of the generator contactor relay.

(3) Bus tie relay (coil B), when energized

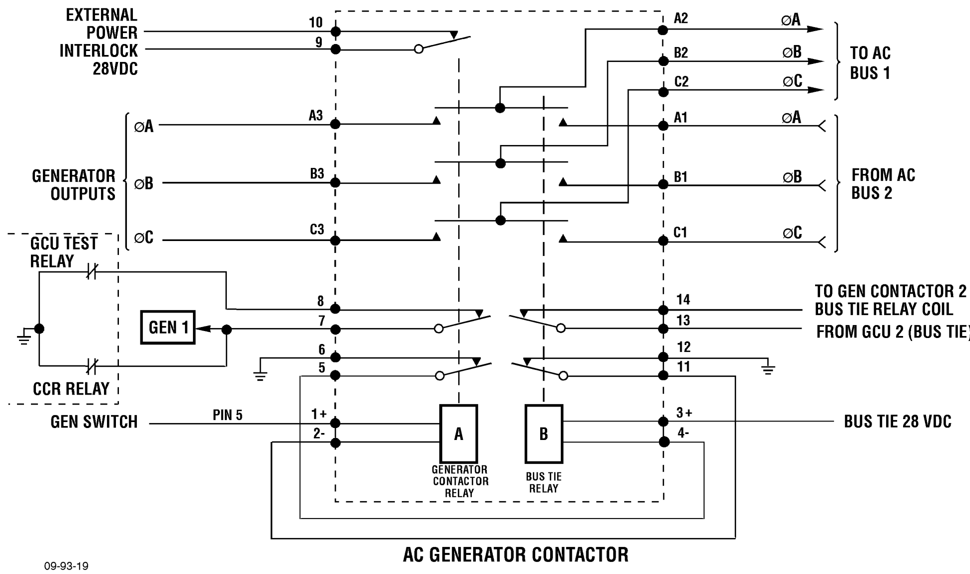
(a) Connects the AC essential bus to the output terminals of the other system's AC generator contactor. Both AC essential buses are then POWERED BY the other system's AC generator.

(b) Opens the control end of the generator contactor relay (coil A), preventing it from energizing while the bus tie relay (coil B) is energized.

(c) The No. 2 system is similar, except it opens the control end of it's generator contactor relay (coil A) via the normally closed external power contactor (coil A) contacts.

(d) Opens the supply end of the No. 2 system's bus tie relay (coil B), preventing the No. 2 system's bus tie relay (coil B) from energizing and disconnecting both AC essential buses from the AC generator.

AC CONTACTOR SIMPLIFIED FUNCTIONAL DIAGRAM DE-ENERGIZED



AC GENERATOR CONTACTOR

NOTES

(4) The bus tie relay (coil B) de-energizes when the opposite system's AC generator switch is placed in the OFF/RESET position, or when both switches are in GEN position and neither system is operating properly.

(a) 28 VDC from the opposite system's DC essential bus is removed from the supply end of the bus tie relay (coil B). RECTIFIED PMG DC VOLTAGE (28 VDC) may not be available if an AC generator fault exists.

1) No. 1 system's bus tie relay (coil B) supply end is also controlled by the normally-closed (coil B) contacts of the external power contactor.

2) No. 2 system's bus tie relay (coil B) supply end is also controlled by the normally-closed (coil B) contacts of the No. 1 system's bus tie relay.

(b) Ground remains connected to the control end of the bus tie relay (coil B) by the normally closed (coil B) contacts of the generator contactor relay.

(5) Bus tie relay (coil B), when de-energized

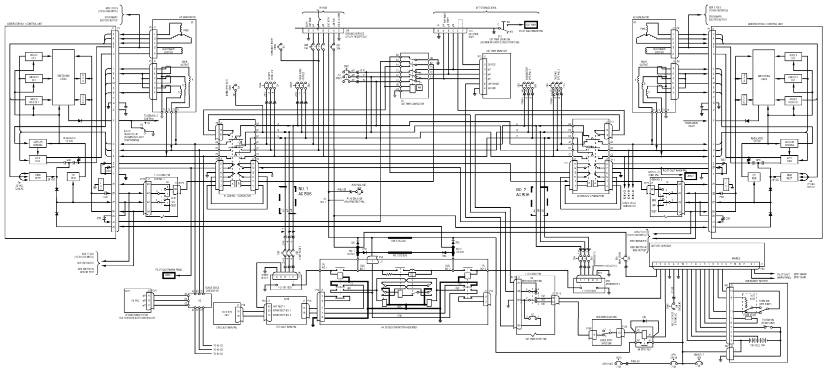
(a) Disconnects the AC essential bus from the output terminals of the other system's AC generator contactor. Then, both AC essential buses are NOT POWERED BY the other system's AC generator.

(b) Closes the control end of the generator contactor relay (coil A).

(c) The No. 2 system is similar, except it closes the control end of it's generator contactor relay (coil A) via the normally closed external power contactor (coil A) contacts.

(d) Closes the supply end of the No. 2 system's bus tie relay (coil B).

AH-64A ELECTRICAL SYSTEM SCHEMATIC



09-94-06

NOTES

M. Generator contactor relay (coil A) operation, initial conditions

1. The AC generator switch is in the GEN position.

2. The AC generator is operating normally.

3. The GCU GCR and CCR relays are energized, RECTIFIED PMG DC VOLTAGE (28 VDC) from P1, pin e, of the GCU, is applied to the upper section of the AC generator switch, common terminal.

4. Three-phase, 115/200 VAC, 400 Hz output from the AC generator is applied to the AC generator terminals, A3, B3 and C3, of the AC generator contactor.

5. The bus relay is de-energized, because no bus tie voltage is available from the GCU's, open CCR (coil B) contacts.

N. Generator contactor relay (coil A) operation, coil A energized

1. Energizing the generator contactor relay (coil A)

   a. The RECTIFIED PMG DC VOLTAGE (28 VDC) from the GCU P1, pin e, is connected across the upper section of the AC generator switch, common terminal, to the GEN terminal.

   b. The RECTIFIED PMG DC VOLTAGE (28 VDC) from the lower section of the AC generator switch, GEN terminal, is applied to P5, pin 1.

   c. The RECTIFIED PMG DC VOLTAGE (28 VDC) from J1, pin 1, is applied to the supply end of the generator contactor relay (coil A).

   d. Ground is applied to P5, pin 12.

   e. Ground from J1, pin 12, is applied to the normally-closed (coil A) contacts of the bus tie relay.

   f. Ground is connected across the normally-closed (coil A) contacts of the bus tie relay and is applied to J1, pin 11.

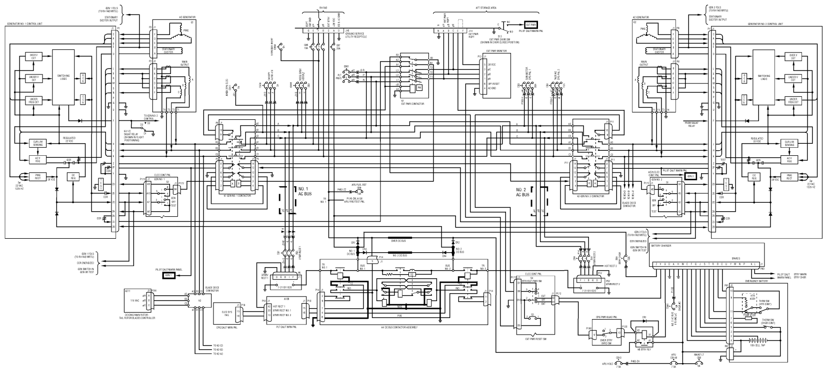
   g. Ground from P5, pin 11, is applied to P5, pin 2.

   h. Ground from J1, pin 2 is applied to the control end of the generator contactor relay (coil A).

2. Connecting the AC generator to the AC essential bus

   a. The generator contactor relay (coil A), energizes CHANGING THE STATE OF THE NORMALLY-OPEN CONTACTS, TO CLOSED; AND THE NORMALLY-CLOSED CONTACTS TO OPEN. Simultaneously, the three rockers connect the AC generator terminals A3, B3, and C3 to the AC generator contactor output terminals A2, B2, and C2.

AH-64A ELECTRICAL SYSTEM SCHEMATIC



09-94-06

NOTES

b. The three-phase, 115/200 VAC, 400 Hz, AC generator output applied to the AC generator terminals A3, B3, and C3 is connected across the closed rockers to the AC generator contactor output terminals, A2, B2, and C2.

c. The three-phase, 115/200 VAC, 400 Hz from the AC generator contactor output terminals, A2, B2, and C2 is applied to the AC essential bus and the bus tie terminals A1, B1, and C1, of the other system's bus tie relay.

d. The AC essential bus now has power APPLIED.

3. Opening the external power interlock

a. The energized generator contactor relay (coil A), opens the (external power interlock) contacts, that are connected to J1/P5, pins 9 and 10. This opens the external power interlock circuit and prevents application of external power to the helicopter as long as the AC generator is on line.

4. Opening the bus-tie interlock

a. Ground is applied to P5, pin 6.

b. Ground from J1, pin 6, is applied to the open (coil B) contacts of the generator contactor relay.

c. The open (coil B) contacts of the generator contactor relay remove ground from J1, pin 5.

d. Ground is removed from P5, pin 5, and P5, pin 4.

e. Ground is removed from J1, pin 4, and the control end of the bus tie relay (coil B) and prevents the bus tie relay (coil B) from energizing while the generator contactor relay (coil A) is energized.

5. Extinguishing the GEN caution light

a. Ground is applied to P1, pin Y, of the GCU.

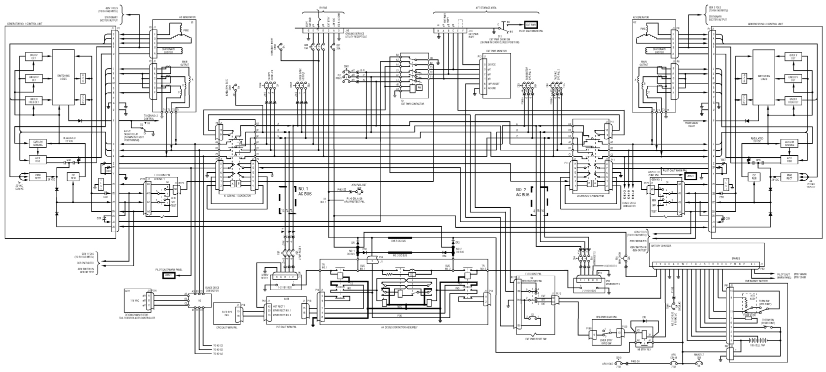
b. Ground from J1, pin Y, is applied to the open (Gen caution light) contacts of the CCR.

c. Ground from J1, pin Y, is also applied to the normally-closed contacts of the TEST relay.

d. Ground is connected across the normally-closed contacts of the TEST relay and is applied to J1, pin Z.

e. Ground from P1, pin Z, is applied to the AC generator contactor P5, pin 8.

AH-64A ELECTRICAL SYSTEM SCHEMATIC



09-94-06

NOTES

f. Ground from J1, pin 8, is applied to the open (Gen caution light) contacts of the generator contactor relay.

g. The open (Gen caution light) contacts of the generator contactor relay remove ground from J1, pin 7.

h. Ground is removed from P5, pin 7 and from the GEN caution light (the CCR relay, GEN caution light contacts are open already), causing the light to extinguish, indicating that the AC generator is operating normally and is on-line.

O. Generator contactor relay (coil A) operation, coil A de-energized

1. De-energizing the generator contactor relay (coil A)

a. The open contacts of the AC generator switch in the OFF/RESET position removes the RECTIFIED PMG DC VOLTAGE (28 VDC) from P5, pin 1.

b. The RECTIFIED PMG DC VOLTAGE (28 VDC) from J1, pin 1, is removed from the supply end of the generator contactor relay (coil A).

2. Disconnecting the AC generator from the AC essential bus

a. The generator contactor relay (coil A) de-energizes, CHANGING THE STATE OF THE CLOSED CONTACTS, TO NORMALLY-OPEN; AND THE OPEN CONTACTS TO NORMALLY-CLOSED. Simultaneously, the three rockers disconnect the AC generator terminals A3, B3, and C3 from the AC generator contactor output terminals A2, B2, and C2.

b. The three-phase, 115/200 VAC, 400 Hz, AC generator output is removed from the AC generator terminals A3, B3, and C3 and disconnected from the open rockers of the AC generator contactor output terminals, A2, B2, and C2.

c. The three-phase, 115/200 VAC, 400 Hz from AC generator contactor output terminals, A2, B2, and C2 is disconnected from the AC essential bus and the bus tie terminals A1, B1, and C1, of the other system's bus tie relay.

d. The AC essential bus power is REMOVED.

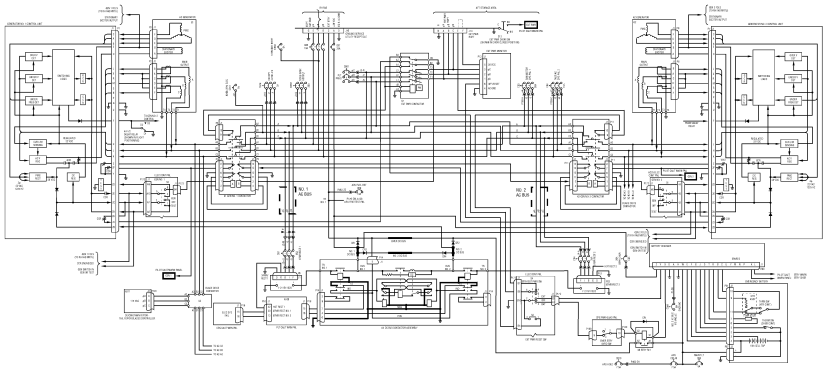
e. Ground remains applied to P5, pin 12.

f. Ground from J1, pin 12, is applied to the normally-closed (coil A) contacts of the bus tie relay.

g. Ground remains connected across the normally-closed (coil A) contacts of the bus tie relay and is applied to J1, pin 11.

h. Ground from P5, pin 11, is applied to P5, pin 2.

AH-64A ELECTRICAL SYSTEM SCHEMATIC



09-94-06

NOTES

i. Ground from J1, pin 2 remains applied to the control end of the generator contactor relay (coil A).

3. Closing the external power interlock

a. The de-energized generator contactor relay, closes the (external power interlock) contacts, that are connected to J1/P5, pins 9 and 10. This closes part of the external power interlock circuit and will allow the application of external power to the helicopter if ALL the other interlocks are closed.

4. Closing the bus-tie interlock

a. Ground is applied to P5, pin 6.

b. Ground from J1, pin 6, is applied to the normally-closed (coil B) contacts of the generator contactor relay.

c. Ground is connected across the normally-closed (coil B) contacts of the generator contactor relay to J1, pin 5.

d. Ground from P5, pin 5, is applied to P5, pin 4.

e. Ground from J1, pin 4, is applied to the control end of the bus tie relay (coil B).

f. The bus tie interlock ground to the control end of the bus tie relay (coil B), allowing it to energize during bus tie operation.

5. Illuminating the GEN caution light

a. Ground is applied to P1, pin Y, of the GCU.

b. Ground from J1, pin Y, is applied to the normally-closed (Gen caution light) contacts of the CCR.

c. Ground is connected across the normally-closed (Gen caution light) contacts of the CCR relay and is applied to J1, pin Z.

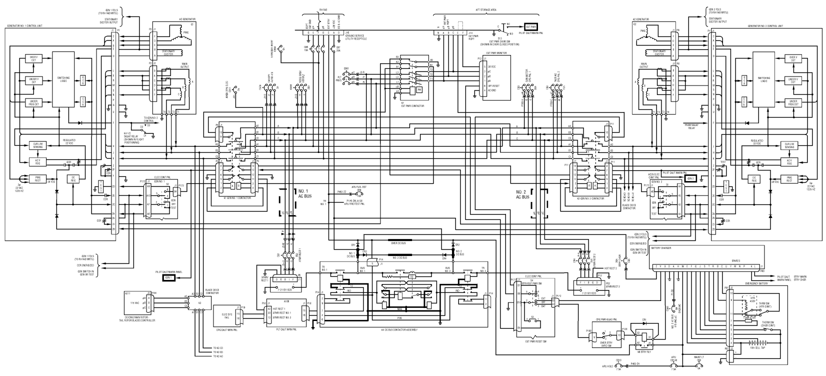
d. Ground from J1, pin Y, is also applied to the normally-closed contacts of the TEST relay.

e. Ground is connected across the normally-closed contacts of the TEST relay and is applied to J1, pin Z.

f. Ground from P1, pin Z, is applied to the AC generator contactor P5, pin 8.

g. Ground from J1, pin 8, is applied to the normally-closed (Gen caution light) contacts of the generator contactor relay.

AH-64A ELECTRICAL SYSTEM SCHEMATIC



09-94-06

NOTES

h. The ground is connected the across the normally-closed (Gen caution light) contacts of the generator contactor relay to J1, pin 7.

i. Ground is applied from P5, pin 7, to the GEN caution light, causing the light to illuminate.

P. Bus tie relay (coil B) energized operation, initial conditions

1. Both system's AC generator switches are in the GEN position.

2. No. 2 system

a. The No. 2 AC generator is operating normally.

b. The No. 2 GCU GCR and CCR relays are energized.

c. Three-phase, 115/200 VAC, 400 Hz output from the No. 2 AC generator is applied to the AC generator terminals, A3, B3, and C3 of the No. 2 AC generator contactor.

d. Three-phase, 115/200 VAC, 400 Hz is connected across the AC generator contactor output terminals, A2, B2, and C2 of the No. 2 AC generator contactor.

e. Three-phase, 115/200 VAC, 400 Hz is applied to the No. 2 AC essential bus AND THE No. 1 AC GENERATOR CONTACTOR bus tie terminals, A1, B1 and C1.

f. The No. 2 bus relay is de-energized, because bus tie voltage is not available from the No. 2 GCU's, open CCR (coil B) contacts.

3. No. 1 system

a. The No. 1 AC generator is operating abnormally.

b. The No. 1 GCU GCR and CCR relays are de-energized.

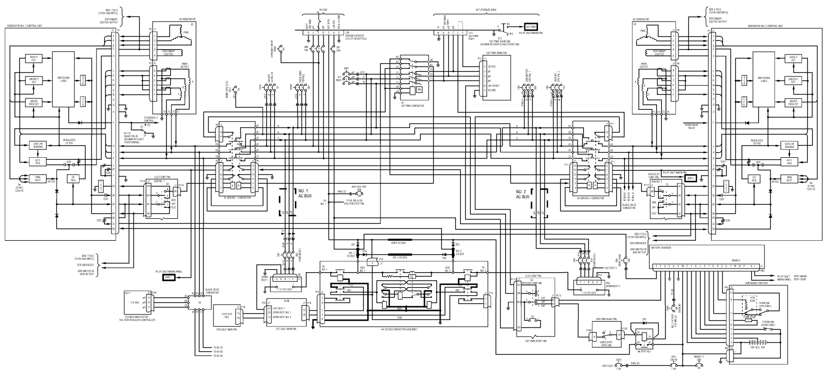
c. Three-phase, 115/200 VAC, 400 Hz output from the No. 1 AC generator is removed from the AC generator terminals, A3, B3, and C3 of the No. 1 AC generator contactor.

d. Three-phase, 115/200 VAC, 400 Hz is removed from the AC generator contactor output terminals, A2, B2, and C2 of the No. 1 AC generator contactor.

e. Three-phase, 115/200 VAC, 400 Hz is removed from the No. 1 AC essential bus.

f. The No. 1 bus relay will energize, because bus tie voltage is available from the GCU's, normally-closed CCR (coil B) contacts.

AH-64A ELECTRICAL SYSTEM SCHEMATIC



09-94-06

NOTES

Q. Bus tie relay (coil B) energized

1. Energizing the No. 1 system bus-tie relay (coil B)

   a. Ground is applied to P5, pin 6.

   b. Ground from J1, pin 6, is applied to the normally-closed (coil B) contacts of the generator contactor relay.

   c. The normally-closed (coil B) contacts of the generator contactor relay connects ground from J1, pin 5.

   d. Ground is applied to P5, pin 5, and P5, pin 4.

   e. Ground is applied to J1, pin 4, the control end of the bus tie relay (coil B).

   f. 28 VDC from the No. 2 system's DC essential bus is applied to the No. 1 system's GCU P1, pin b. RECTIFIED PMG DC VOLTAGE (28 VDC) from the No. 1 GCU may not be available if a PMG circuit or RECTIFIER circuit fault exists.

   g. 28 VDC from J1, pin b, is applied to the isolation diode.

   h. 28 VDC from the isolation diode is applied to J1, pin c.

   i. 28 VDC from J1, pin c, is applied to P1, pin k.

   j. 28 VDC from J1, pin k, is applied to the normally-closed (coil B) contacts of the CCR.

   k. 28 VDC is connected across the normally-closed (coil B) contacts of the CCR and is applied to J1, pin j.

   l. 28 VDC from P1, pin j, is applied to A3 and A2, the normally-closed (coil B) contacts of the external power contactor.

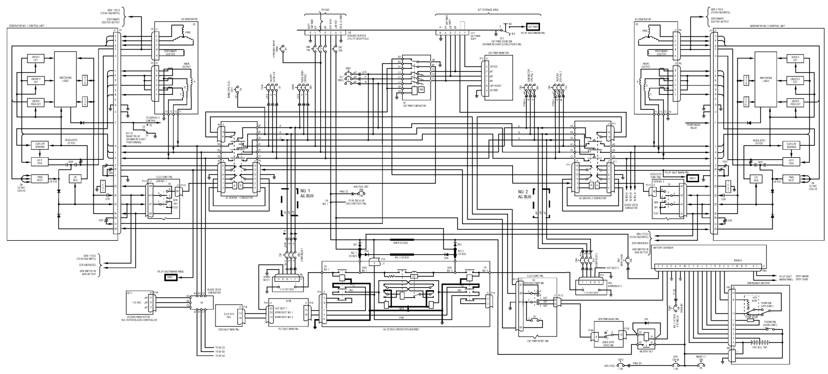
   m. 28 VDC is connected across A3 and A2, the normally-closed (coil B) contacts of the external power contactor and is applied to P5, pin 3, of the AC generator contactor.

   n. 28 VDC from J1, pin 3, is applied to the supply end of the bus tie relay (coil B).

2. Connecting the No. 1 AC essential bus to the bus tie

   a. The No. 1 bus tie relay (coil B) energizes.

AH-64A ELECTRICAL SYSTEM SCHEMATIC



09-94-06

NOTES

b. The Bus tie relay (coil B), energizes CHANGING THE STATE OF THE NORMALLY-OPEN CONTACTS, TO CLOSED; AND THE NORMALLY-CLOSED CONTACTS TO OPEN. Simultaneously, the three rockers connect the bus tie terminals A1, B1, and C1 to the AC generator contactor output terminals A2, B2, and C2.

c. The three-phase, 115/200 VAC, 400 Hz, FROM THE No. 2 AC ESSENTIAL BUS is applied to the No. 1 AC generator contactor bus tie terminals A1, B1, and C1, and is connected across the closed rockers to the AC generator contactor output terminals, A2, B2, and C2.

d. The No. 2 AC ESSENTIAL BUS, three-phase, 115/200 VAC, 400 Hz, from No. 1 AC generator contactor output terminals, A2, B2, and C2 is applied to the No. 1 AC essential bus.

e. The No. 1 AC essential bus now has power APPLIED from the No. 2 AC essential bus. BOTH AC essential buses are then POWERED BY the No. 2 AC GENERATOR.

3. Opening the No. 1 generator contactor relay (coil A) interlock

a. Ground is applied to P5, pin 12.

b. Ground from J1, pin 12, is applied to the open (coil A) contacts of the bus tie relay.

c. Ground is disconnected from J1, pin 5, by the open (coil A) contacts of the bus tie relay.

d. Ground is removed from P5, pin 5, and P5, pin 4.

e. Ground is removed from J1, pin 4, and the control end of the generator contactor relay (coil A).

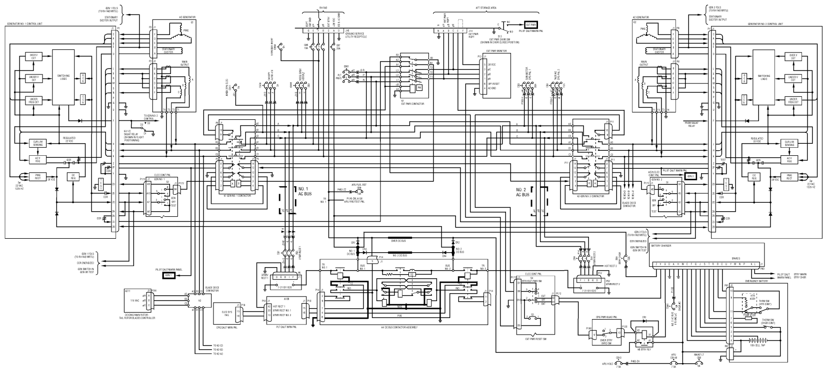
f. Removing the ground from the control end of the generator contactor relay (coil A) prevents it from energizing during bus tie operation.

4. Bus tie during a failure of the No. 2 system is similar, except that ground to the control end of the No. 2 generator contactor relay (coil A) is opened via the open (coil A) contacts of the No. 2 bus tie relay AND the (coil A) contacts of the external power contactor.

5. Opening the No. 2 system's bus tie interlock

a. The open (coil B) contacts of the No. 1 system bus tie relay disconnects RECTIFIED PMG DC VOLTAGE (28 VDC) from the supply end of the No. 2 system's bus tie relay (coil B), preventing the No. 2 system's bus tie relay (coil B) from energizing AND DISCONNECTING BOTH AC ESSENTIAL BUSES FROM THE No. 2 AC GENERATOR.

AH-64A ELECTRICAL SYSTEM SCHEMATIC



09-94-06

NOTES

b. This prevents loss of power from both AC essential and DC essential buses to the helicopter systems.

R. Bus tie relay (coil B) de-energized operation, initial conditions

1. The No. 2 system's AC generator switch is in the GEN position.

2. No. 2 system

   a. The No. 2 AC generator is operating normally.

   b. The No. 2 GCU, GCR, and CCR relays are energized.

   c. Three-phase, 115/200 VAC, 400 Hz output from the No. 2 AC generator is applied to the AC generator terminals, A3, B3, and C3 of the No. 2 AC generator contactor.

   d. Three-phase, 115/200 VAC, 400 Hz is connected to the No. 2 AC essential bus AND No. 1 AC GENERATOR CONTACTOR's bus tie terminals A1, B1, and C1.

   e. The No. 2 bus relay is de-energized because bus tie voltage is not available from the GCU's open CCR (coil B) contacts.

3. The No. 1 system's AC generator switch is in the OFF/RESET position.

4. No. 1 system

   a. The No. 1 AC generator is not producing an output.

   b. The No. 1 GCU's GCR, and CCR relays are de-energized.

   c. Three-phase, 115/200 VAC, 400 Hz output from the No. 1 AC generator is removed from the AC generator terminals, A3, B3, and C3 of the AC generator contactor.

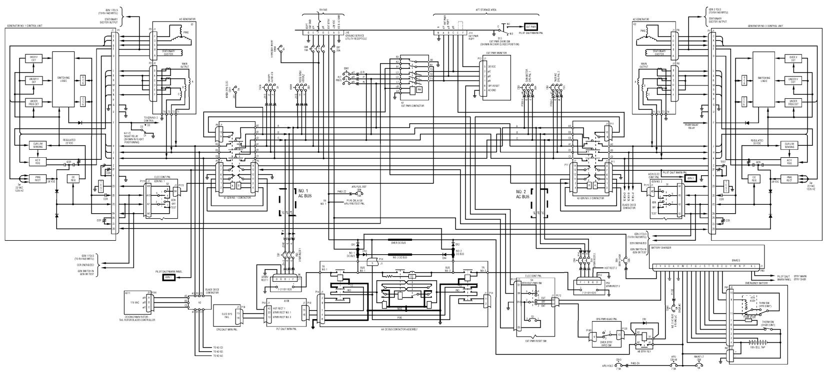
   d. Three-phase, 115/200 VAC, 400 Hz is removed from the AC generator contactor output terminals A2, B2, and C2 of the No. 1 AC generator contactor.

   e. Three-phase, 115/200 VAC, 400 Hz is removed from the No. 1 AC essential bus.

   f. The No. 1 bus relay will energize because bus tie voltage is available from the GCU's normally-closed CCR (coil B) contacts.

5. The No. 1 AC essential bus is tied to the No. 2 AC essential bus. BOTH AC essential buses are then POWERED BY the No. 2 AC GENERATOR.

AH-64A ELECTRICAL SYSTEM SCHEMATIC



09-94-06

NOTES

S. Bus tie relay (coil B) de-energized

1. De-energizing the No. 1 system bus-tie relay (coil B)

a. Placing the AC generator switch to the GEN position connects the RECTIFIED PMG DC VOLTAGE (28 VDC) across the lower section of the AC generator switch and applies it to P1, pin a, of the GCU.

b. The GCU fault summing logic circuit detects that the RECTIFIED PMG DC VOLTAGE (28 VDC) has been applied by the AC generator switch.

c. The GCU activates the AC generator, the GCR, and checks it for faults.

d. The GCU energizes the CCR if the AC generator is operating properly.

e. The closed (coil A) contacts of the CCR apply RECTIFIED PMG DC VOLTAGE (28 VDC) to J1, pin e.

f. The RECTIFIED PMG DC VOLTAGE (28 VDC) from P1, pin e, is applied to the upper section of the AC generator switch common terminal, and connected through the closed switch contacts to the GEN terminal.

g. The RECTIFIED PMG DC VOLTAGE (28 VDC) from the AC generator switch GEN terminal, is applied to P5/J1 pin 1 of the AC generator contactor and to the supply end of the generator contactor relay (coil A).

h. The generator contactor relay (coil A) will not energize because the generator contactor relay (coil A) interlock circuit is held open by the energized bus tie relay (coil A) contacts.

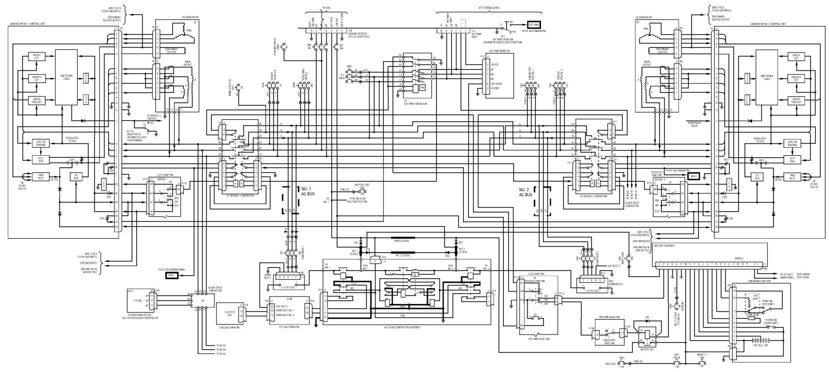
i. The open (coil B) contacts of the CCR removes the RECTIFIED PMG DC VOLTAGE (28 VDC) from J1/P1, pin j.

j. RECTIFIED PMG DC VOLTAGE (28 VDC) is removed from A3 and A2, the normally-closed (coil B) contacts of the external power contactor.

k. RECTIFIED PMG DC VOLTAGE (28 VDC) is removed from P5, pin 3, of the AC generator contactor.

l. RECTIFIED PMG DC VOLTAGE (28 VDC) is removed from J1, pin 3, and the supply end of the bus tie relay (coil B).

AH-64A ELECTRICAL SYSTEM SCHEMATIC



09-94-06

NOTES

2. Disconnecting the No. 1 AC essential bus from the bus tie

   a. The No. 1 bus tie relay (coil B) de-energizes.

   b. The bus tie relay (coil B), de-energizes CHANGING THE STATE OF THE CLOSED CONTACTS, TO NORMALLY-OPEN ; AND THE OPEN CONTACTS TO NORMALLY-CLOSED. Simultaneously, the three rockers disconnect the bus tie terminals A1, B1, and C1 from the AC generator contactor output terminals A2, B2, and C2.

   c. The No. 2 AC ESSENTIAL BUS, three-phase, 115/200 VAC, 400 Hz, applied to the No. 1 AC generator contactor bus tie terminals A1, B1, and C1, IS DISCONNECTED by the open rockers of the AC generator contactor output terminals A2, B2, and C2.

   d. The No. 2 AC ESSENTIAL BUS, three-phase, 115/200 VAC, 400 Hz, is removed from No. 1 AC generator contactor output terminals A2, B2, C2 and the No. 1 AC essential bus.

   e. The No. 1 AC essential bus now has power REMOVED.

   f. The No. 2 AC essential bus continues to be powered by the No. 2 AC generator.

3. Closing the No. 1 generator contactor relay (coil A) interlock

   a. Ground is applied to P5, pin 12.

   b. Ground from J1, pin 12, is applied to the normally-closed (coil A) contacts of the bus tie relay.

   c. Ground is connected across the normally-closed (coil B) contacts of the bus tie relay to J1, pin 5 .

   d. Ground from P5, pin 5, is applied to P5, pin 4.

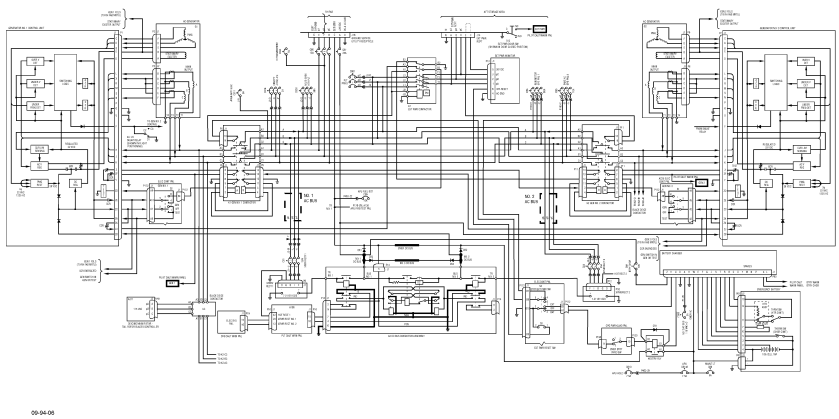
   e. Ground from J1, pin 4, is applied to the control end of the generator contactor relay (coil A).

4. Connecting the AC generator to the AC essential bus

   a. RECTIFIED PMG DC VOLTAGE (28 VDC) is already applied to the supply end of the generator contactor relay (coil A) from the closed upper contacts of the AC generator switch.

   b. The generator contactor relay (coil A) energizes CHANGING THE STATE OF THE NORMALLY-OPEN CONTACTS, TO CLOSED; AND THE NORMALLY-CLOSED CONTACTS TO OPEN.

AH-64A ELECTRICAL SYSTEM SCHEMATIC



NOTES

c. The three-phase, 115/200 VAC, 400 Hz from AC generator contactor output terminals A2, B2, and C2 is applied to the AC essential bus and the bus tie terminals A1, B1, and C1, of the other system's bus tie relay.

d. The AC essential bus now has power APPLIED.

5. Opening the No. 1 system's bus tie interlock

a. Ground is applied to P5, pin 6.

b. Ground from J1, pin 6, is applied to the open (coil B) contacts of the generator contactor relay.

c. The open (coil B) contacts of the generator contactor relay remove ground from J1, pin 5.

d. Ground is removed from P5, pin 5, and P5, pin 4.

e. Ground is removed from J1, pin 4, and the control end of the bus tie relay (coil B).

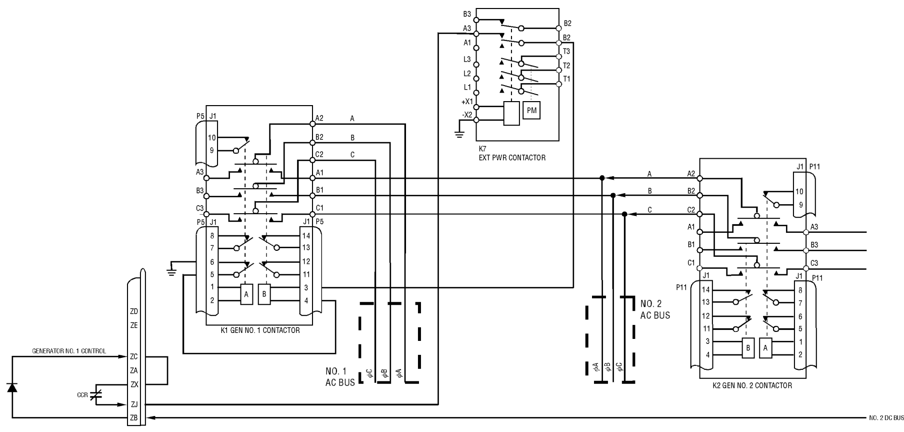
f. This prevents the AC generator contactor bus tie relay (coil B) from energizing whenever the generator contactor relay (coil A) is energized.

6. Removing bus tie if the No. 1 system is operating and the No. 2 system is brought on line is similar, except that ground to the control end of the No. 2 generator contactor relay (coil A) is opened via the open (coil A) contacts of the No. 2 bus tie relay and the (coil A) contacts of the external power contactor.

7. Closing the No. 2 system's bus tie interlock

a. The closed (coil B) contacts of the No. 1 system's bus tie relay connects RECTIFIED PMG DC VOLTAGE (28 VDC) to the supply end of the No. 2 system's bus tie relay (coil B), allowing the No. 2 system's bus tie relay (coil B) to energize if a failure occurs in the No. 2 system.

AC GENERATOR 1 OR GCU 1 FAILURE



09-94-33

NOTES

T. AC generator 1 failure

1. When AC generator No. 1 fails, GCU No. 1 de-energizes it's CCR which removes RECTIFIED PMG DC VOLTAGE (28 VDC), and/or DC essential bus No.2 (28 VDC), from P1, pin e, and the upper section of the AC generator switch.

2. The generator contactor relay (coil A) No. 1 has RECTIFIED PMG DC VOLTAGE (28 VDC), and/or DC essential bus No.2 (28 VDC), interrupted by the normally-open (coil A) contacts of the CCR.

3. The generator contactor relay (coil A) No. 1 de-energizes, disconnecting the No. 1 AC generator defective AC generator's three-phase, 115/200 VAC, 400 Hz output from its bus, through the normally open rockers of the AC generator terminals A3, B3, and C3, and the AC generator contactor output terminals, A2, B2, and C2.

4. The normally-closed (GEN caution light) contacts of generator contactor relay No. 1 provides two grounds, one from the de-energized (GEN caution light) contacts of the CCR and the other from the TEST relay, to illuminate the GEN 1 caution light via P/J 1, pins 7 and 8 of the AC generator contactor.

5. The lower section of the No. 1 generator control switch still has DC essential bus No. 2 (28 VDC), via the isolation diodes, regardless of the AC generator No. 1's PMG output. This allows bus tie operation if the AC generator No. 1's PMG circuit fails.

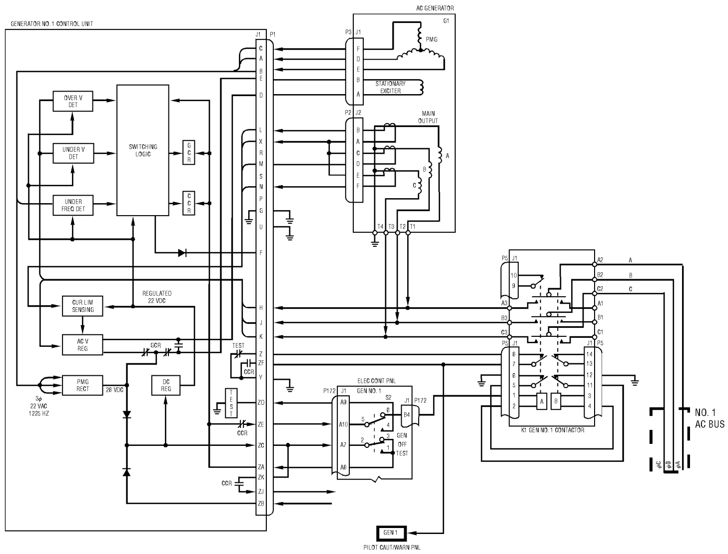
6. RECTIFIED PMG DC VOLTAGE (28 VDC), and/or DC essential bus No. 2 (28 VDC), is then applied to bus tie relay (coil B) No. 1, via the normally closed (coil B) contacts of the external power contactor.

7. Ground is connected via P/J1, pins 5 and 6, of the normally-closed (coil B) contacts of the generator contactor relay No. 1.

8. The bus tie relay (coil B) No. 1 energizes and connects AC essential bus No. 2 to AC essential bus No. 1, and locks out the generator contactor relay No. 1 and bus tie relay No. 2.

9. The AC generator No. 2 now provides three-phase, 115/200 VAC, 400 Hz power to both AC essential buses.

GENERATOR CONTACTOR RELAY 1 FAILURE



09-94-34

NOTES

U. Generator Contactor Relay Failure

1. A generator contactor relay (coil A) failure may be the result of either a shorted or open coil windings. A defective switch or open control wire could cause the same indications. Voltage and/or continuity checks will be necessary to isolate the problem.

2. If the windings short, the magnetic field resulting from current flow through the winding will be weak and the relay will de-energize. The shorted winding will usually burn "open" due to the decreased DC resistance and the resulting increased current flow.

3. If the winding is open, or opens as the result of a short, the magnetic field will cease to exist because no current can flow in the circuit to sustain the magnetic field and the relay will de-energize.

4. In either case, when the generator contactor relay (coil A) de-energizes, it disconnects the AC generator's three-phase, 115/200 VAC, 400 Hz output from its bus through the normally open rockers of the AC generator terminals A3, B3, C3, and the AC generator contactor output terminals A2, B2, and C2.

5. The GCU does not sense a fault because the output of the generator is still correct, the GCU and CCR relays remain energized.

6. The energized CCR (GEN caution light) contacts are open, removing ground from the GEN 1 caution light.

7. The normally-closed (GEN caution light) contacts of generator contactor relay No. 1 provides a ground, from the de-energized (GEN caution light) contacts of the TEST relay, to the GEN 1 caution light, via P/J 1, pins 7 and 8, causing it to ILLUMINATE.

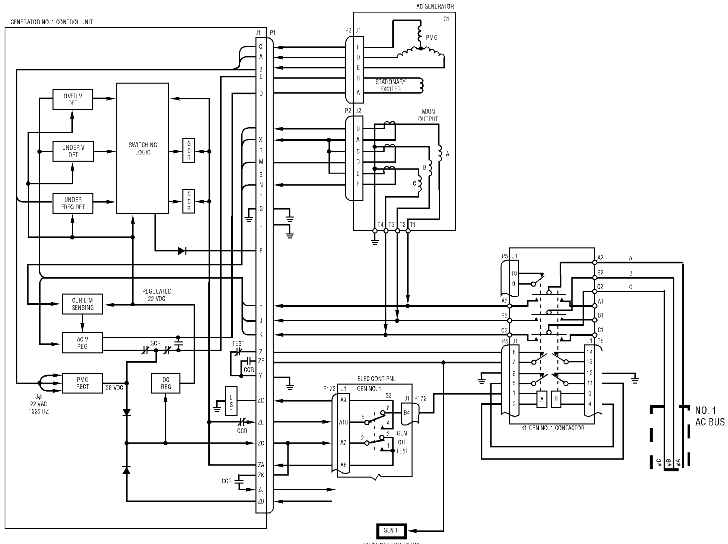
8. With the CCR still energized, the open (coil B) contacts of the CCR prevents RECTIFIED PMG DC VOLTAGE (28 VDC), from being connected to J/P1, pin k, the external power contactor's normally-closed (coil B) contacts A2 and A3, P5/J1, pin 3, and the bus tie relay (coil B).

9. This prevents the bus tie from energizing and the AC essential bus No. 1 is lost.

10. To regain AC essential bus No. 1, the No. 1 AC generator control switch must be placed to the OFF/RESET position. This de-energizes the No. 1 GCU's CCR relay.

11. The RECTIFIED PMG DC VOLTAGE (28 VDC), and /or DC essential bus No.2 (28 VDC), via the normally-closed contacts of the CCR is connected to J/P1, pin k, the external power contactor's normally-closed (coil B) contacts A2 and A3, P5/J1, pin 3, and the bus tie relay (coil B), causing it to energize.

GENERATOR CONTACTOR RELAY 1 FAILURE



09-94-34

NOTES

12. The energized bus tie relay No. 1 connects AC essential bus No. 2 to AC essential bus No. 1, and locks out the generator contactor relay No. 1 and bus tie relay No. 2.

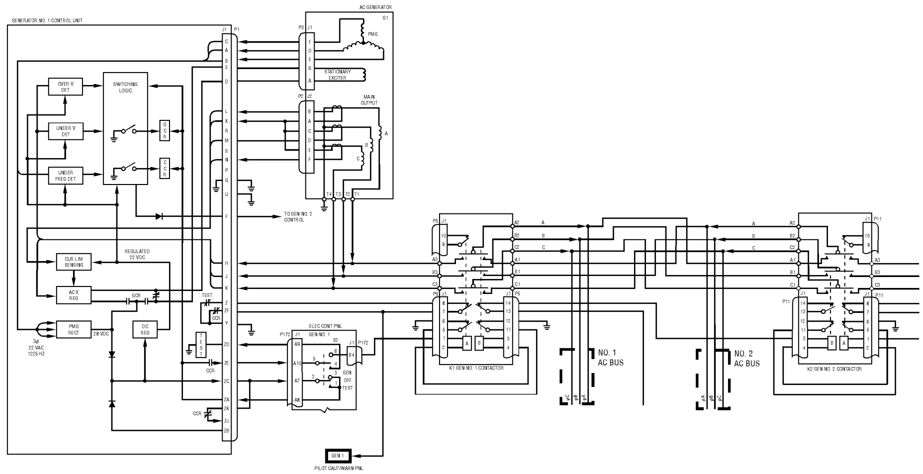
13. The AC generator No. 2 now provides three-phase, 115/200 VAC, 400 Hz power to both AC essential buses.

14. This discrepancy can be verified by

    a. Observing the GEN caution light illuminated with AC generator switch in the GEN position.

    b. Observing the GEN caution light not illuminated with AC generator switch in the TEST position.

BUS TIE 1 RELAY FAILURE



09-94-35

NOTES

V. Bus Tie 1 Relay Failure

1. A bus tie relay failure is similar to generator contactor relay failure.

2. With a defective bus tie relay No. 1

   a. The AC generator No. 2 cannot supply power to the AC essential bus No. 1, and AC essential bus No. 1 power is lost.

   b. The AC generator No. 1 can supply power to both AC essential bus No. 1 and 2.

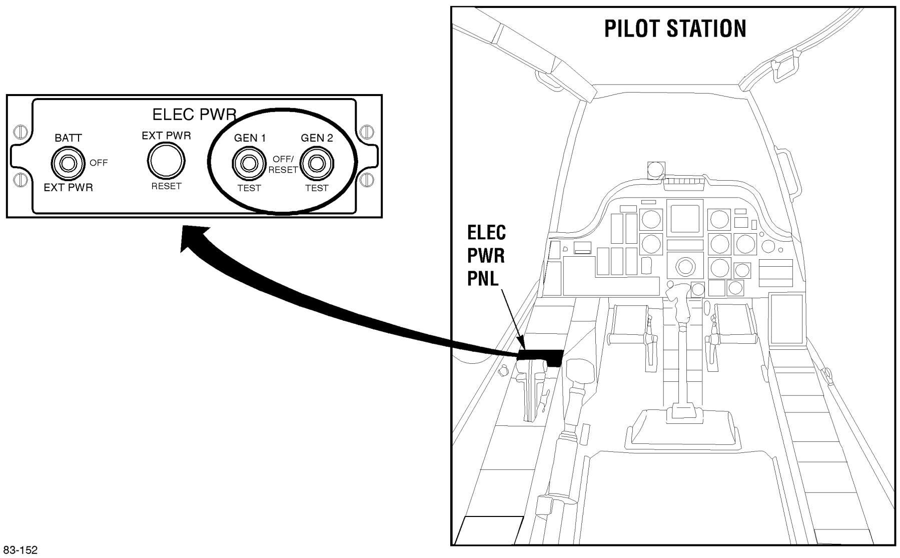
3. With a defective bus tie relay No. 2

   a. The AC generator No. 1 cannot supply power to the AC essential bus No. 2, and AC essential bus No. 2 power is lost.

   b. The AC generator No. 2 can supply power to the AC essential bus No. 1 and 2.

   c. AC essential bus No. 2 cannot be powered during helicopter external power operations.

PILOTs ELEC PWR CONTROL PANEL



83-152

NOTES

W. GEN 1 and GEN 2 switch characteristics

1. Provide operational control for the AC generators.

2. Mounted on the electrical power control panel in the pilot's left console.

3. Double-pole, double-throw, three-position toggle switch.

X. GEN 1 and GEN 2 switch operation

1. GEN position brings the respective AC generator on line.

   a. Terminals 5 and 6 energize the generator contactor relay (coil A) by completing the circuit and providing RECTIFIED PMG DC VOLTAGE (28 VDC) from the GCU, CCR closed (coil A) contacts. Ground is provided by the normally-closed (coil A) contacts of the bus tie relay.

   b. Terminals 2 and 3 connect RECTIFIED PMG DC VOLTAGE (28 VDC) to the GCU to initiate GCU operations.

2. OFF/RESET position disconnects the AC generator from the bus and resets the GCU fault sensing circuits.

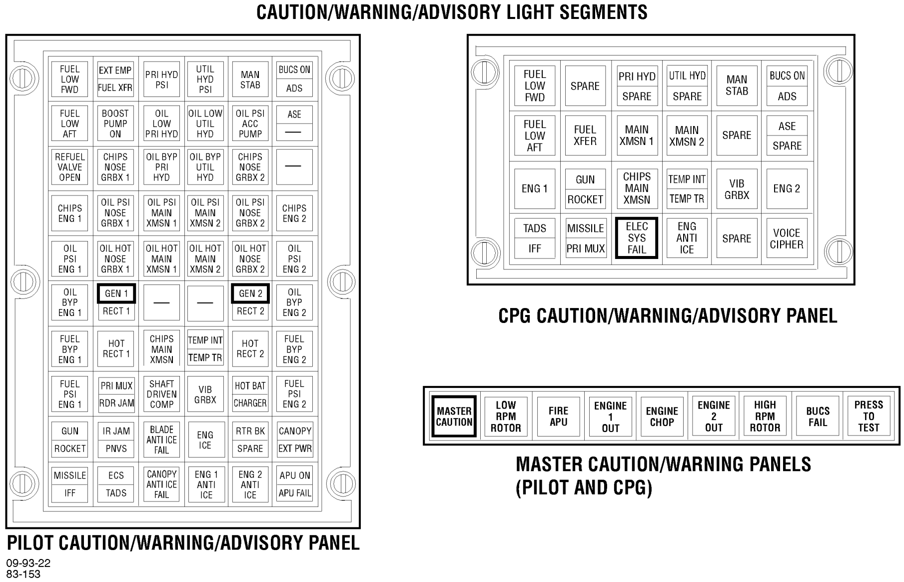
3. TEST position is a momentary contact position that permits the AC generator exciter output to be tested for faults and function, without energizing the AC generator contactor (coil A) and connecting the AC generator to its AC essential bus.

   a. Terminals 5 and 4 energize the TEST relay by completing the circuit, via the normally-closed contacts of the generator contactor relay, and providing RECTIFIED PMG DC VOLTAGE (28 VDC) from the GCU, CCR closed (coil A) contacts.

   b. Ground is connected directly to the TEST relay inside the GCU.

   c. The GEN caution light will extinguish.

AC ELECTRICAL POWER SYSTEM CAUTION LIGHTS



NOTES

Y. Caution/Warning Lights

1. GEN 1 and GEN 2 caution light

a. When extinguished

(1) Advises the pilot that the AC generator is operating normally and is on-line. AC generator switch is in the GEN position.

(2) Advises the pilot that the AC generator is operating normally and is off-line. AC generator switch is in the TEST position.

b. When illuminated

(1) Advises the pilot that an AC generator is off-line. AC generator switch is in the OFF/RESET position.

(2) Advises the pilot that an AC generator is off-line due to an AC generator fault. AC generator switch is in the GEN of TEST positions.

c. Mounted on the pilot's caution/warning/advisory panel.

d. Description

(1) Amber-colored light

(2) Operation is controlled by a ground from either the CCR normally-closed (GEN caution light) contacts from GCU J1, pin f, or the normally-closed (GEN caution light) contacts of the TEST relay from GCU J1, pin Z, via the AC generator contactor relay J1, pins 7 and 8.

2. ELEC SYS FAIL warning light

a. When illuminated, advises the CPG that both generators and both T/Rs have failed. The battery is operating the DC emergency bus.

b. Located on the CPG caution/warning/advisory panel.

c. Is controlled by the pilot crewstation caution warning panel.

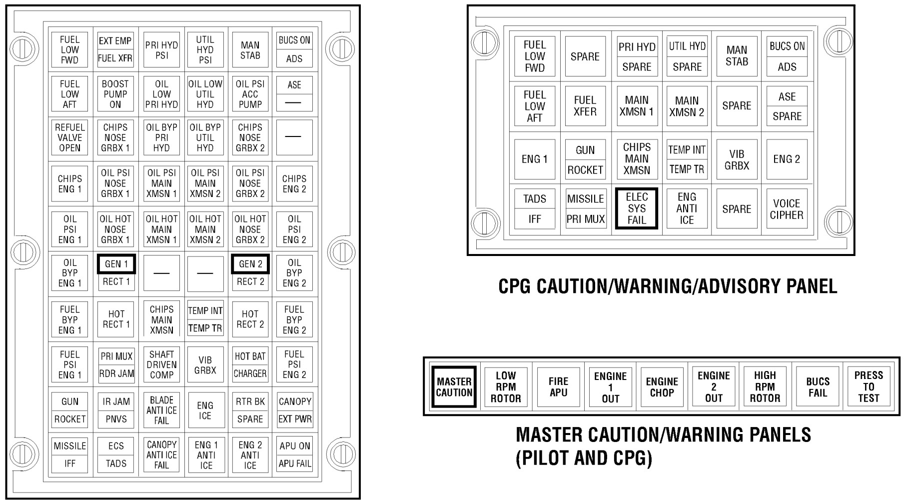
d. Description

(1) Red-colored light

(2) Illuminates if both generators and both T/Rs fail.

AC ELECTRICAL POWER SYSTEM CAUTION LIGHTS

CAUTION/WARNING/ADVISORY LIGHT SEGMENTS



CPG CAUTION/WARNING/ADVISORY PANEL

MASTER CAUTION/WARNING PANELS (PILOT AND CPG)

PILOT CAUTION/WARNING/ADVISORY PANEL

09-93-22
83-153

NOTES

3. Master caution/warning light

   a. Advises the pilot or CPG that a caution/warning/advisory panel light has illuminated.

   b. Located on the master caution/warning panel in each crewstation.

   c. Description

      (1) Amber in color

      (2) Flashes when any caution/warning/advisory panel light comes on.

4. The generators and GCUs are tested by the FD/LS when the initiated FD/LS 18 maintenance mode test is selected.

   a. P1, pin e, and P7, pin e, are RECTIFIED PMG DC VOLTAGE (28 VDC) signals for generator 1 and 2, respectively. These monitored points are connected to the left and right forward avionics bay multiplex remote terminal unit type I, respectively.

   b. P1, pin a, and P7, pin a are the monitor points for the generator control switch GEN and TEST positions for generator 1 and 2. These monitored points are connected to the left and right forward avionics bay multiplex remote terminal unit type I.

   c. P1, pin E, and P7, pin E, is the GCU stationary exciter control winding output for generator 1 and 2. These monitored points are connected to the left and right forward avionics bay multiplex remote terminal unit type I.