Chapter 11

AIRCRAFT ELECTRICAL SYSTEMS

Small aircraft often use DC-only systems, mainly because of simplicity, cost, and weight limitations. Large airline aircraft use high quality constant-frequency systems, which are very reliable and provide excellent services in support of modern computers, communication equipment and aircraft systems. Medium sized aircraft, particularly turboprop types, without the electrical power demands of large jets, often use a combination of DC, CFAC and ACW systems to provide suitable electrical power for those aircraft.

DC SYSTEMS OR AC SYSTEMS

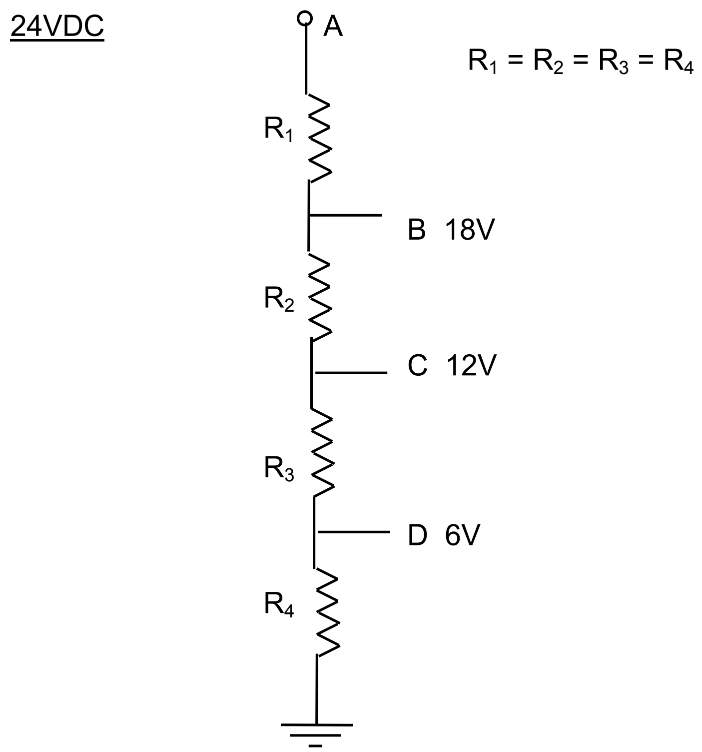
Direct current power is useful and will be required somewhere in every electrical system. To reverse direction of electric motors, the polarity of the applied voltage can be switched using a relay. Battery charging is a DC process and any emergency system will have DC devices, because of the importance of batteries as the last resort supply. Direct current is a very acceptable form of energy for light aircraft and relatively low powered systems.

Alternating current requires significantly more effort and cost to produce in an aircraft environment, when compared with DC. However, if the aircraft cost/size relationship can support the production of AC, then there are some significant advantages of AC systems when compared with DC systems.

Voltage Conversion

To change one AC voltage to another AC voltage, a transformer is used. If then, a DC voltage is required, semi-conductor diodes are used. The energy consumed by these circuits is minute and relates to leakage only. When equipment is connected, almost all the current available (capacity) from the supply is available, on demand, to that equipment. A function of current flow in AC circuits is impedance. This means we can control current by means other than changing circuit resistance, as current flow through resistance, produces heat as a by-product, which can cause further problems.

Conversion of one DC voltage to another appears very simple, and it is, however the process is very inefficient. When a voltage divider network is used, this is what happens.



DC VOLTAGE DIVIDER NETWORK

The 24VDC is divided equally by the four equal value resistances to produce the voltages as shown. Before any consumer is connected, current must flow from the supply to earth and so energy is already being used. When a consumer is connected to point C, perhaps a 12V radio, the radio resistance is now in parallel with R_3 and R_2. This has the effect of reducing the voltage below 12 volts at point C and consequently less energy is available to the consumer.

If, however, greater amounts of current are required by a consumer, division of current via resistors (voltage divider network) can be made to work. This is achieved by reducing the resistance in the circuit. Unfortunately, this means the circuit will use more power, even when the consumer is off.

A factor affecting circuit reliability occurs when switching large DC currents. The arcing that occurs at relays, contact points and switches is all uni-directional and causes a build up of metal and carbon deposits, which in turn shortens equipment life.

The use of alternating current allows high voltages and currents to be used. The three-phase option also increases current availability and therefore greater power is available to do the work.

The changing nature of AC means that it can be induced across an airgap. Many motors and generators do not require physical contact to transfer power and transformers have no moving parts.

There are two types of AC electrical systems:

- Constant Frequency AC systems, (CFAC), and
- Frequency Wild AC systems (ACW).

CONSTANT FREQUENCY AC GENERATING SYSTEMS (CFAC)

The generators are the heart of any electrical system. They must be reliable and have the combined capacity to provide power for normal services. A brief description of generators and other components commonly used in aircraft electrical systems follows.

The Generator

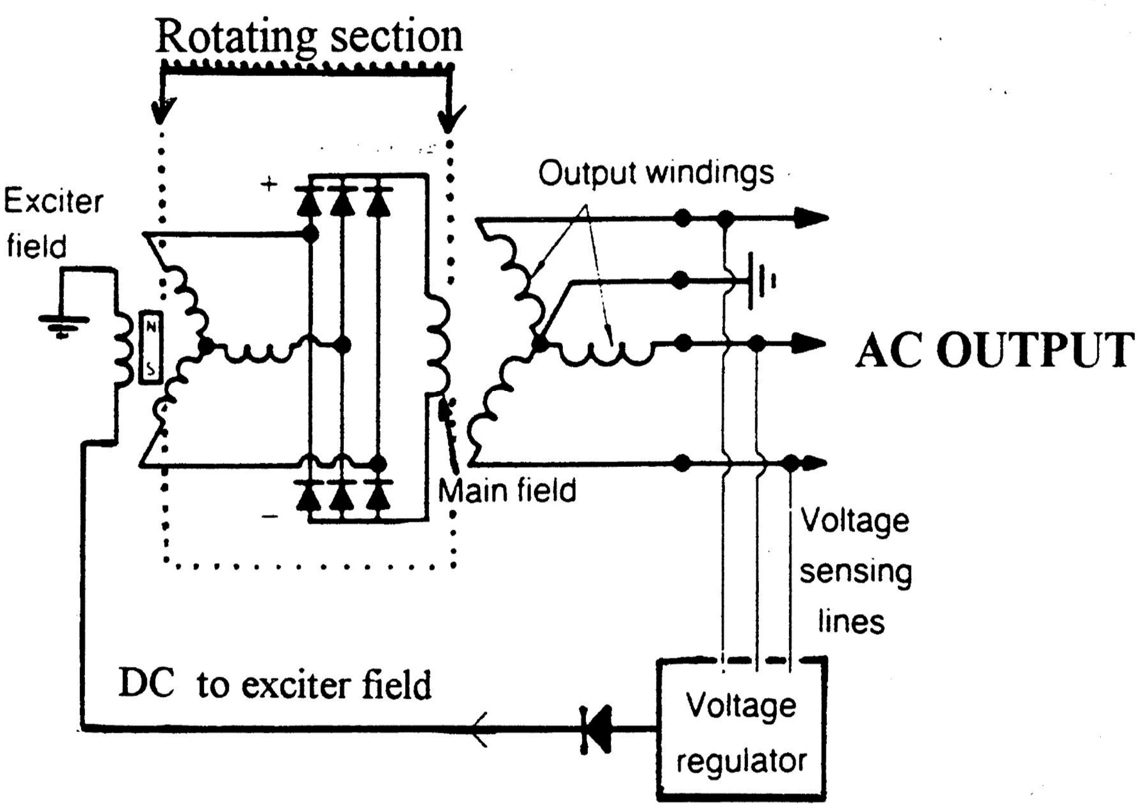
Most modern CFAC generating systems are fitted with brushless AC generators. The generators are initially self excited by a rotating permanent magnet after which excitation is from the generator output.

Generator output is regulated 115 VAC 400 Hz 3∅ and power rated between 20 and 60 kilovolt Amperes (kVA). AC generators on large jet transports can supply up to 90 kVA with ramair cooling, with a short duration capability (5 seconds) of 120kVA.

Generator cooling is necessary and can be by ram air, bleed air or oil. Ram air is used after take-off with augmentation from bleed air during flight at low speeds and bleed air cooling is also used on the ground. Generator temperatures are monitored on an EICAS or ECAM page.

The brushless generator has several advantages over brushed types. No brushes means no physical contact, so no brush wear or arcing occurs and this improves reliability and safety and provides a significant maintenance cost saving.

The three phase AC supply has a significant advantage over single phase by increasing the amount of current available, and therefore power available to consumer equipment. This provides a power benefit but caution in handling 3∅ supplies is required. Connection to phase sensitive equipment like 3∅ motors and transformers is critical. Incorrect phase sequence in a motor would cause that motor to rotate in the opposite direction. Connecting 3∅ transformers and motors in parallel with incorrect phase sequence could cause burn-out.



A BRUSHLESS 3∅ AC GENERATOR

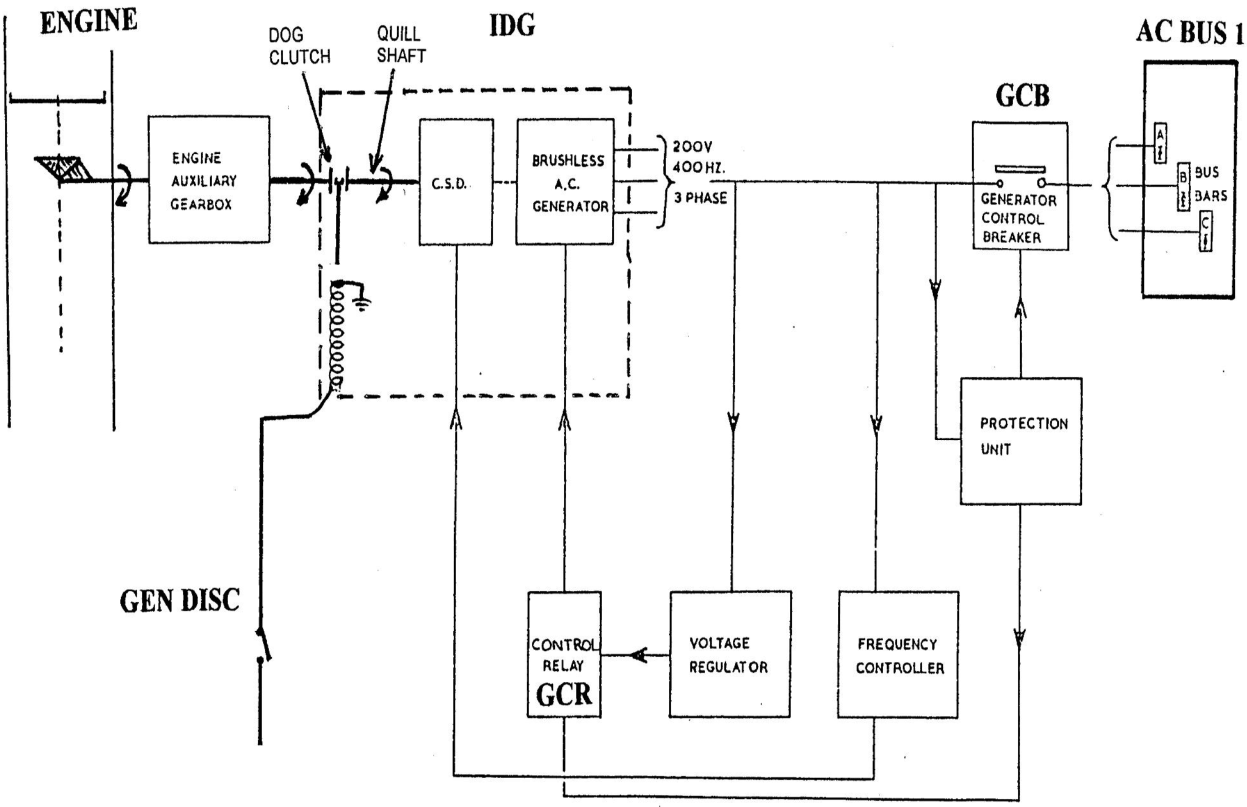
Constant Speed Drive (CSD)

As the output of the generator is required to be at a constant frequency, then its input drive speed must also be constant. A constant speed drive unit is required to convert the varying speed drive from the engine into a constant speed for the generator. Gas turbine engines usually operate between 7,000 and 10,000 RPM.

A hydro-mechanical drive, similar in function to an automotive automatic gear box is the most commonly used. Mechanical governors in the CSD maintain output rotation speed constant, with fine speed adjustments from signals obtained from the frequency controller. The constant speed function of the CSD is similar to that of an aircraft propeller system. The oil system for the CSD is independent of the engine oil system. Oil inlet and outlet temperatures and low oil pressure are monitored and displayed on control panels.

A facility for disconnecting the engine drive from the CSD in the event of a generator or gear box malfunction is provided. Should an electrical fault occur, the circuit breaker system will protect each circuit. However, if the generator overheated or had a mechanical problem, its rotation may need to be stopped before serious damage can occur. Shutting down the engine will never be the first option. A guarded switch provided for the pilot, labeled ‘GEN DISC’, activates a solenoid which pulls a ‘dog clutch’ open, effectively breaking the drive between the engine gearbox and the CSD. Once the generator has been disconnected, it **cannot be reset in flight**.

The CSD is not separate from the generator in modern large jet transport aircraft, but is built into the generator. Boeing calls these units integrated drive generators (IDG), and Airbus sometimes lists the same item as an integrated constant speed drive (ICSD).



THE CONSTANT SPEED DRIVE IN A SYSTEM

Frequency Regulator

The frequency regulator provides regulating signals to the CSD so that the generator output frequency is maintained at 400Hz $\pm$ 4Hz. This device uses a magnetic amplifier and transistorized frequency discriminator circuits, to supply signals to the CSD oil circuit flow control valve.

Voltage Regulator

The voltage regulator maintains a constant output voltage of the generator, irrespective of the electrical load. This is achieved by continual adjustments to the current (DC) flowing in the generator field windings.

Fault Protection Unit

In order to achieve the necessary degree of safety required, a CFAC generating system must include certain protection circuits to continually monitor system performance. Within the protection unit, are transistor logic circuits and controls for the opening or closing of the Generator Control Relay (GCR) and the Generator Control Breaker (GCB), depending on the integrity of the circuit.

System protection is provided for :

- Over voltage
- Under voltage
- Generator over speed
- Generator under speed
- Line to line bus bar faults
- Line to earth bus bar faults.

When the systems are paralleled, discrimination circuits are required to ensure that only the faulty system is disconnected from the bus bar in the event of a generator failure. Interconnections are made between the individual protective units when the generator control breakers and the bus tie breakers are made and that is how the systems are paralleled.

Generator Control Relay (GCR)

When the generator control relay is closed, the generator field excitation circuit from the voltage regulator is completed. When tripped open, the generator is no longer excited and its output is lost. An error signal from the fault protection unit will trip the GCR.

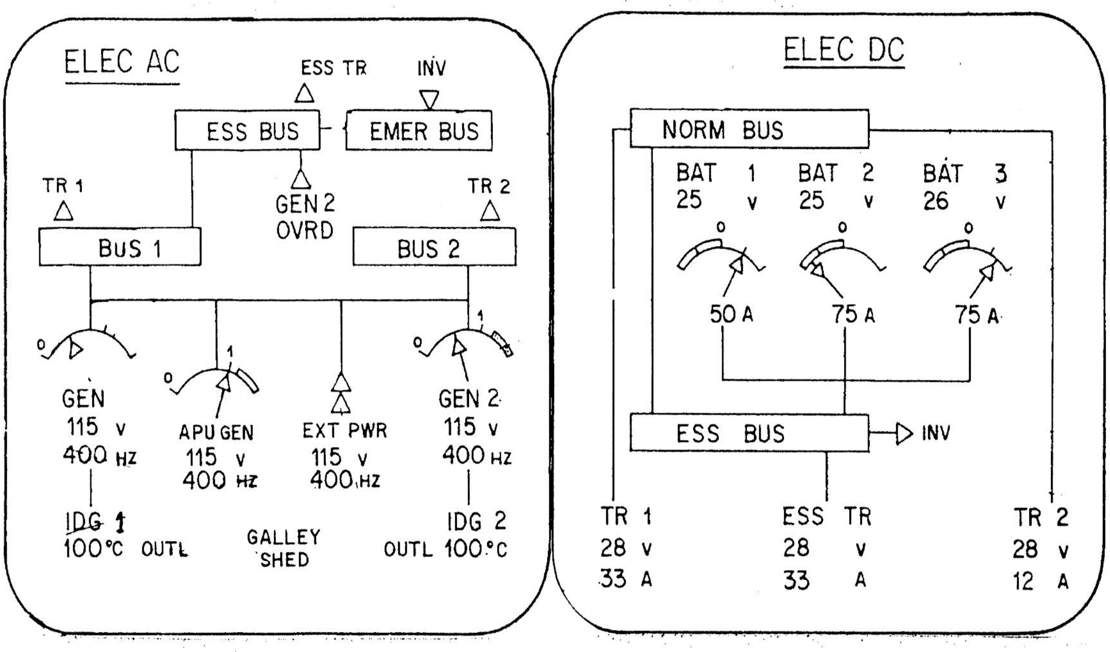
Generator Circuit Breaker (GCB)

Closing a generator circuit breaker connects the generator output voltage to the generator bus bar. Under paralleled conditions the GCB will not close unless voltage, frequency and phase sequence are correct. Closing of the GCB is usually indicated on the control panel by a magnetic in-line indicator or lights. The closure of the GCB bringing a generator 'on line' will automatically disconnect any external power supplies.

Generator Failure Warning Indications

A generator failure warning light which comes 'on' when the associated generator circuit breaker is tripped or the generator fails. The centralized warning system light will show and audio systems will operate.

On older aircraft, one voltmeter and one frequency meter only is provided for a CFAC system. Selection of a particular generating system by means of a multi-position rotary switch, enables the voltage and frequency for the selected generator to be observed. The EICAS or ECAM presents this information on the Electrical System page.



ELECTRICAL SYSTEM PAGES: AIRBUS

Bus Tie Breakers (BTB)

A bus tie breaker connects a generator to its synchronizing bus bar. Control of a BTB is automatic and in its normal position for a parallel system is closed, but disconnects open under fault conditions. The normal condition for the BTB in a split system is open. The BTB will close if one generator fails to provide power for the other system. Visual indications by means of magnetic line indicators on the control panel, centralized warning systems and audio are provided if a fault on the generator system causes the GCB to trip.

Synchronizing Unit

Before two generating systems are paralleled, the generator's phases must be synchronized so that A∅ in generator one must occur at the same time as A∅ in the other. The synchronizing unit ensures that the bus tie breaker cannot be closed until the generators are phase aligned. There are two methods in use :-

- **Manual**. (Lamp Dark Method) A synchronizing lamp on the panel will be out or 'dark' when synchronism is achieved. Operation of the Sync push switch, closes the bus tie breaker.

- **Automatic Control**. The circuit is so designed that the synch--push switch can be pressed, but the bus tie breaker will not close until the systems are "In Phase".

In modern aircraft, when parallel systems are used, synchronizing the phases is fully automatic and the pilot does not have to interfere with the system.

Emergency Power Supplies

Unlike the DC system, batteries cannot be used directly as emergency AC power. Standby AC generator systems, separate from the primary generating systems are driven from either:

(a) a Ram Air Turbine (RAT),
(b) the Auxiliary Power Unit (APU) ,
(c) pneumatic air system, or
(d) the aircraft hydraulic system.

Indirectly, static or rotary inverters, powered from the battery can be used to generate emergency AC power. This is limited to the capacity of the battery.

The **RAT** is a ram air turbine driven generator providing 115 VAC 3∅ 400 Hz. A small door can be open in the fuselage or an air scoop can be physically extended into the slip stream to turn the generator. This an emergency source of AC power for the operation of essential flight services in the event of failure of the main AC generator(s).

If the generator is the type that is pivoted into the slip stream, retraction can only be carried out on the ground. There is a severe drag penalty for operating a RAT.

APU generators are only available within the permitted operating parameters of the APU. Airborne operation of the APU is often limited by its air intake design and the airworthiness classification of that aircraft (ETOPS). A constant speed gas turbine engine, usually mounted in the fuselage tail cone, drives an aircraft generator. As the APU is a constant speed gas turbine engine, its generator (s) are not fitted with a CSD. The APU provides compressor air for air conditioning and electrical power for ground operations and as stated, it is sometimes available for emergency operation while airborne

Pneumatic and Hydraulic system generators are usually termed 'DEMAND GENERATORS' as they can supplement the electrical system anytime the demand exceeds normal supply capacity of the operating generators.

LOAD SHARING

Bus Tie Principle (Parallel Operations)

Load sharing is the principle of balancing the demand on the generators so they all deliver equal amounts of current. Designed to guarantee a continuous reliable supply, load sharing also extends the generator operational life.

When paralleling AC supplies, three fundamental rules apply :

1. Voltage of each supply must be the same.
2. Frequency of each supply must be the same.
3. Phase of each supply must be the same

If these conditions are not met, a potential difference will exist causing current flow between supplies and the most likely result is overheat and burn-out.

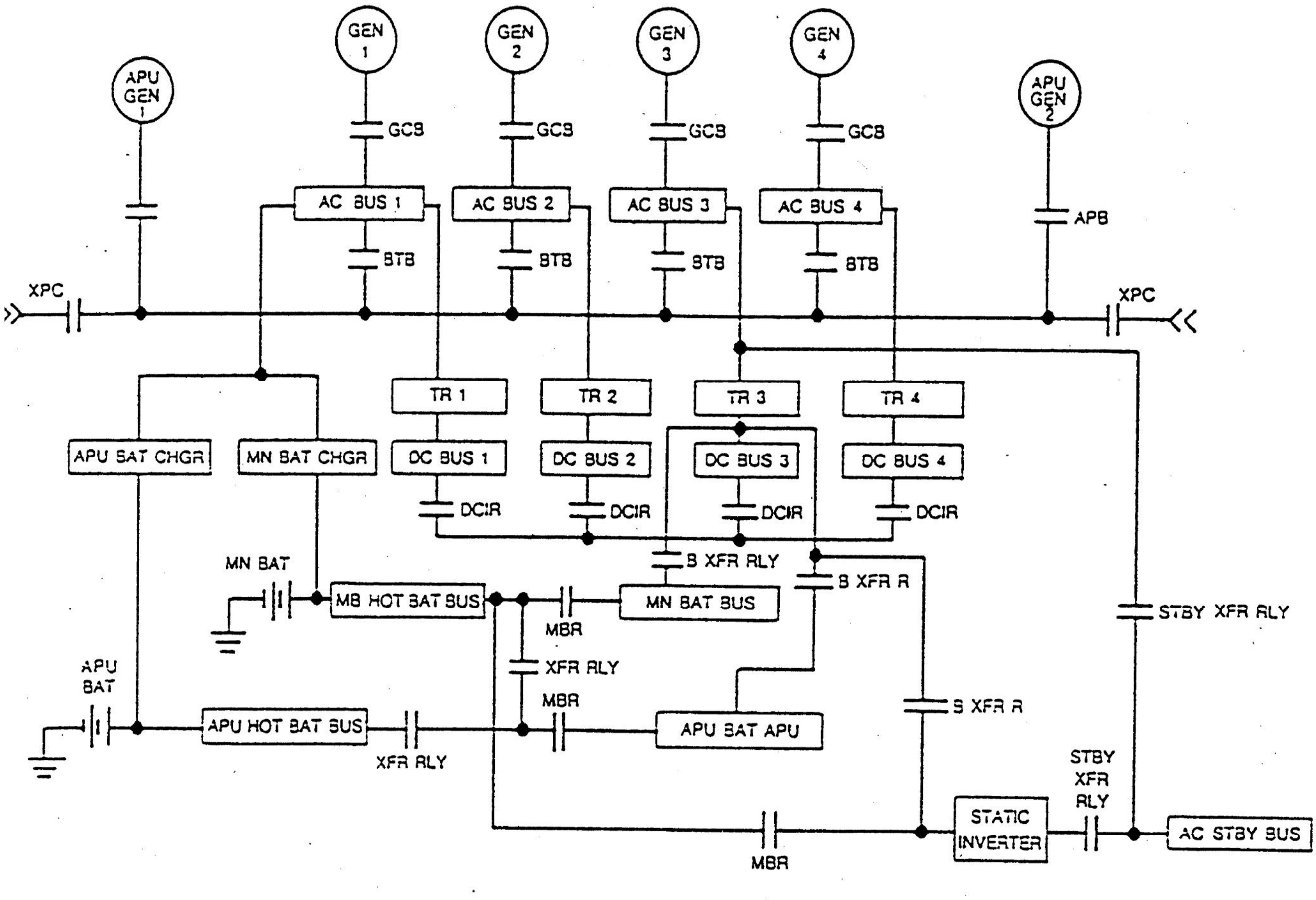
Note : *AC generators are never connected in series. If an increased voltage is required a generator is designed to provide that voltage or a step up transformer is used. This flexibility is one of the main advantages of AC power when compared to DC power.*

Additional circuits have been added to each system to provide voltage regulation and frequency control as follows :

- Reactive Load Sharing Control. This is necessary to ensure that once systems are paralleled the reactive load (kVAR) on the bus bars is shared equally between systems. Reactive load sharing is carried out by the voltage regulator.

- Active Load Sharing. This is necessary to ensure that once the systems are paralleled, the real load kW on the bus bars is shared equally between systems. Active load sharing is carried out by the frequency controller.

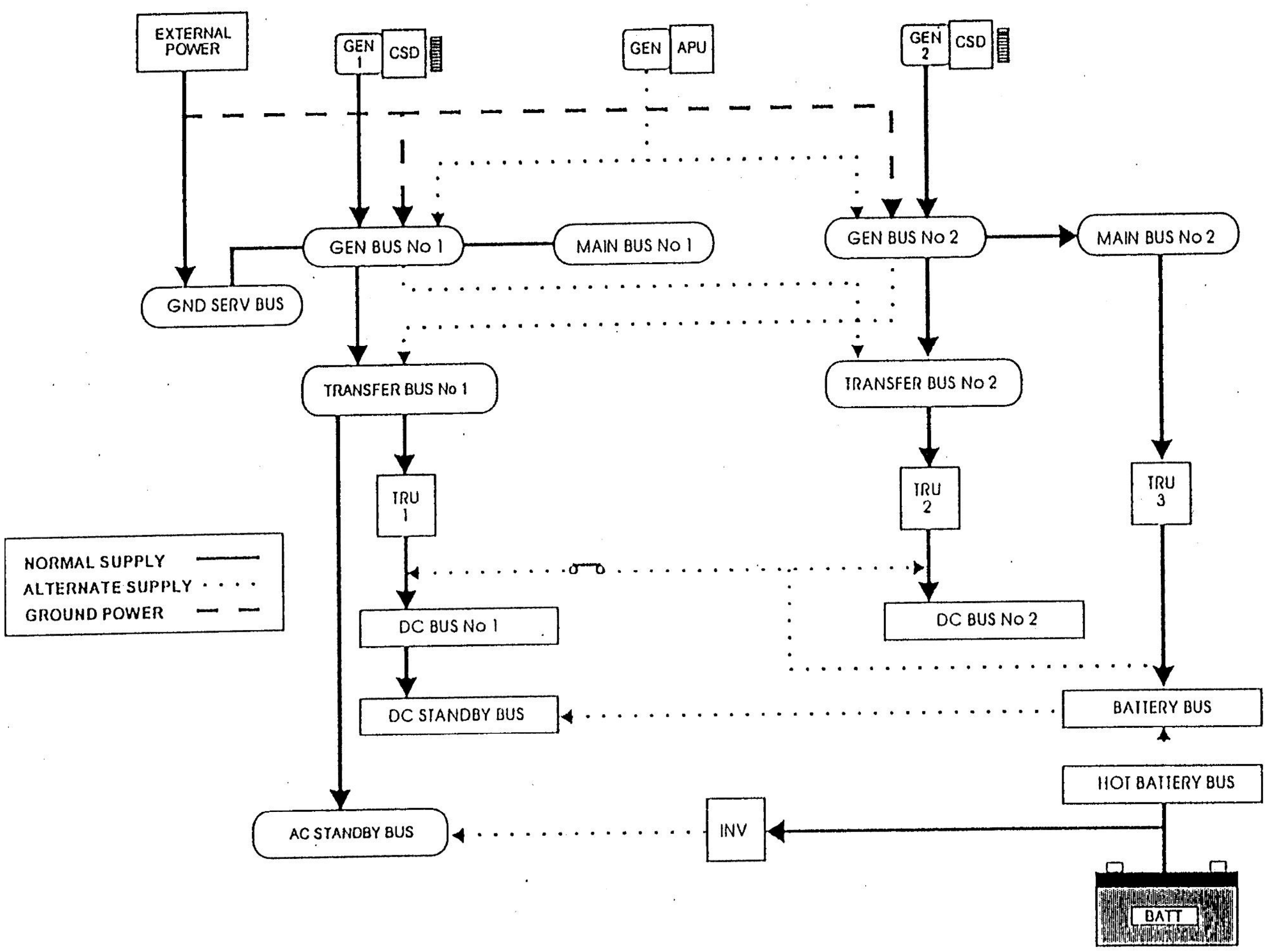
Reactive and active load sharing circuits are not connected until the generator control breakers and the generator bus tie breakers are closed. That is until the systems are paralleled.



B747 SCHEMATIC - FOUR GENERATORS PARALLELED

Split Systems **(Non parallel operations)**

As more modern aircraft become two engine machines, only two main generators are available. The designers allocate equipment to keep the demands on each generator fairly equal but separate. This is known as a split system. Should one generator fail a transfer bus provides continuity of supply. This means the complexities of BUS TIE protection and phase synchronization can be avoided.



TWIN ENGINED AIRCRAFT - TWO GENERATOR SPLIT SYSTEM

FREQUENCY WILD AC **(ACW)**

Frequency wild is a term used for AC generation which disregard frequency changes. Some electrical equipment is not frequency sensitive and such AC power can be used for anti-ice, de-ice circuits, heating and lighting.

The alternator on modern light aircraft is frequency wild and its output is rectified to DC. Modern alternators are separately excited devices and they require battery power to make the initial magnetic field. Once operating, they can self sustain. However, if the alternator is switched off for any reason and then switched on again, it cannot reactivate unless power is available for the field from the battery or another alternator.

EXAMPLE SYSTEM: ATR72

The ATR72 aircraft has a DC system as its primary power, supplied by starter generators. It uses inverters for constant frequency AC and has an ACW system powered by two frequency wild generators.

The following description refers only to the ACW system.

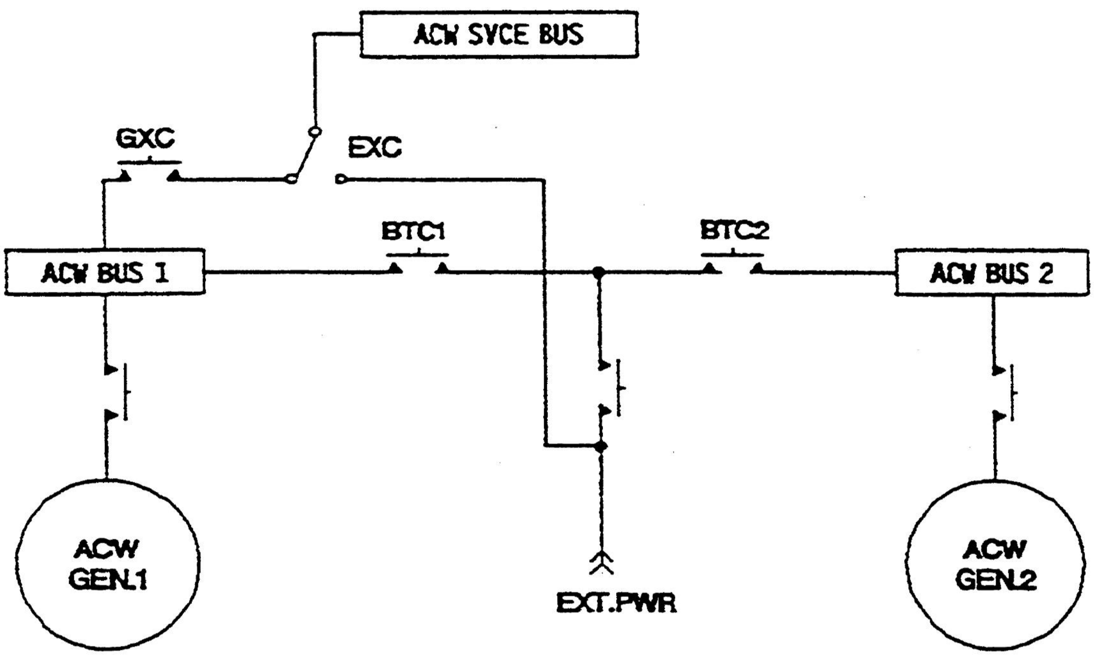
The ACW generation system consists of two engine driven 3 phase generators. Each generator is a brushless, air cooled type and is rated to deliver 20 kVA for continuous operation.

Normal operating frequency range: 341 to 488 Hz (70 to 100% NP).

Each generator is controlled by a Generator Control Unit (GCU) which provides the following control and protection functions:

- over voltage
- power and fault current limiting
- bus tie lock out
- under voltage
- differential protection
- under frequency
- open phase
- over frequency
- voltage regulation

The Bus Protection Control Unit (BPCU) performs the functions required for control and protection of the EXT PWR, the Bus Tie Relays (BTR) or Bus Tie Contactor (BTC) and SVCE BUS.



AN ACW TERTIARY ELECRICAL SYSTEM

The aircraft ACW distribution network consists of three busses:

- two main busses ACW BUS 1 and 2

- ACW SVCE BUS

ACW BUS 1 and 2

The ACW BUS 1 is normally supplied by the LH generator and the ACW BUS 2 by the RH generator.

Incase of generator failure, the associated ACW BUS will automatically be supplied by the other generator through the BUS TIE CONTACTORS (1 and 2).

As soon as EXT PWR is connected, selected ON and checked “acceptable” in voltage, frequency, phase, and current by the BPCU, it has priority over the engine driven generators.

ACW SVCE BUS

The ACW SVCE BUS supplied power inflight, and on the ground during airplane servicing operations. The ACW SVCE BUS can be supplied from EXT PWR or ACW BUS 1. A switch located on the cabin attendant panel controls the power to ACW SVCE BUS.

When the aircraft is operating from EXT PWR with ACW BUS 1 OFF, the ACW SVCE BUS is fed from EXT PWR through contactor EXC.

The ACW SVCE BUS is automatically shed when one generator is off line.

The ACW is used only for heating and lighting functions and is voltage regulated.

ACW BUS 1	ACW BUS 2	ACW SVCE BUS
Capt. Pitot Probe	F/O Pitot Probe	Galley Oven
Capt. Alpha Probe	F/O Alpha Probe	Galley Lights
Capt. TAT Probe	F/O TAT Probe	
Stby Pitot Probe	F/O Ice Detector	
Emeg Inst. Lights	Taxi Light	
Normal Inst. Lights	Right Landing Light	
Left Landing Light	Right Strobe	
Left and Rear Strobes	Right Side Pax Reading Lights	
Left Side Pax Reading Lights		
Toilet System		

LOAD SHEDDING

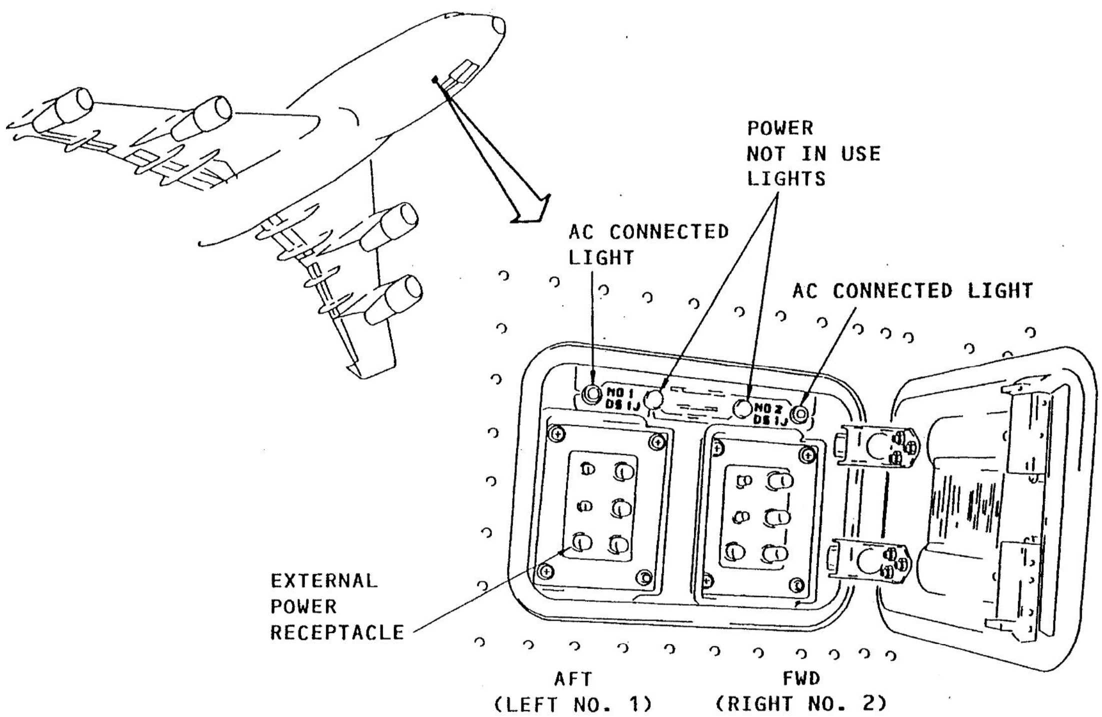
Load shedding is the principle of reducing current used, usually because of a generator failure. In a light aircraft DC system, load shedding is a procedure carried out if the alternator fails, by switching off non-essential equipment. If the alternator fails or is turned off, the total bus bar load is provided by the battery. As all equipment is parallel connected to the bus bar, any equipment that is switched off will reduce the total current draw or load and the operating life of the battery is extended.

In large aircraft, equipment priorities have already been decided. As generators fail, a system of computer 'logic', automatically disconnects the lowest priority equipment, allowing the remaining generators to continue to operate within their design parameters.

GROUND POWER

The standard ground power unit requirement is for a 115 VAC 400 Hz 3∅ AC supply. This unit can be plugged into the aircraft to maintain all electrical services. A constant frequency aircraft power supply embodies automatic protection circuits which ensure that :-

> Ground power cannot be connected to the aircraft distribution system if the system is already being supplied from the aircraft generating system.
>
> Ground power cannot be connected if the phase sequence of the supply is incorrect.
>
> Ground power is rejected and switched off at the source if an over voltage occurs.



EXTERNAL POWER PANEL

MONITORING AND FAULT MANAGEMENT

LIGHT AIRCRAFT

Modern electrical systems are very reliable, however, some faults do occur. Emergency checks lists provide a means of correct or permitted actions in relation to the fault.

Generator Failure (or Alternator in DC System)

The generator can stop providing power for a number of reasons:

Generator drive system (belt) fails.

Generator CB trips.

Open circuit of supply cable or poor earthing.

Low Engine RPM.

The failure will always be alerted with a warning light and the onus is on the pilot take the correct action.

- Generator central relay (GCR) trips: overload condition, probably caused by excessive demand on the generator, a short circuit in the equipment or on the supply wiring.

  ACTION: Switch off offending equipment if known, wait for at least one minute for GCR to cool and attempt one reset only.

- Low engine RPM: it is normal for the ALT light to illuminate when the engine speed drops below about 1000 RPM.

  ACTION: Increase RPM when flight condition allows.

- Generator drive or cable failure: no airborne corrective action is possible. All services will be available, as the battery will maintain the supply for about 30 minutes.

  ACTION:
  - Switch off non-essential equipment to preserve battery power. This is load shedding.
  - Prepare for recovery to a suitable airfield.

    Note 1: Should the battery power become completely consumed all electrical services will be lost, including radios and critical engine indications.

    Note 2: The engine will not fail because of an electrical system fault, as the ignition system is separate.

    Note 3: If at all possible land at an airfield in preference to a paddock.

HEAVY AIRCRAFT

The Boeing 747-300 is used as an example of the type of conditions that can be encounted on large aircraft. As you study this section, you may need to refer to the B747 Schematic on page 11-10

On modern aircraft, electrical system operation is fully automated and simplified by the use of microprocessors, digital electronics and cathode ray tube (CRT) or liquid crystal displays (LCD) for flight station display screens. A crew alerting system is based on the philosophy of warnings, caution and advisory, coupled with red or amber colour displays to show priorities.

A computer processes inputs from the various aircraft systems so that system configuration and failure information is displayed on the screens.

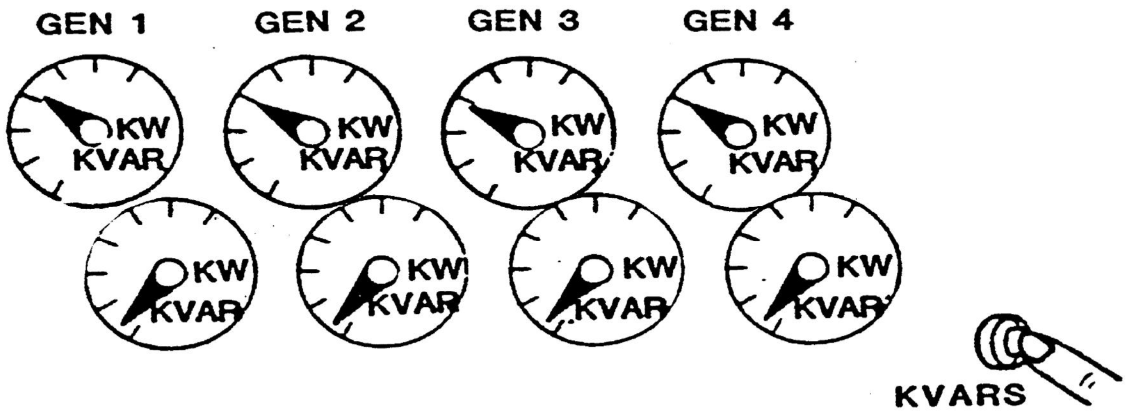
For example, a failed AC bus, results in an AC BUS OFF caution message, in amber, on the screen and the illumination of the MASTER CAUTION light and AC BUS OFF light on the pilot's panel.

Power

Because True power (KW) is larger than reactive power (KVAR), the maximum load is expressed in KW in the limitations section of the Operations Manual.

It is the kilowatts reading which is normally monitored for equal load sharing and to be within limits.

The KVAR reading is useful for monitoring the operation of the voltage regulator. The effect of a drifting regulator shows up on the KVAR reading. For example, a high KVAR indication on one generator system would identify the malfunctioning regulator. Ideally, we want to see equal load sharing between generators for both KW and KVARs.

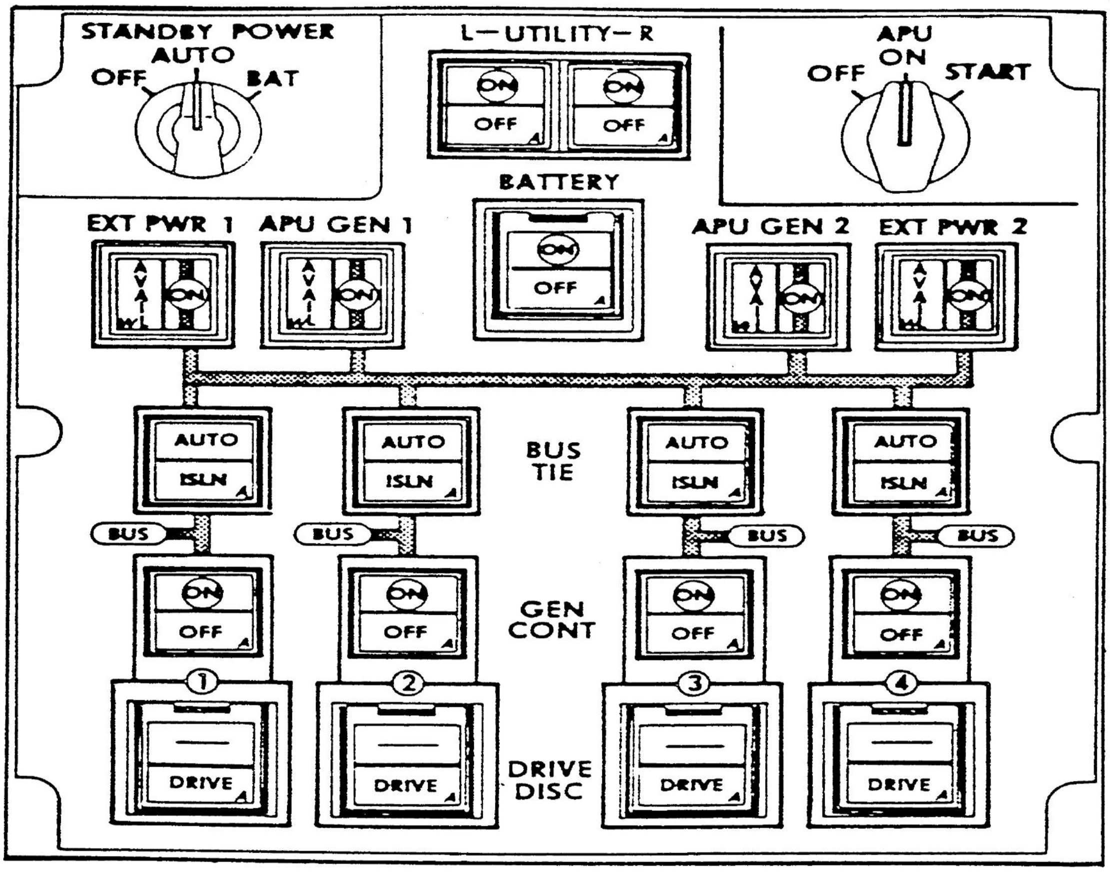


KW and KVAR INDICATIONS

Excess generator capacity is such, that even with the loss of one generator, normal cruise loads can still be satisfied with the remaining three.

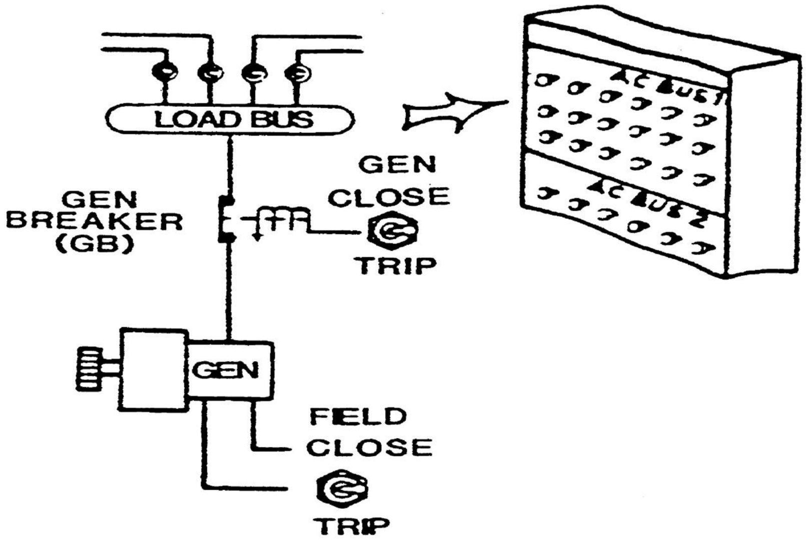
The monitoring of KW limits is not a problem when operating on 3 generators. However, generator limitations will be approached if operating with less than three generators and heavy electrical loads will have to be shed.
On more recent aircraft, the APU generator can be used in flight to assume the load of a failed main generator.

PILOTS ELECTRICAL SYSTEMS PANEL



PILOTS PANEL

When closed, the generator breaker connects the generator to its load bus which distributes electrical power to the 'individual circuits' connected to it. Each generator feeds its respective load bus, so that generator 1 supplies load bus 1, generator 2 supplies load bus 2 and so on. See B747 Schematic page 11-10.



INDIVIDUAL CIRCUITS ARE PROTECTED BY A CIRCUIT BREAKER.

Load Busses

Load busses are joined together by a bus tie to provide for generator redundancy capacity. In the 2 generator system, each load bus is connected to the bus tie through its bus tie breaker, the BTB.

Bus Tie Switch

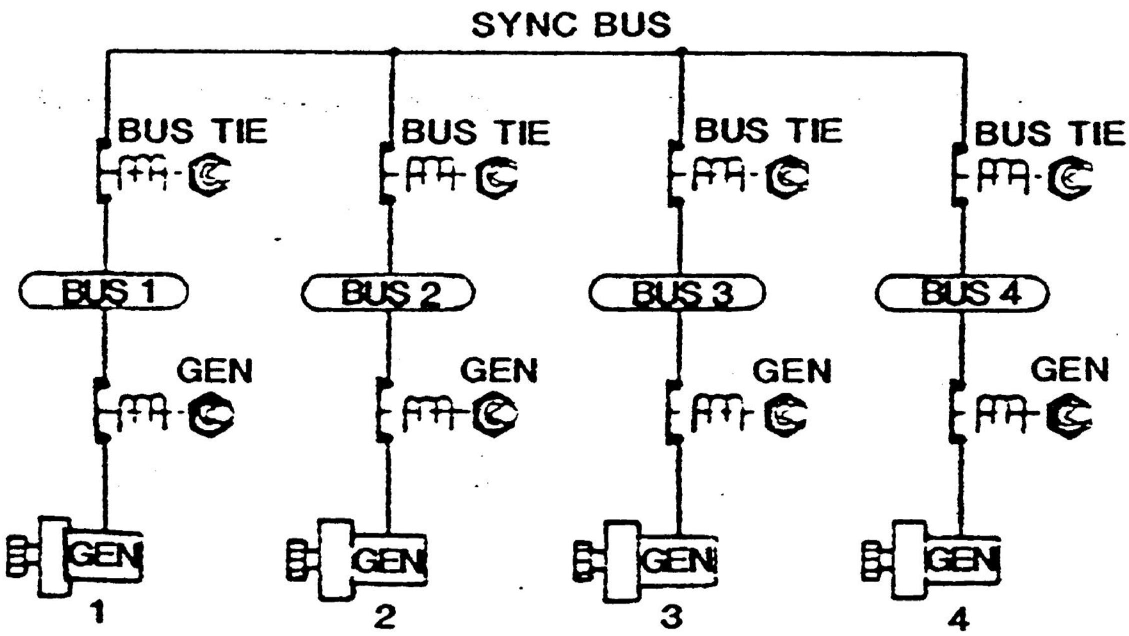
The bus tie breaker is controlled by its bus tie switch. Bus tie breakers are normally closed at all times.

Should one generator fail, its load bus would still be powered from the other.

In a four generator system, the four load busses are similarly connected together by normally closed bus tie breakers.

Synchronizing Bus

The interconnecting wiring, referred to as the synchronizing bus, permits synchronization of generators, so that voltage and frequency outputs are in phase.



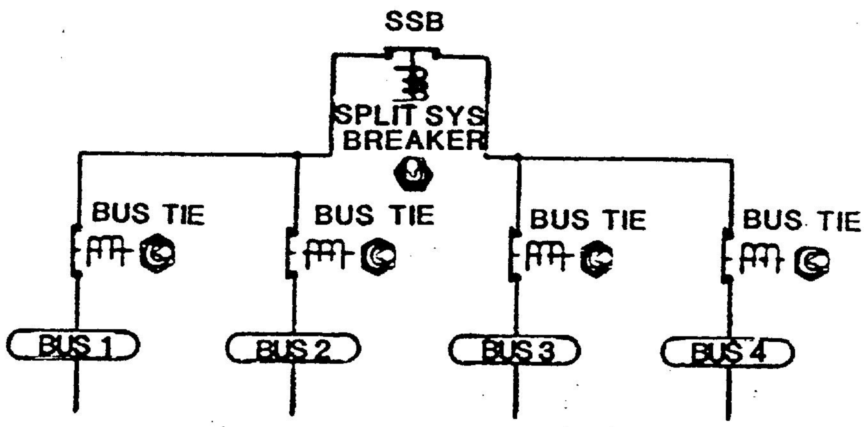
THE SYNC BUS IS THE MAIN TIE SYSTEM

The schematic shows normal operation of four generators in parallel. Should one generator fail, its associated load bus would still be powered from the other three.

Split System Breaker

To provide greater flexibility in the bus tie arrangement, the system can be split by the SPLIT SYSTEM BREAKER, the SSB, so that load busses 1 and 2 constitute one half and load busses 3 and 4 the other half.

The split system breaker provides automatic control and protection for a number of operational requirements and system isolation for certain faults.



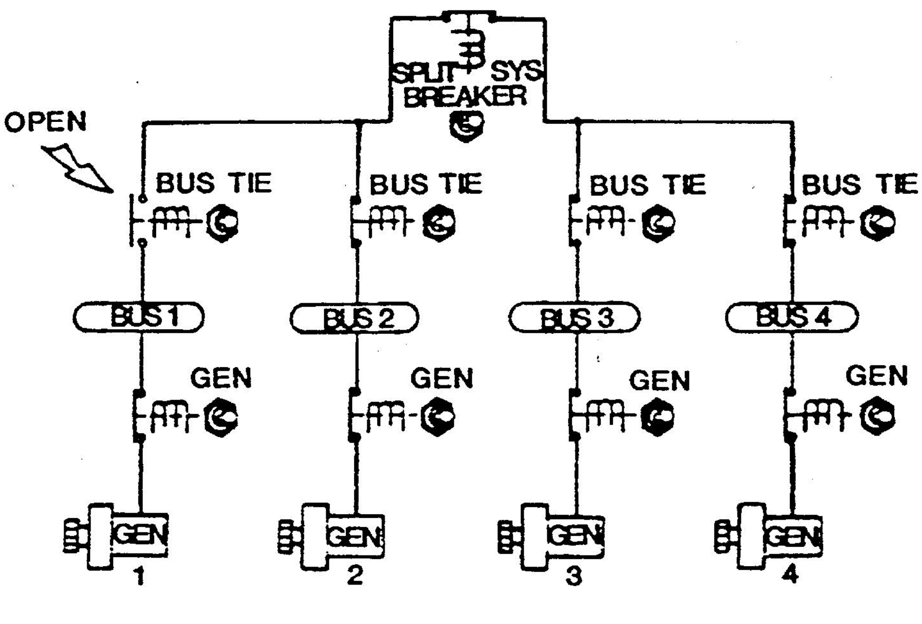
SPLIT SYSTEM BREAKER - ALL GENERATORS SYNCHRONIZED

One function of the split system breaker is shown here. It is designed to open automatically if an attempt is made to parallel external power sources through the bus system. External power sources cannot be paralleled because they cannot be synchronized for load sharing, voltage regulation or phasing.

For certain malfunctions, a generator can be isolated and kept operating to supply its own bus, opening the bus tie breaker.

For example, problems such as unbalanced load sharing or load oscillation on a paralleled generator, is reason enough to isolate it from the others.

The problems become relatively minor when the generator is operating 'isolated' and there would be no need to disconnect its CSD.



SPLIT SYSTEM BREAKER - GENERATOR No 1 ISOLATED

Normal Operations

Returning to normal operations for a four generator system, if all load buses are powered, then all bus ties breakers and the split system breaker are closed.

Breaker Lights

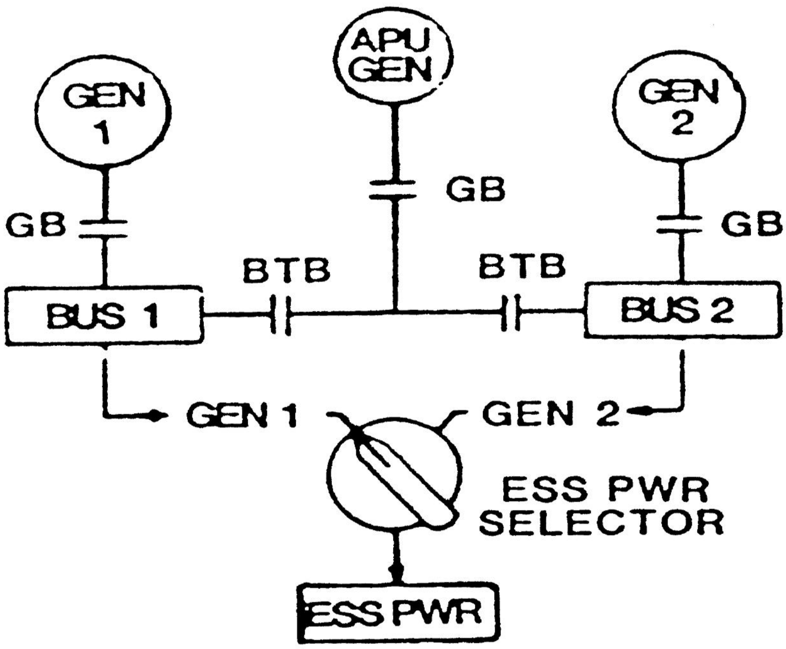
To confirm the open or close position of any breaker it is usual to have an associated light which illuminates amber if the breaker is open.

Essential AC Power

Some circuits considered essential for safety of flight are grouped together on the essential AC bus. Let us consider the power source for this bus.

Essential AC loads are normally powered from one of the generator busses - here bus 1 is selected.

Should bus 1 fail, essential power can be restored by selecting GEN 2.
Further redundancy on this particular system is provided by the APU generator which can be used inflight to assume the load of a failed engine generator.

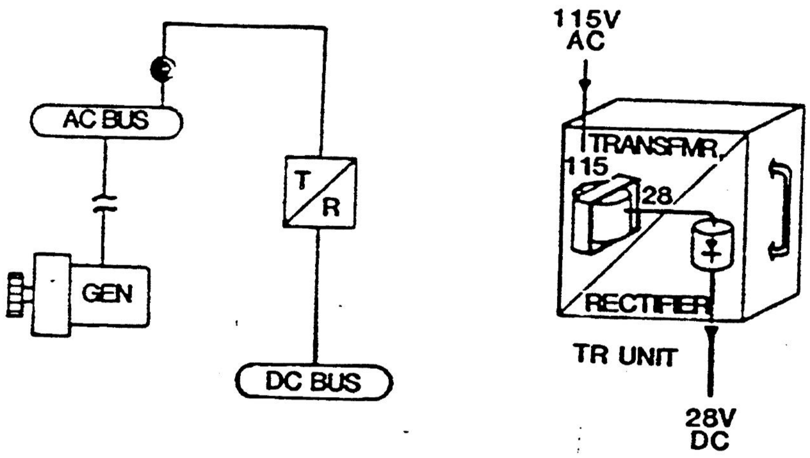


AC ESSENTIAL POWER SELECTION

DC POWER

A transformer - rectifier unit, or TR unit, provides the DC. The nominal voltage is 28 volts. The 115V supply from the AC bus is transformed down to 28V AC then rectified to DC.

This typical schematic shows the symbol for a TR unit - the output from which supplies the DC bus.



AC TO DC

Transformer Rectifier (TR unit)

On this aircraft installation, four TR units are required to satisfy the DC loads.

Each TR unit is supplied by its associated AC bus. Notice that the essential AC bus is the power source for the essential DC bus.

All DC outputs from the TR units go directly to their respective DC bus.

With the loss of a TR unit, redundancy capability is provided by the bus tie.

The lower switches and relays are controls for the bus tie - similar, in fact, to the bus tie breakers previously discussed.

The relays are normally in the closed position and would be opened only to isolate a DC bus in the event of a malfunction.

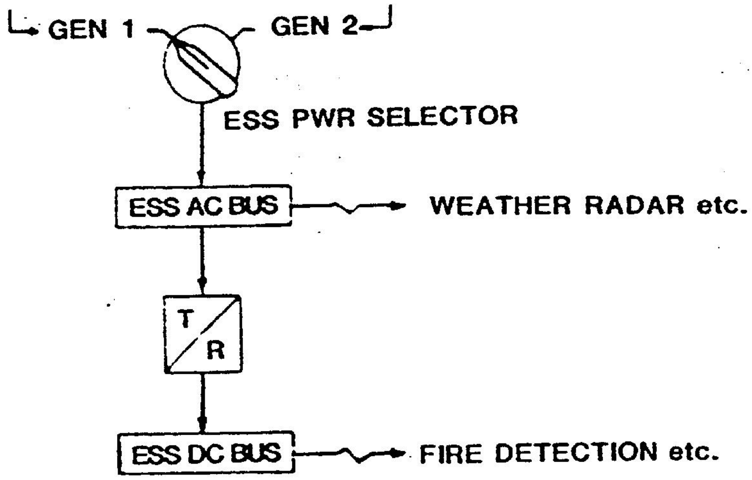
Monitoring DC power

DC power is usually checked by monitoring the voltage on the busses and the current output from the TR units. On this 2 - generator installation, TR 1 has been selected.

If the output from the TR unit supplying DC bus 1 failed, the ammeter would indicate zero. However, the voltmeter would still show the DC bus voltage because DC bus 1 is connected to DC bus 2 through the bus tie.

Essential DC Power

Recall that some circuits essential for the safety of flight, are connected to the essential busses, weather radar and fire detection being just two.

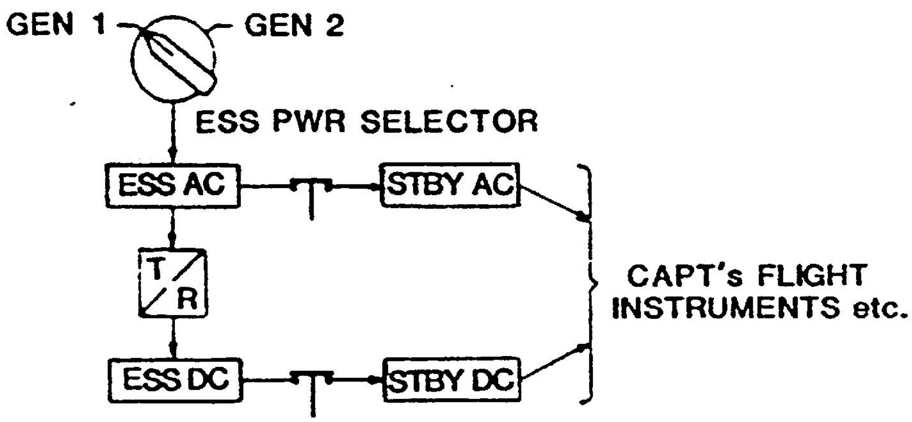


ESSENTIAL DC

STANDBY POWER

On some aircraft, there is a certain group of circuits normally supplied with essential power but through separate busses, called standby busses. They are, in fact, extensions of the essential busses and are connected through normally closed relays.

The standby bus arrangement allows this special group of vital circuits to be powered automatically from a special standby power source if the main power source that normally supplies the essential power fails. This can be the battery or, on some aircraft, a hydraulic driven generator.

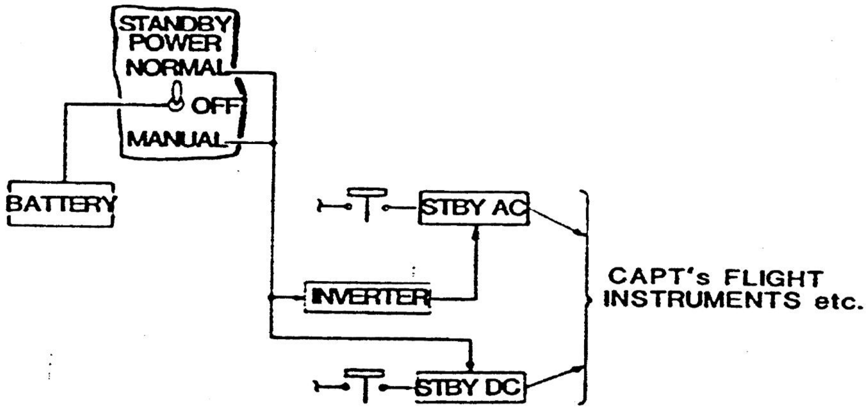


STANDBY POWER

These are the vital systems supplied with standby power.

- **CAPTAIN'S FLT INSTRUMENTS**
  HORIZON
  HEADING
  NAV DISPLAY
- **CAPTAIN'S RADIO**
  COMMS
  P.A.
- **ENGINES**
  N1s, EGTs
  ANTI-ICE, FUEL HEAT
  STANDBY IGNITION

The standby bus arrangement allows this special group of vital circuits to be powered automatically from the standby power source should the main power source fail.



STANDBY POWER IS SWITCH MARKED **NORMAL**-**OFF**-**MANUAL**.

If **essential power** fails with the switch in NORMAL, the standby busses are automatically isolated from the essential busses and are powered from another source.

The aircraft main battery energizes an inverter which supplies 115V to the standby AC bus.

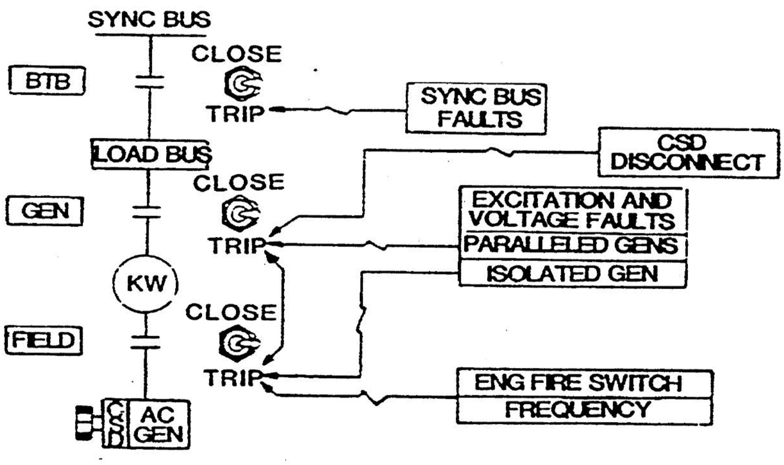
The battery also supplies the standby DC bus directly.

If automatic switching does not take place, selecting MANUAL will restore the standby busses.

With the switch in the OFF position, both standby busses are isolated from any power source.

SUMMARY

- Electrical power systems are automatically controlled to provide correct voltage and frequency and remain within limits, whether the generators are isolated or paralleled.
- Out of tolerance conditions are sensed and a system protection is provided automatically. Here are some typical faults which will trip the associated breaker to protect the system.
- Synchronizing bus faults will trip the bus tie breaker.
- CSD disconnect will always trip the generator breaker.
- An excitation or voltage problem will also trip the generator breaker if the generators are in parallel.
- If the generator is isolated, then the field breaker is tripped.
- The field breaker is also tripped if the associated engine fire switch is operated or if there is a frequency problem.
- Notice that whenever the field breaker trip the generator breaker trips.



ELECTRICAL SYSTEM PROTECTION

CONCLUSION

Because of the problems of parallel operation and the higher voltages involved, CFAC generating systems are more complex than DC systems. The CFAC systems are used on aircraft where the AC power requirements are much greater than the DC requirements, and hence a DC system would be uneconomical to use. CFAC multi channel systems can be operated as independent non paralleled systems (split systems) to reduce system complexity and to increase system safety. Frequency wild systems (ACW) always operate as split systems