Agenda (2/3)

- Module 4 – Design requirements and Safety process
  - 4-1 Requirements
  - **4-2 Safety process**
- Module 5 – Aircraft power systems
  - 5-1 Hydraulic power systems
  - 5-2 Electric power systems
- Module 6 – Aircraft Control systems Architectures
  - 6-1 Hydro Mechanical Systems
  - 6-2 Fly by wire systems
  - 6-3 Fly by wire systems new generation
  - 6-4 A320 FAL Visit

Summary

Introduction to Electrical power

Introduction

- Large transport Aircraft use Electrical power for a large number of applications ranging from
  - high energy demands like electric pumps for hydraulics, Recirculation fan for the airconditioning, ,
  - demands from the navigation, communication and survieance system ,
  - demands for system control, monitoring and indication
  - Lighting
  - Commercial equipment like galleys and entertainment
  - Heating for Anti Ice, Water, Air, Sensors, …..

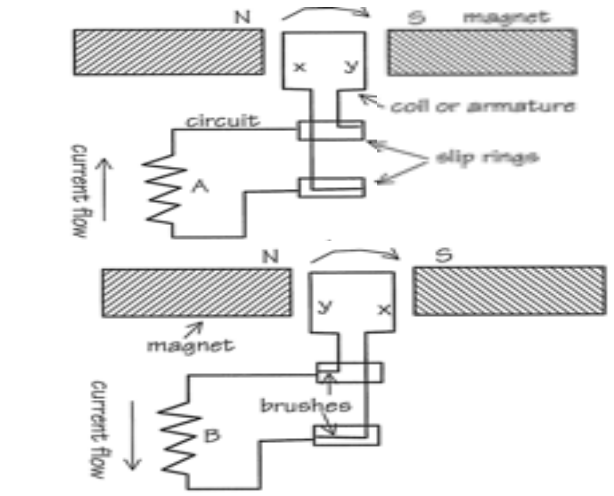
Introduction (2)

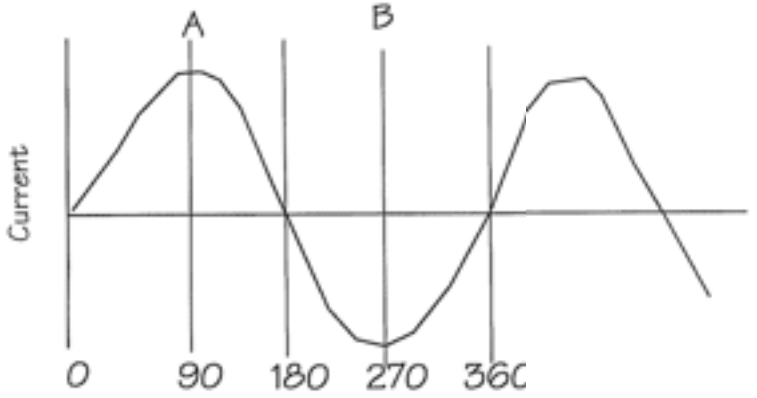
- The basic principal of electrical power generation is that of magnetic field induction. An electric current flowing through a conductor creates an magnetic field around the conductor. In reverse, if a conductor is passed through a magnetic field than an electro magnetic force is is induced in the conductor causing a current flow and generating electricity in case off a generator application.
- Electrical power is described by the the terms:
  - V for Voltage, it is a measure for the electromotive force or the electrical pressure which cause a flow of electricity
  - A for Ampere measure the flow rate
  - O for Ohm the unit for the electrical resistance in a circuit

Basics of el. generation

An alternator consists of a coil rotating in a uniform magnetic field. During rotation the 2 sides of the coil cut the magnetic field in opposite directions including opposites but complementary currents creating a total current. The direction of the current and the polarity of the slip rings revers as the side of the loop moves alternately under the influence of the N and S pole.

The direction of the current flow in the external circuit change direction also and is known as alternating Current (AC)





Basics on electrical generation

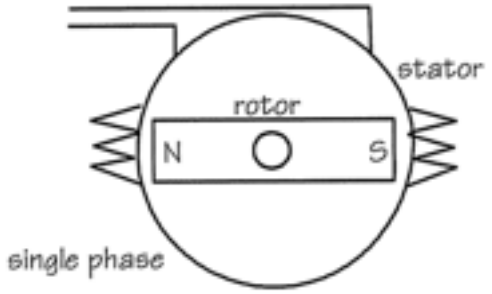
In modern generators the coil is fixed with and the magnetic poles are rotating.

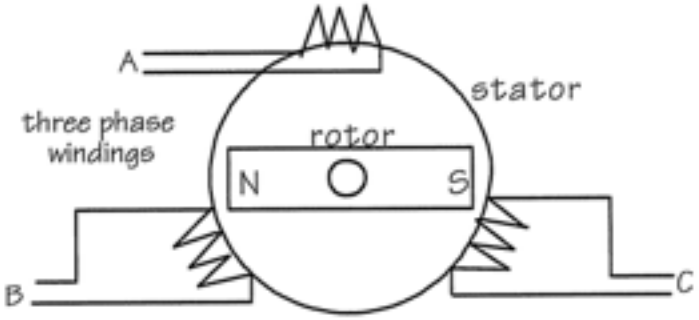
Three phase alternators are used to increase the electrical power output of a single generator.

It consist of three separate single phase coils producing voltage in each winding which is 120° out of phase.

The generators are self exited.

115V /400hz is a typical output

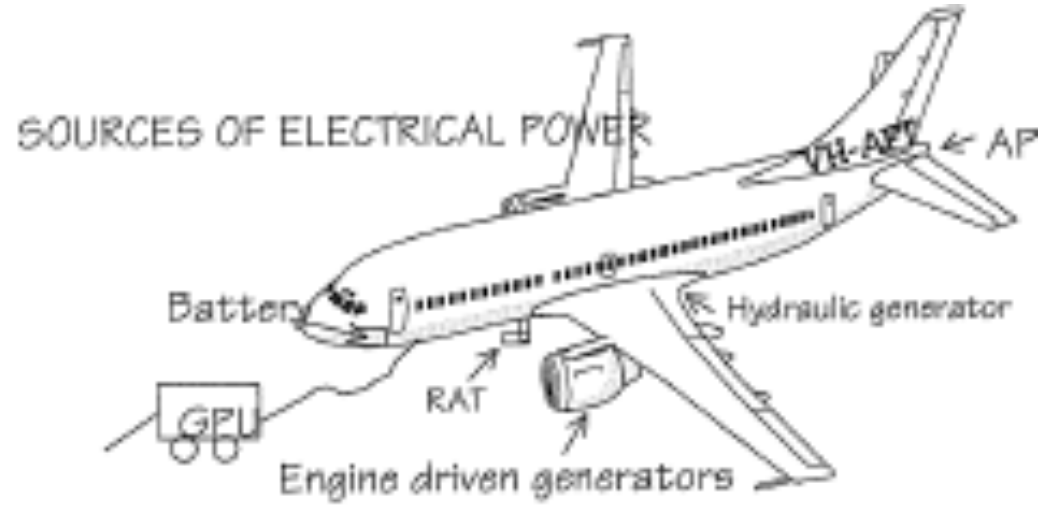




Summary

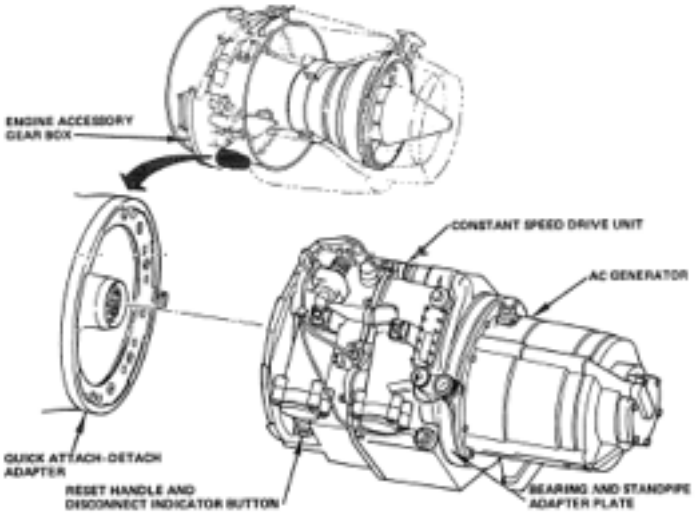
Source of electrical Power

- AC Generator engine powered
- AC generator APU powered
- Ground power (external connections)
- Constant speed drive



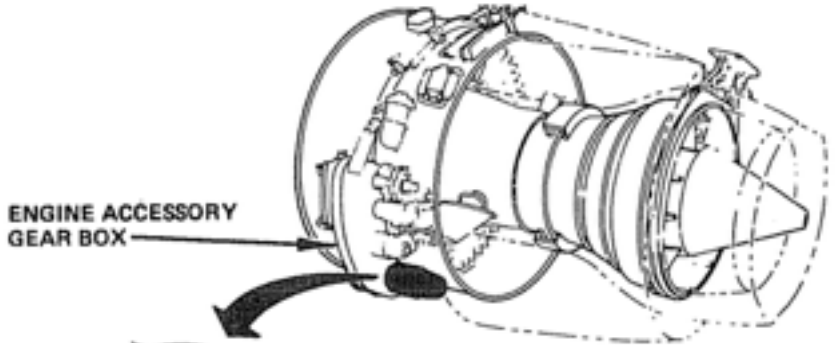
Generators installation

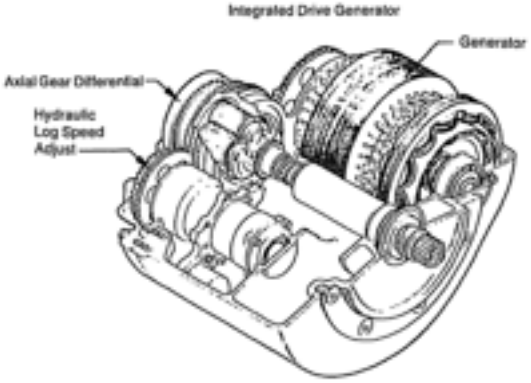
- Generator is powered by the engine,
- Mechanical link to the N1 shaft (Fan/LPT) via the engine gear box
- Drive speed follows the Engine RPM
- Classical positions are
  - the fan case ore
  - the core engine



Generator drive

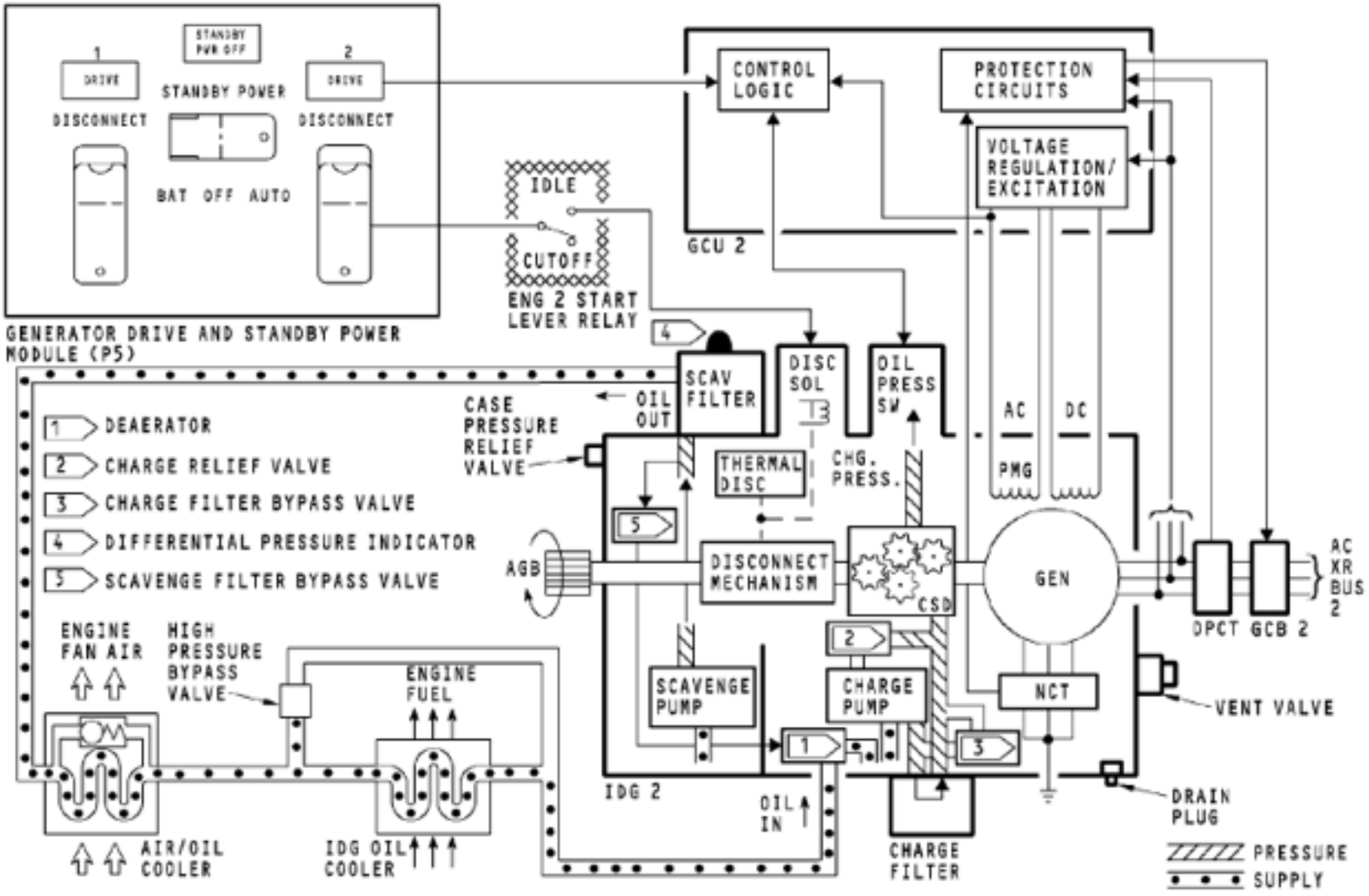
The frequency output of an generator depends on the speed of its rotation. Since most aircraft require AC power with constant frequency the generator must e rotated with constant speed. This function is provided by a integrated Generator drive. This device operates hydraulically and keeps the RPM constant for example 24000 rpm provide a frequency of 400Hz.
Issues : IDG cooling



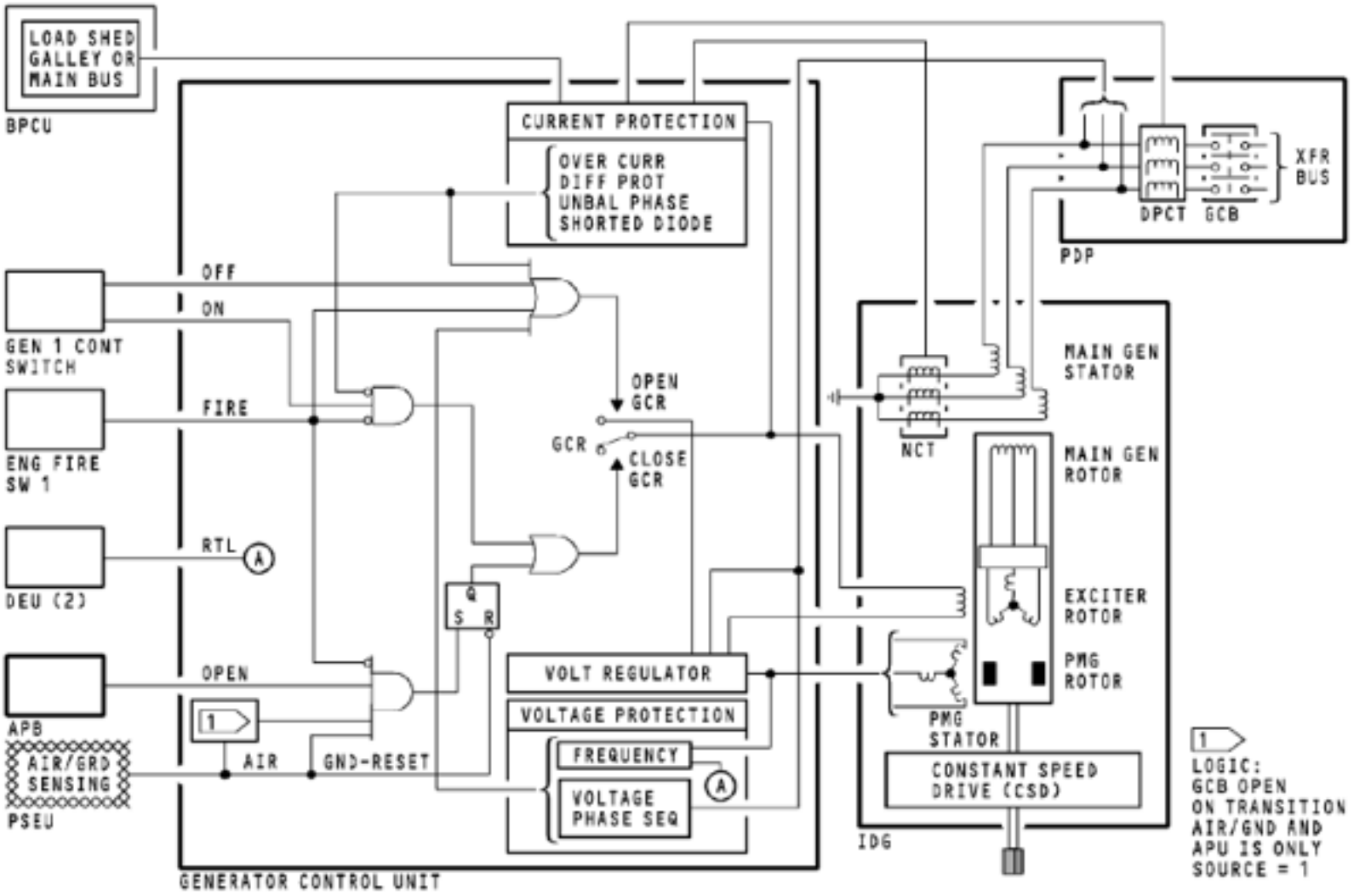


IDG description

- The AC generator is a three-phase, brushless generator. The generator has these components:
- - Exciter rotor (armature)
- - Main generator rotor (field winding)
- - Permanent magnet generator (PMG) rotor
- - Main generator (exciter) stator
- - PMG stator
- - Neutral current transformer (NCT).



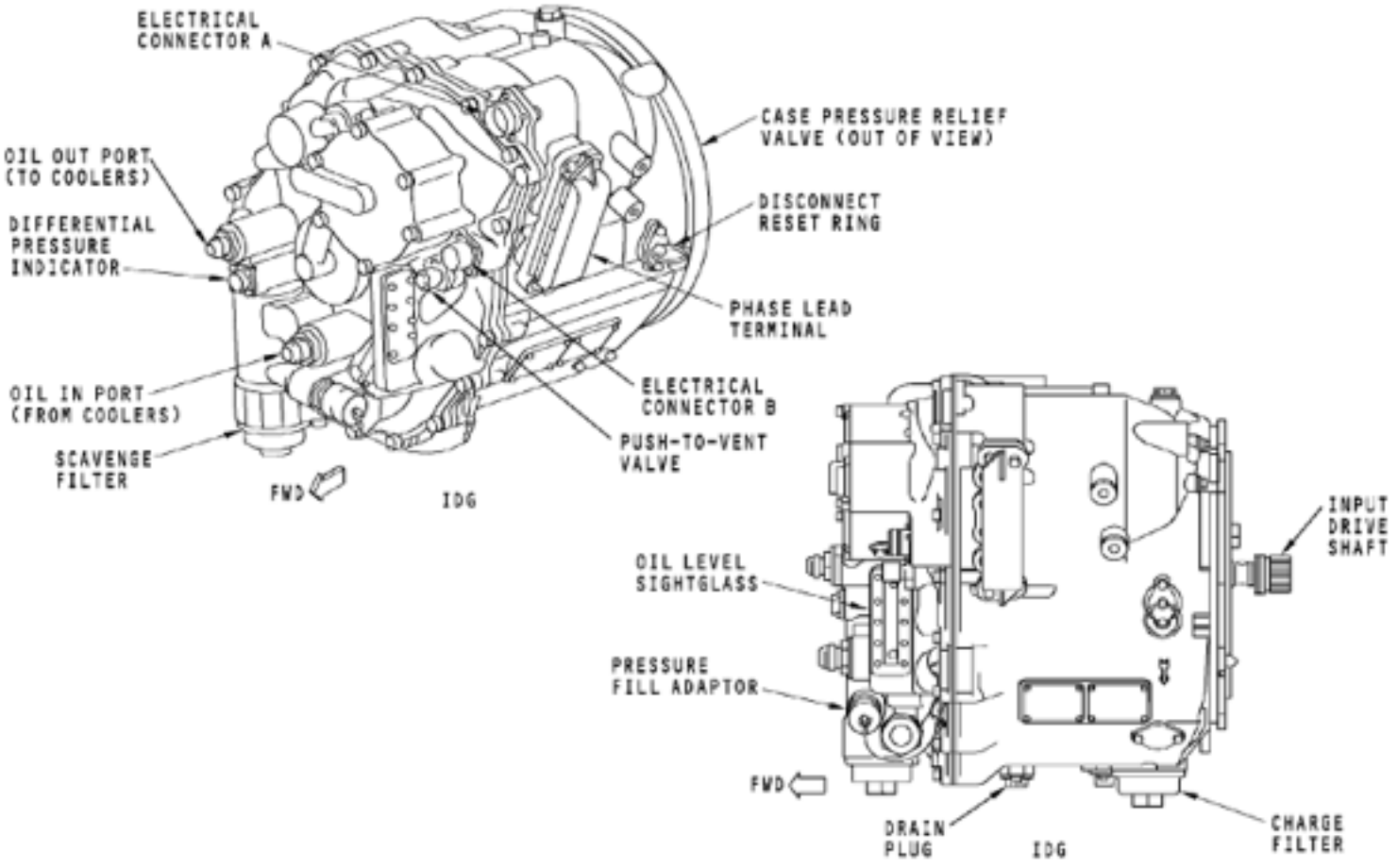
GENERATOR DRIVE - FUNCTIONAL DESCRIPTION



AC GENERATION - GCU - PROTECTION AND EXCITATION

IDG functions

- Generator excitation is performed by an integrated PMG, voltage regulation is performed by the generator control unit. The GCU manage the Generator control circuit breaker for protection of the electrical AC network an the IDG
- Lubrication and cooling is performed by a specific cooling system integrated in the engine
- Activated by a solenoid , the IDG can be manually disconnected . (physical shaft disconnect)
- Thermal disconnect function, shaft overload protection
- Oil pressure / housing pressure control system

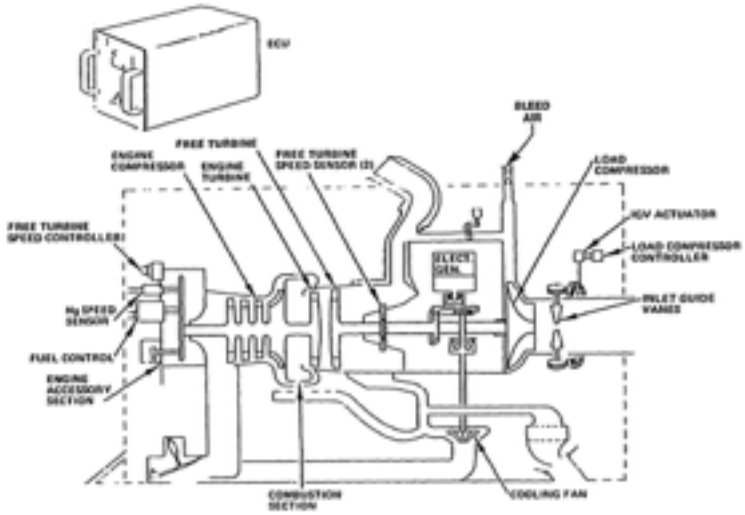


GENERATOR DRIVE - INTEGRATED DRIVE GENERATOR (IDG)

Electrical generation on ground

- For electrical power supply on ground APUs are installed at the rear of the aircraft. Most APUs are operating with constant speed , (regulated by the electronic control box) . Therefore the generator is directly connected to the gearbox of the APU.
- Most APUs have the capability to work also in flight and can act as alternative power supply in case of generator failure (for example for ETOPS operation)
- Via ground connectors, external power supply can be provided by Ground power units

Typical simplified APU



CSMG

- The Constant speed motor generator is a mean to produce electrical energy with the support of the hydraulic system ; in case of loss of hydraulic power the CSMG can be powered by the Ram air turbine.
- Power region is between 5 to 10 KVA (115V ,400hz)

Aircraft Batteries

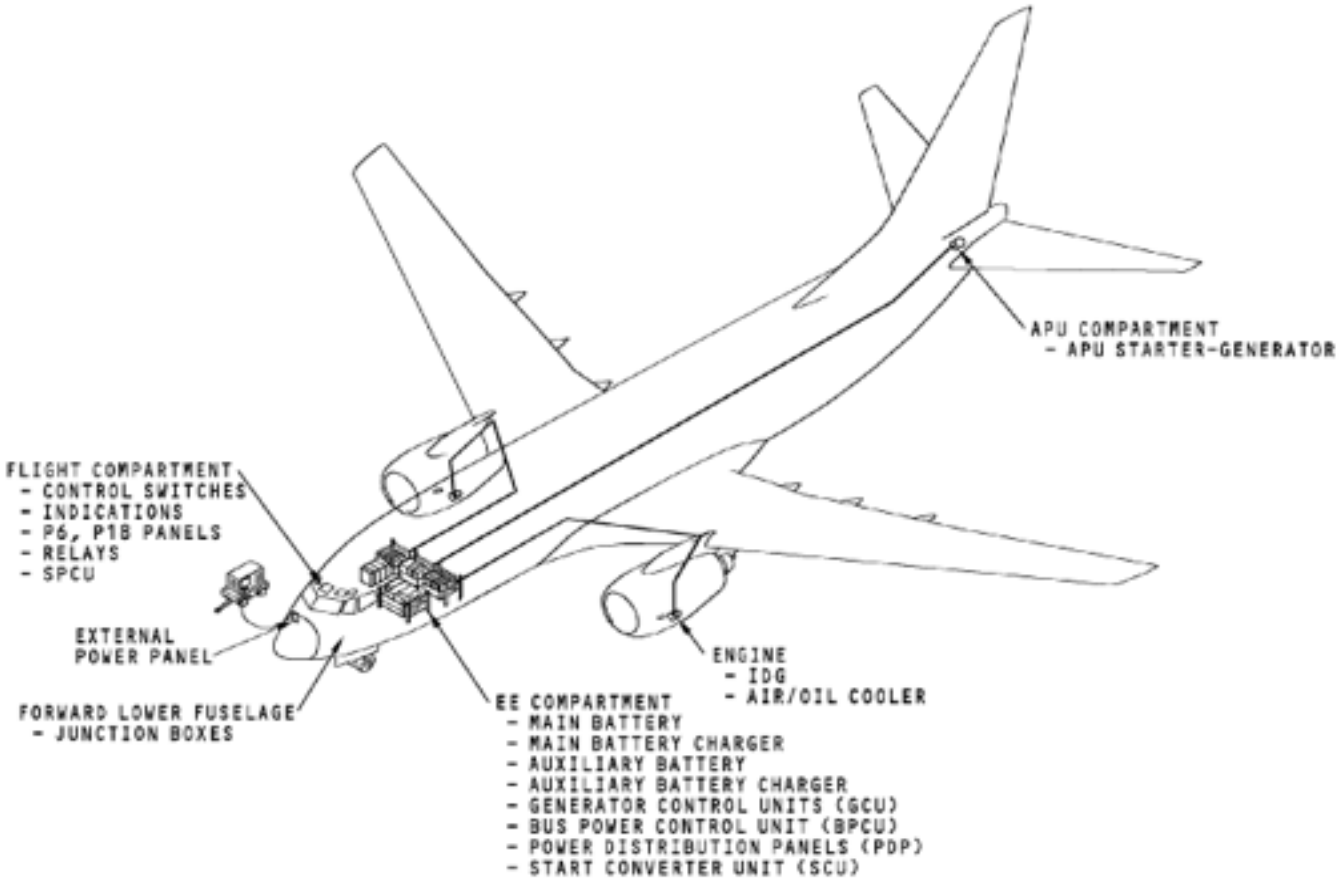
- Batteries are installed at the aircraft for the supply of emergency power
- Each batterie is connected to his own bus
- Batteries are delivering 24V DC power
- With a capacity of appr. 25 Ah
- Different type of battery technology is used with pro and cons for each.
- Batteries require external ventilation.
- Individual systems con have there own Batteries

Summary

Power transformation means

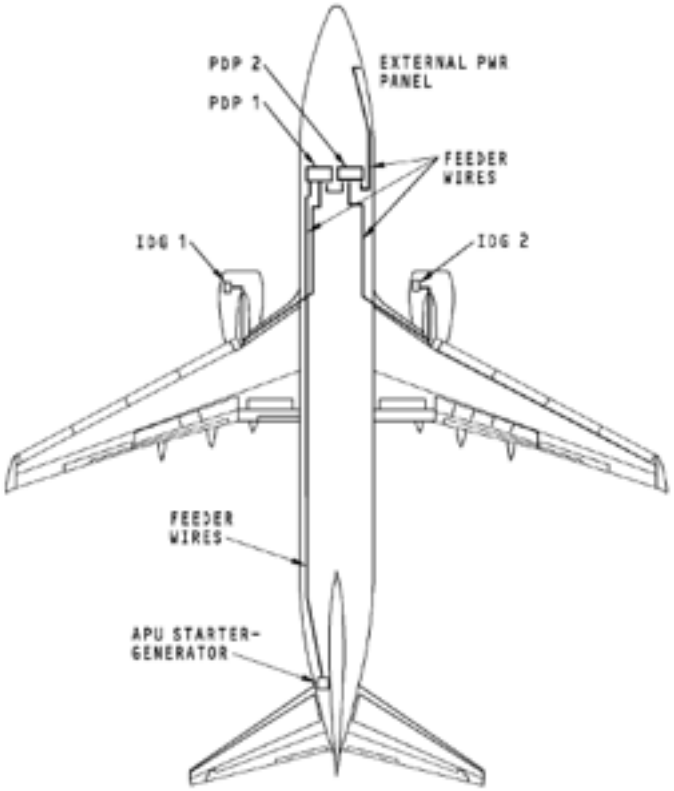
- Transformator/Rectifier
  - Transforms 115V 400hz AC to 28V DC Each AC generator supplies it own TRU
- Static Inverter
  - The static inverter is supplied by the batteries and transforms low voltage DC power to 115V 400Hz power. It is used in case of absence of the CSMG to supply the essential AC network

Typical component location/ segregation

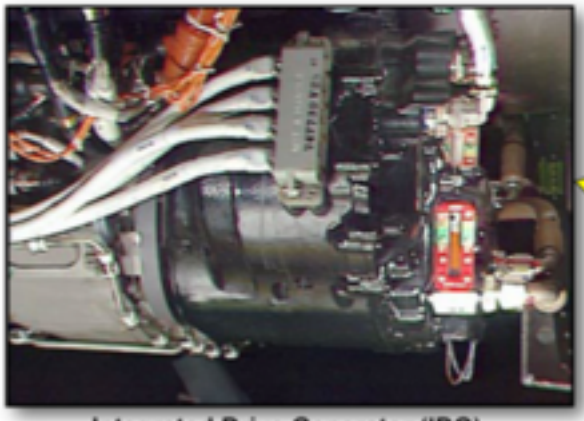


ELECTRICAL POWER - AIRPLANE - COMPONENT LOCATIONS

Typical component location/segregation

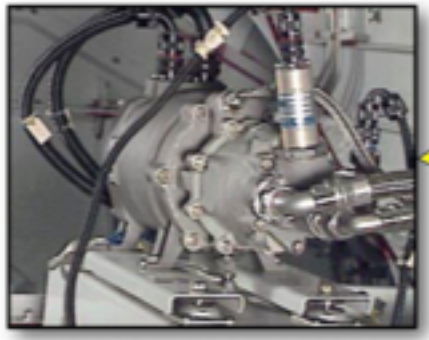


AC GENERATION - AC SOURCE FEEDER WIRE ROUTING - GENERAL DESCRIPTION

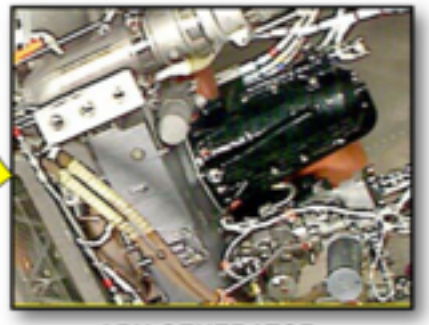


Integrated Drive Generator (IDG)

	VOLTAGE	FREQUENCY	PHASES	POWER
IDG 1/2	115 VAC	400 Hz	3 phases	90 kVA
APU GEN	115 VAC	400 Hz	3 phases	90 kVA
EMER GEN	115 VAC	400 Hz	3 phases	5 kVA



EMERGENCY GENERATOR



APU GENERATOR

COMPONENT LOCATION

Summary

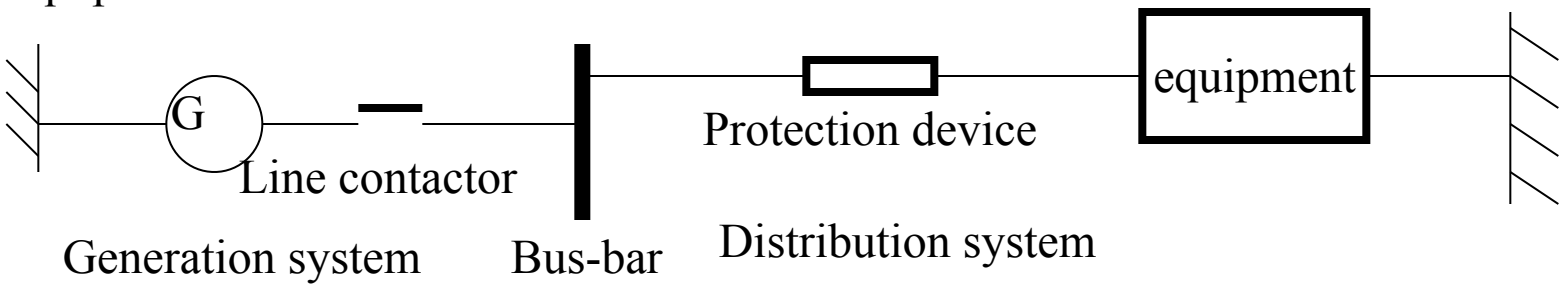
DIFINITION AND FUNCTION

DIFINITION

The aircraft electrical system is a set of power supplies and equipment connected together. They are used to make, supply and control electrical power.

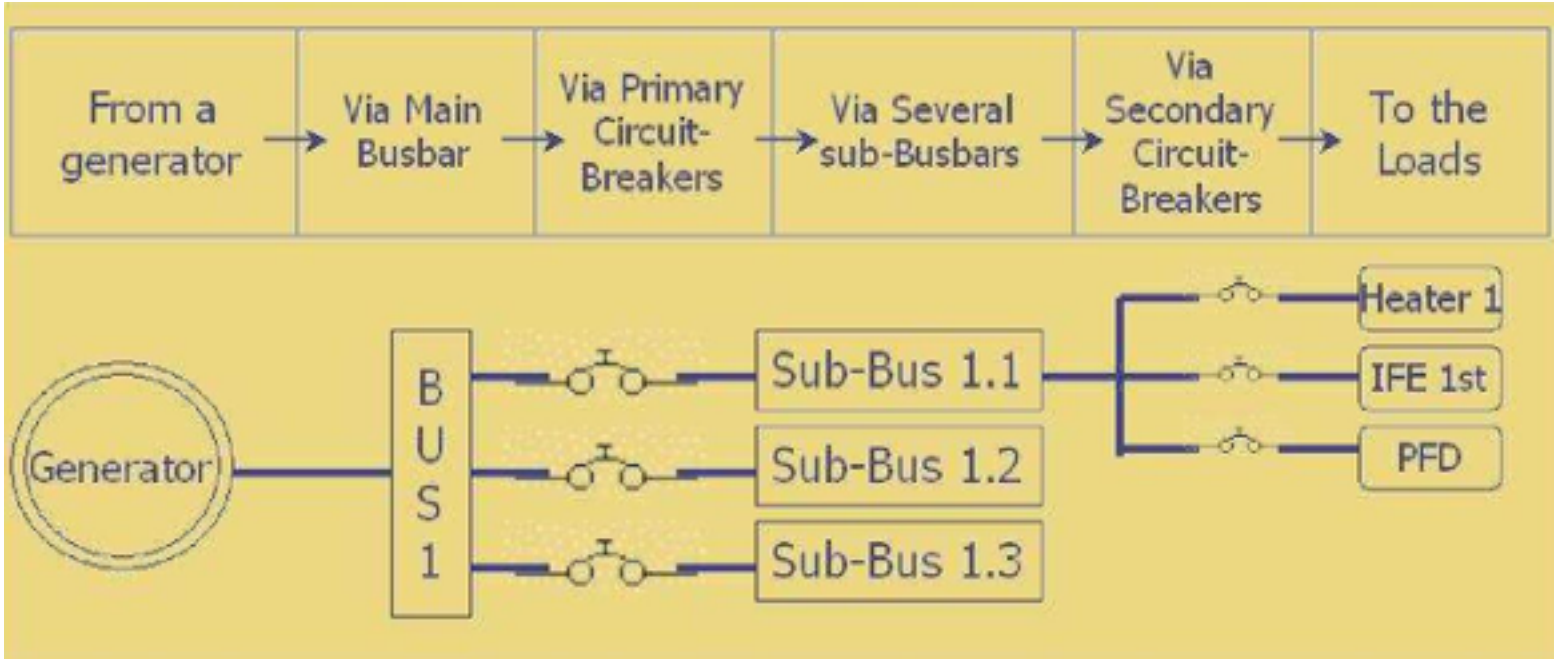
An aircraft electrical system includes:

- one or more generation systems
- one or more bus-bar
- a distribution system
- equipment

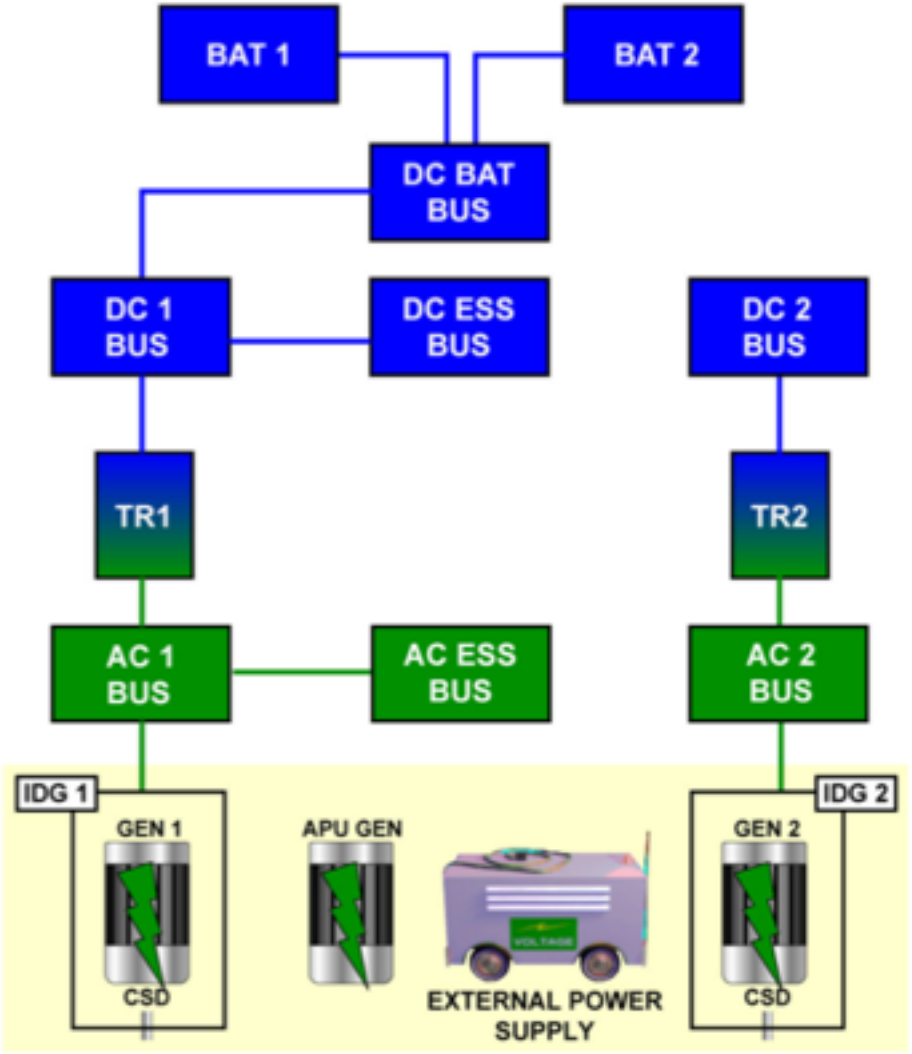


Electrical System Architecture

General Electrical Power Distribution Architecture

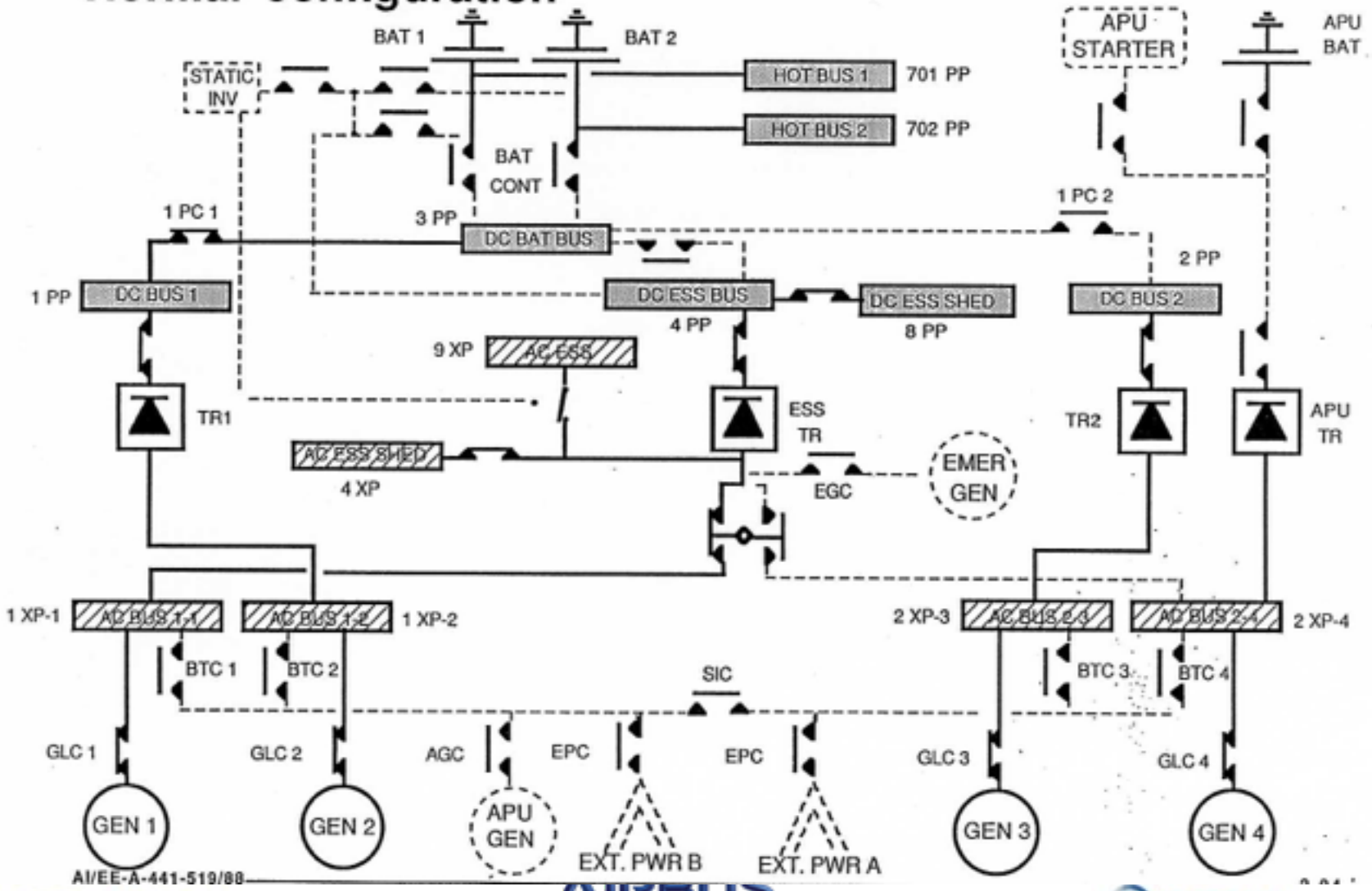


Integrated Drive Generator (IDG)
Constant Speed Drive (CSD)
Transformer Rectifier (TR)
Battery (BAT)
Essential (ESS)
Generator (GEN)



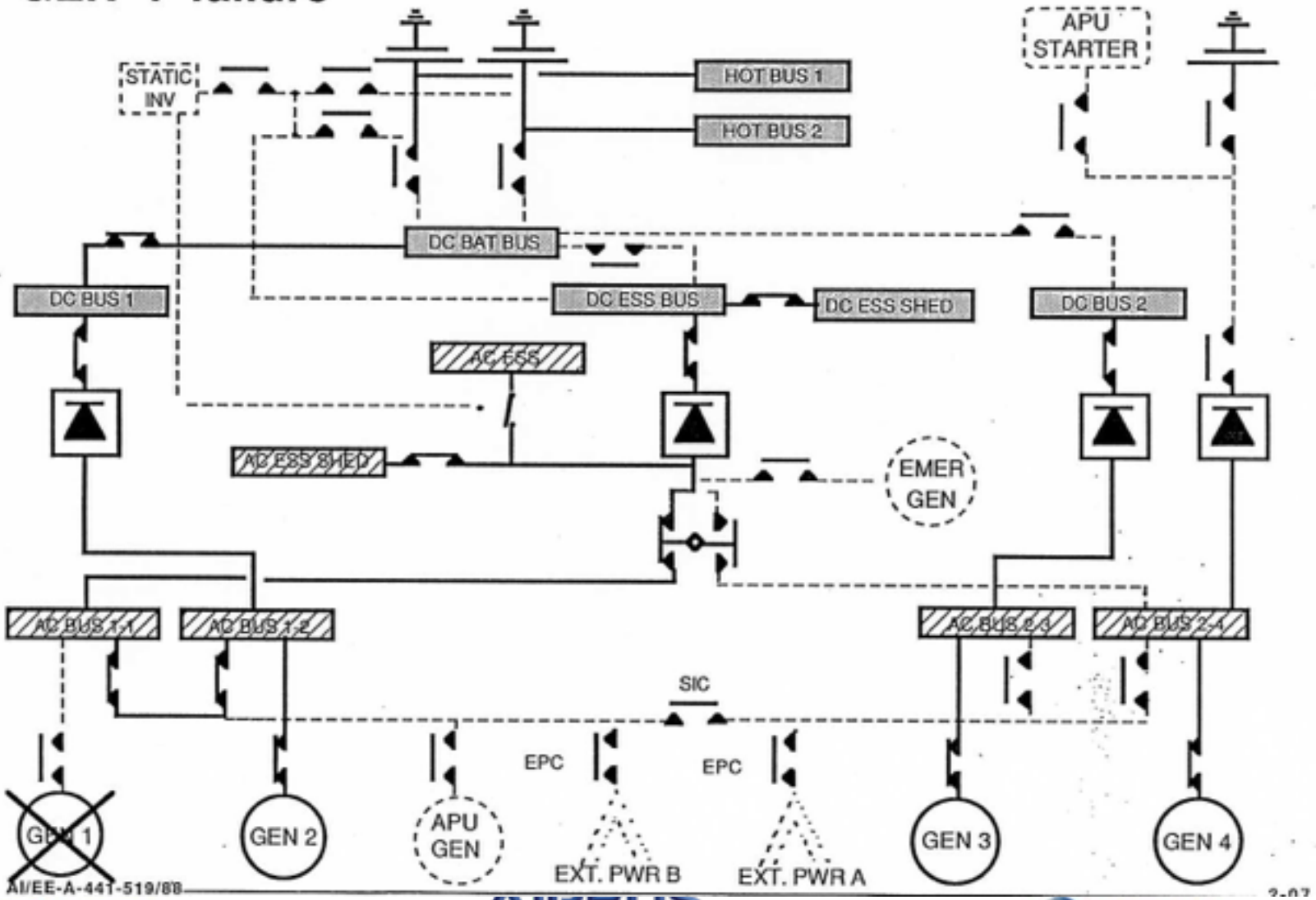
A340 - Electrical System

Normal configuration



A340 - Electrical System

GEN 1 failure



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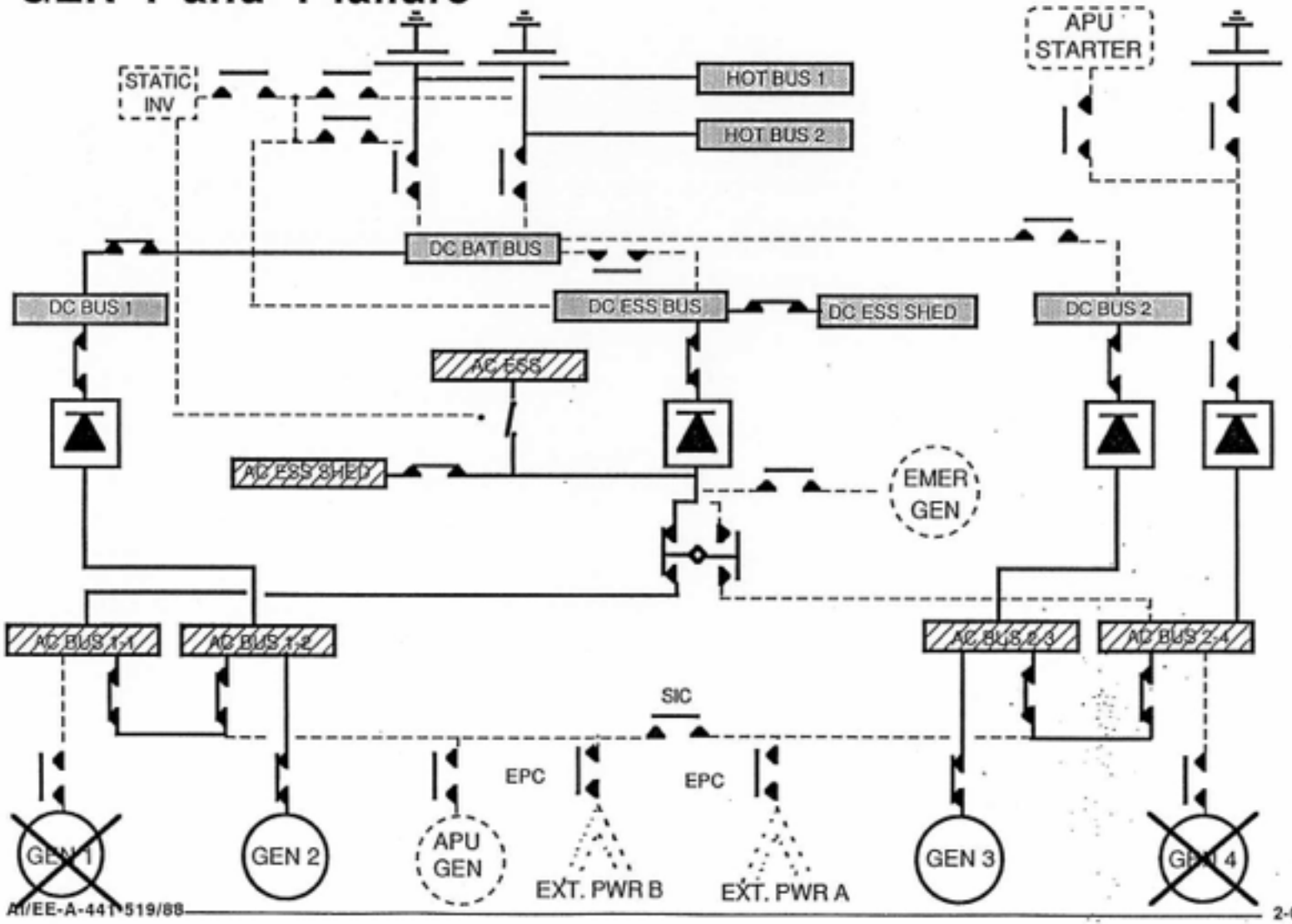
A340 - Electrical System

GEN 1 and 4 failure



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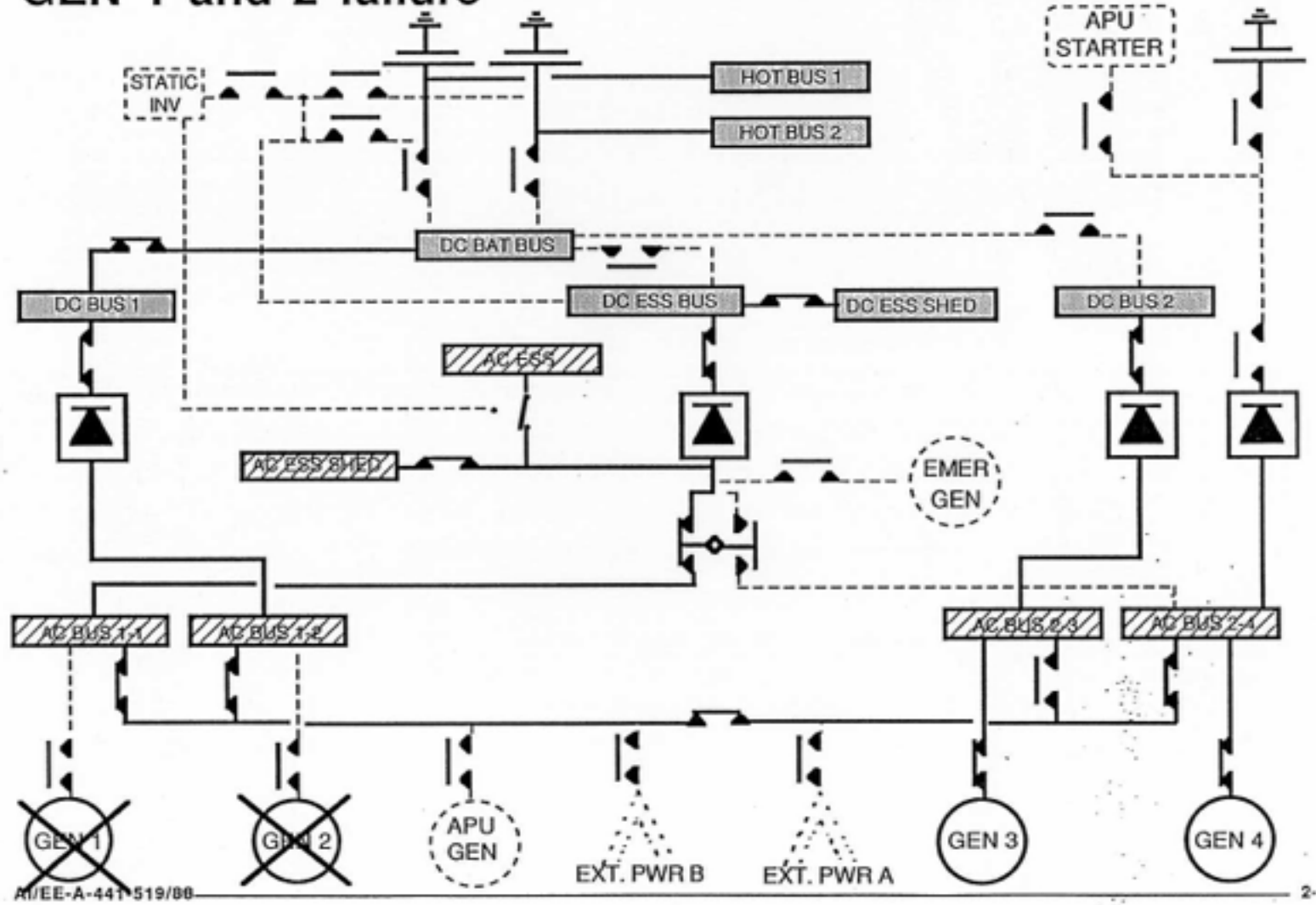
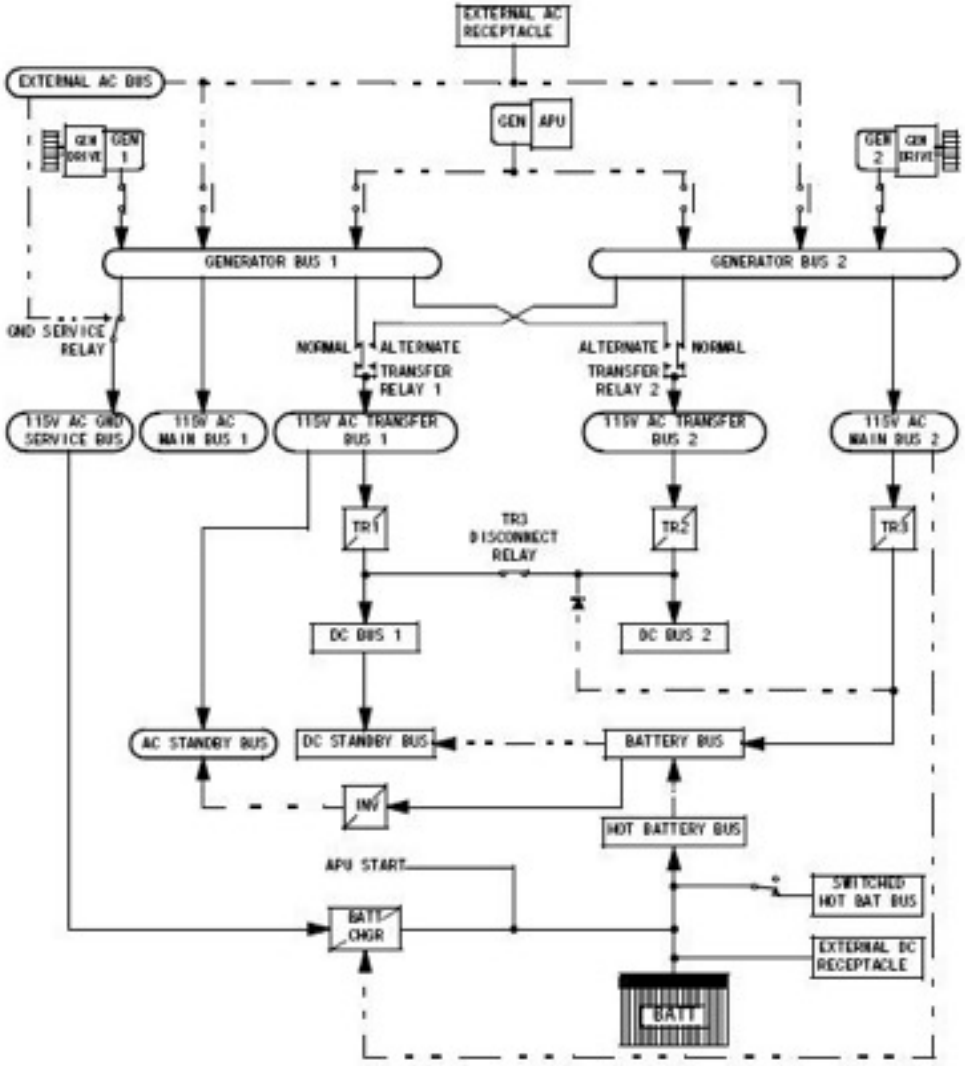
A340 - Electrical System

GEN 1 and 2 failure

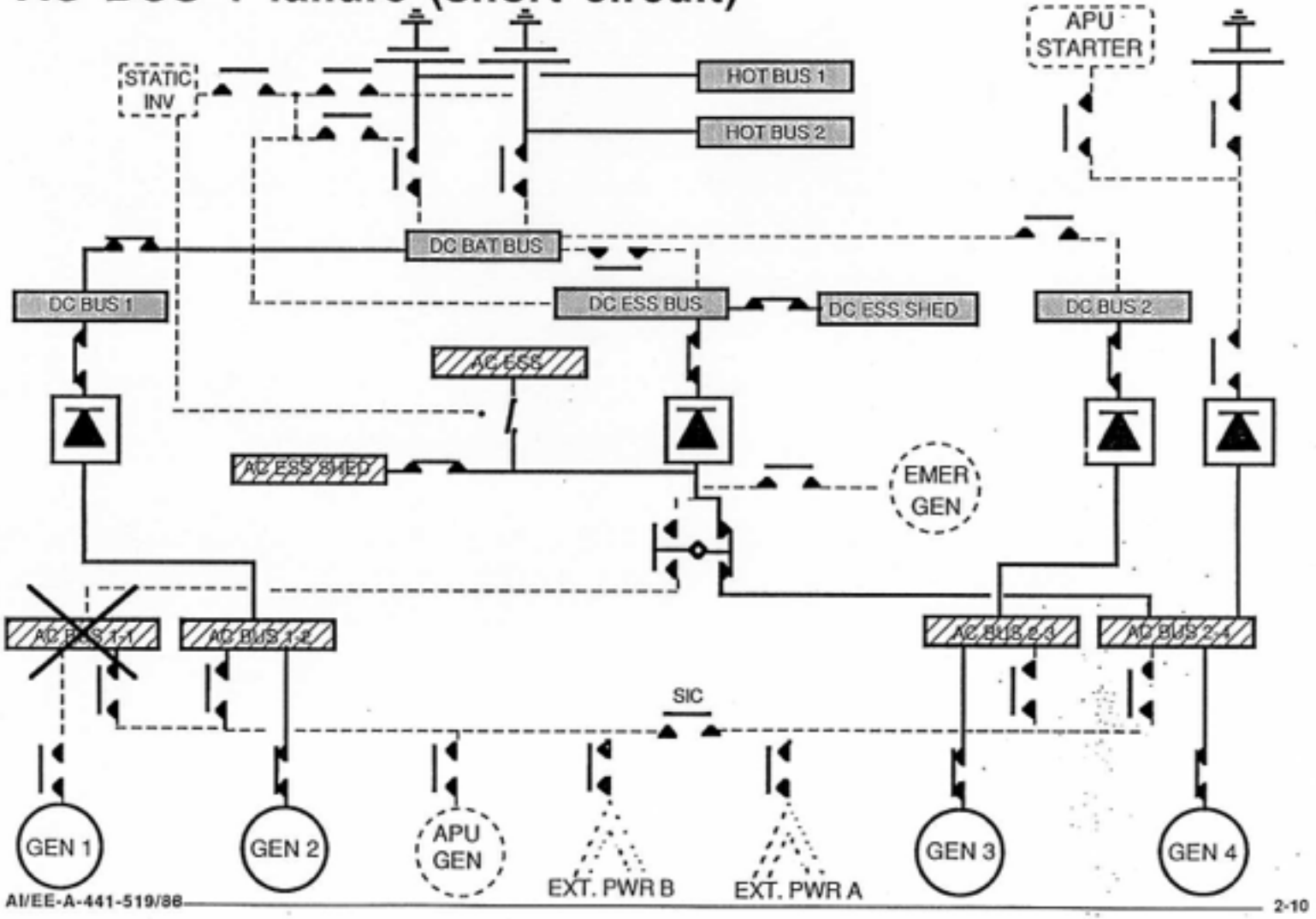


B737 el power supply



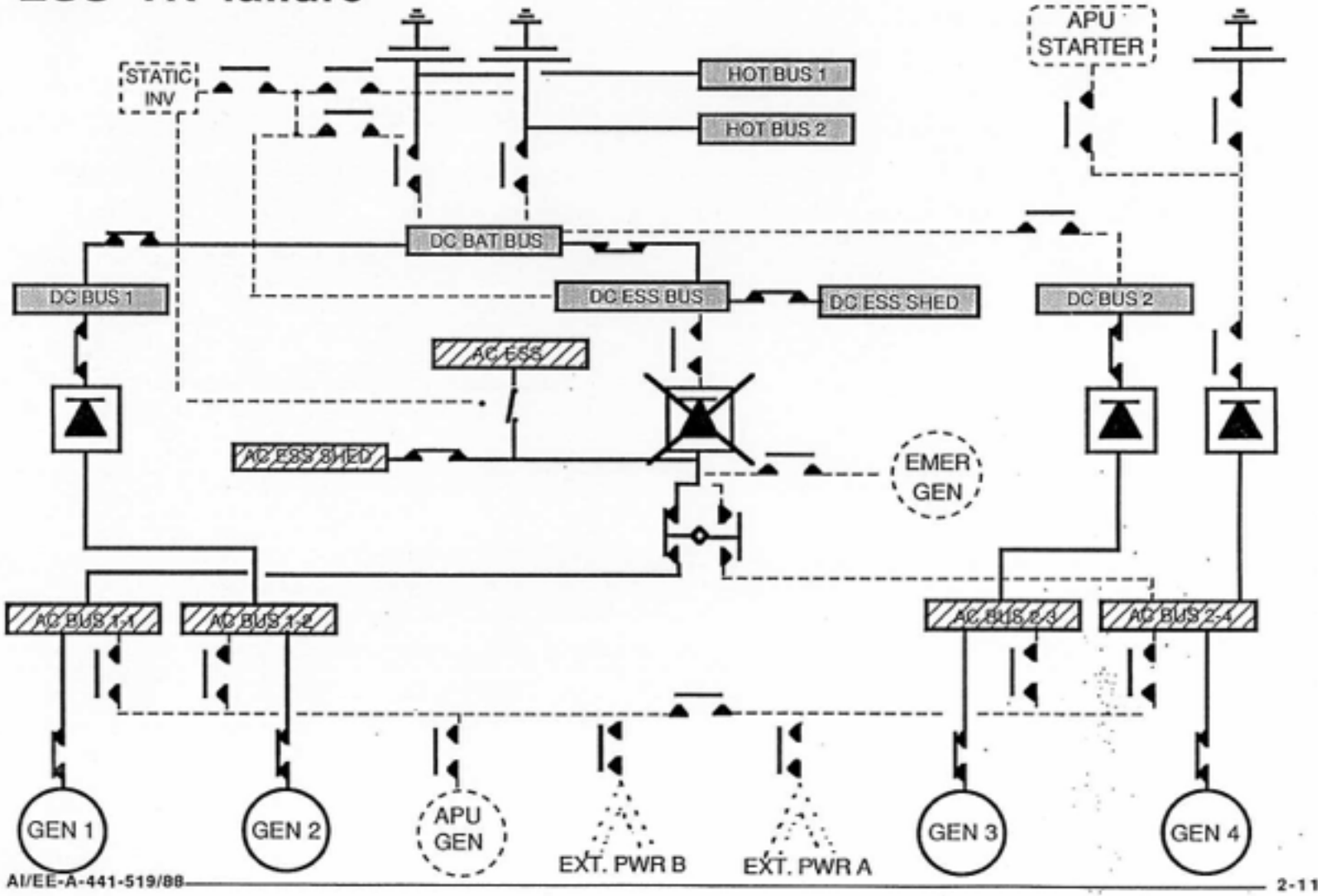
A340 - Electrical System

AC BUS 1 failure (short circuit)



A340 - Electrical System

ESS TR failure



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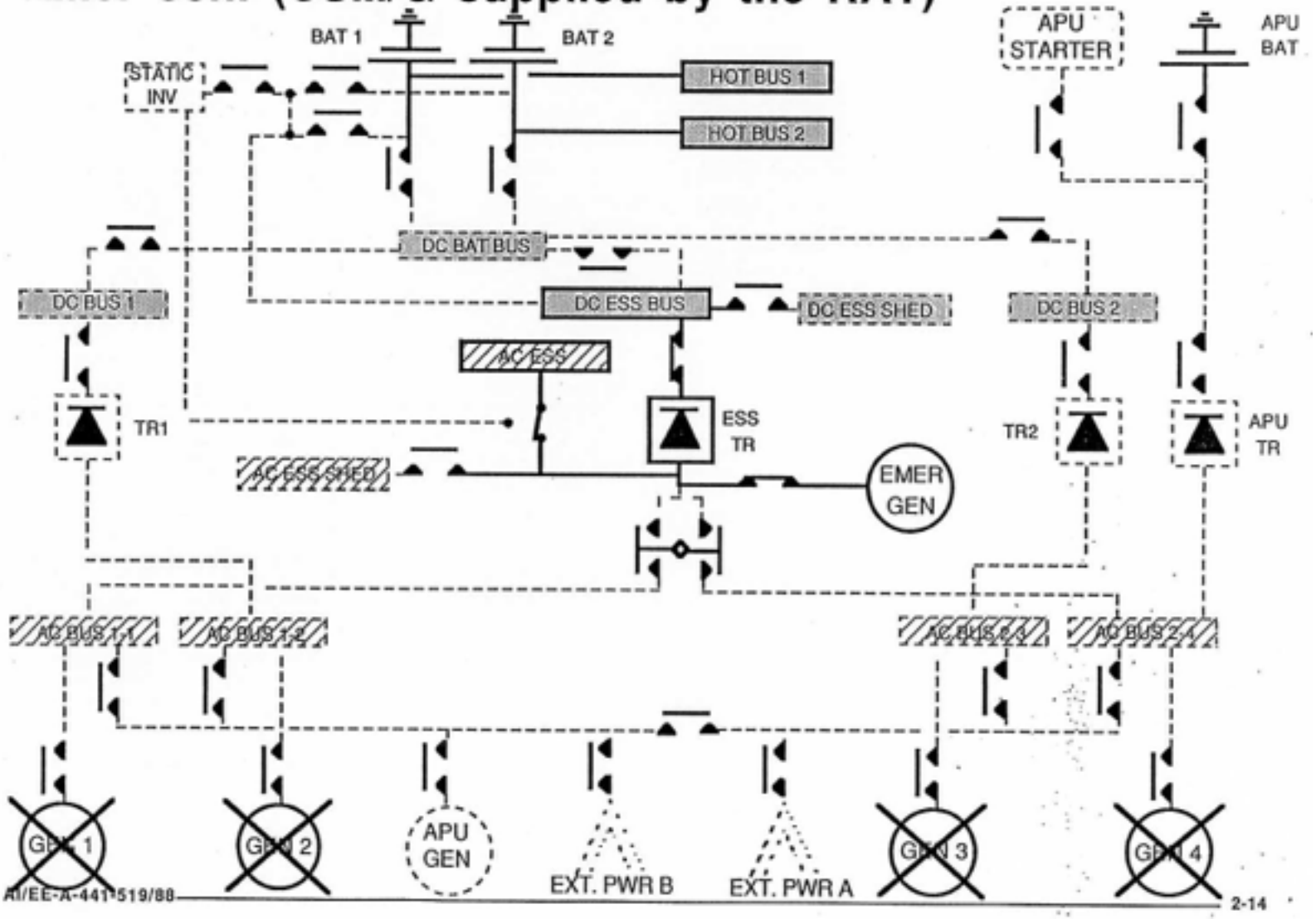
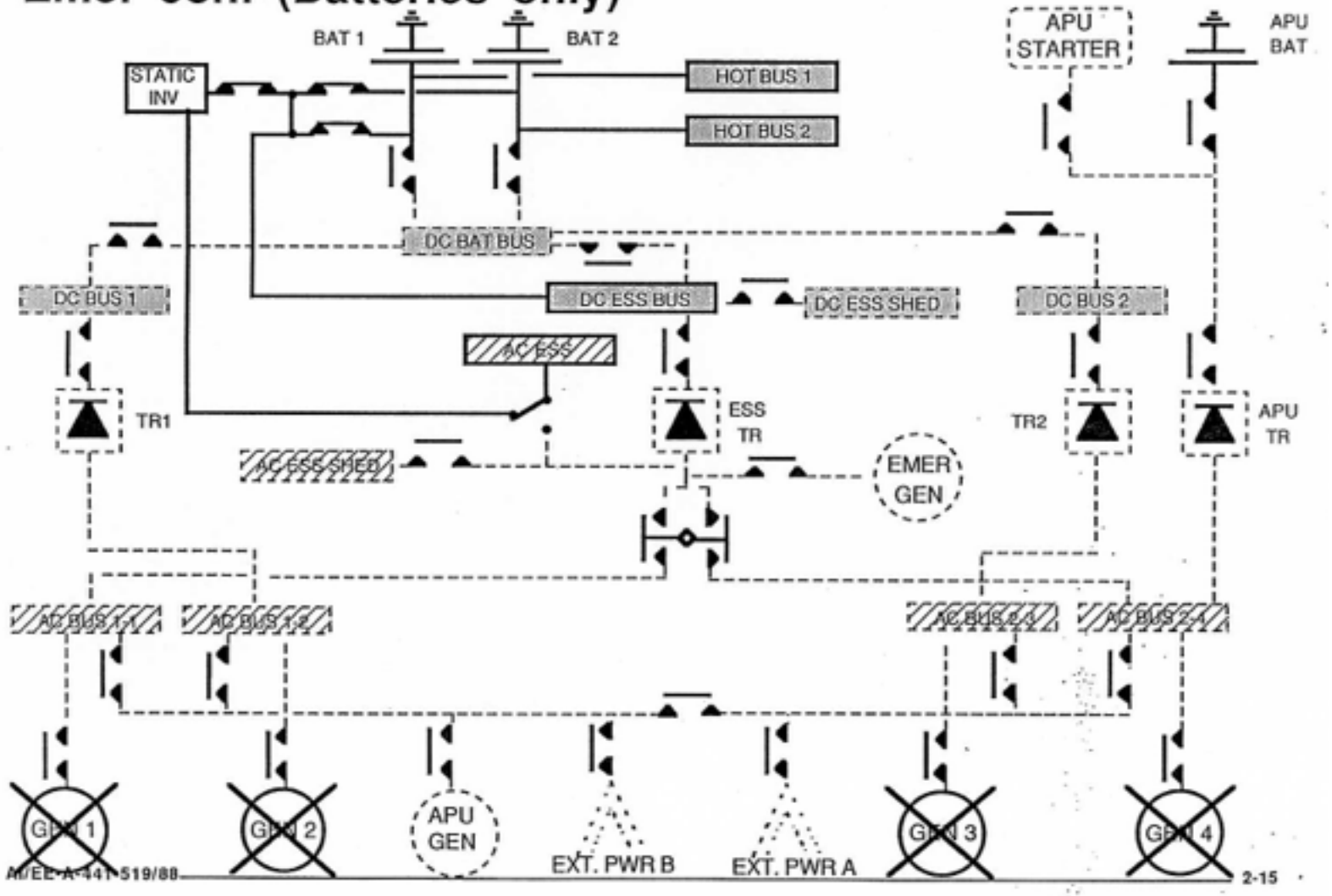
A340 - Electrical System

Emer conf (CSM/G supplied by the RAT)



A340 - Electrical System

Emer conf (Batteries only)



Summary

Reliability requirement / safety analysis

The goal of this analysis is to verify that the definition of the system is in compliance with the safety objectives. These safety objectives are determined depending on the consequences of the failure :

- Catastrophic event : objective < 10^{-9} / flight hour
- Hazardous : 10^{-7} < objective < 10^{-9} / f.h
- Critical : 10^{-5} < objective < 10^{-7} / f.h

To carry out this safety analysis the method is as follows :

- on the electrical system diagram the failure of every equipment is considered, in every case the consequences are analysed
- a new configuration (without the inoperative equipment) of the electrical system diagram is set up

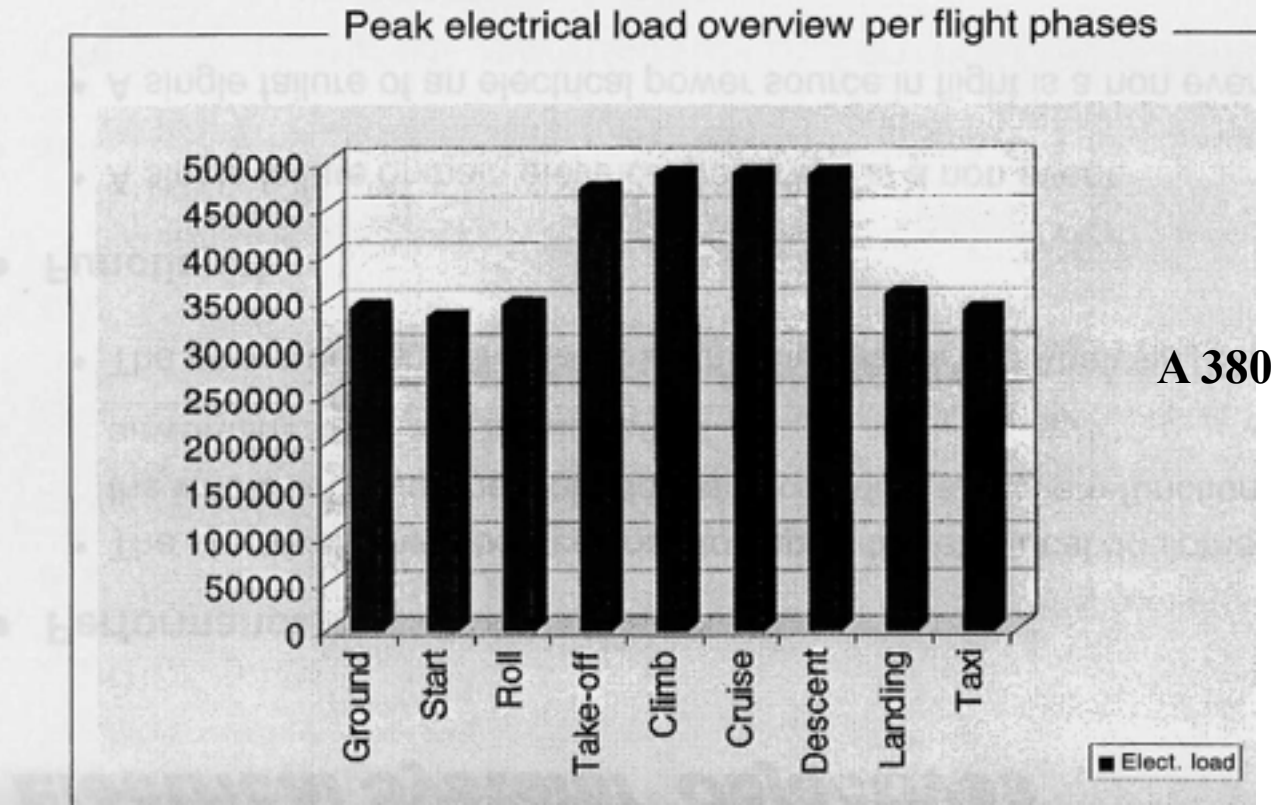
Based on Certification Specification (CS) 25:

Subpart F applicable, in particular CS25.1310 and electrical systems and equipment section from CS25.1351 to CS25.1365

CS25.1310: Power source capacity and distribution
CS25.1351: General
CS25.1353: Electrical equipment and installations
CS25.1355: Distribution system
CS25.1357: Circuit protective devices
CS25.1360: Precautions against injury
CS25.1362: Electrical supplies for emergency conditions
CS25.1363: Electrical system tests
CS25.1365: Electrical appliances, motors and transformers

Summary

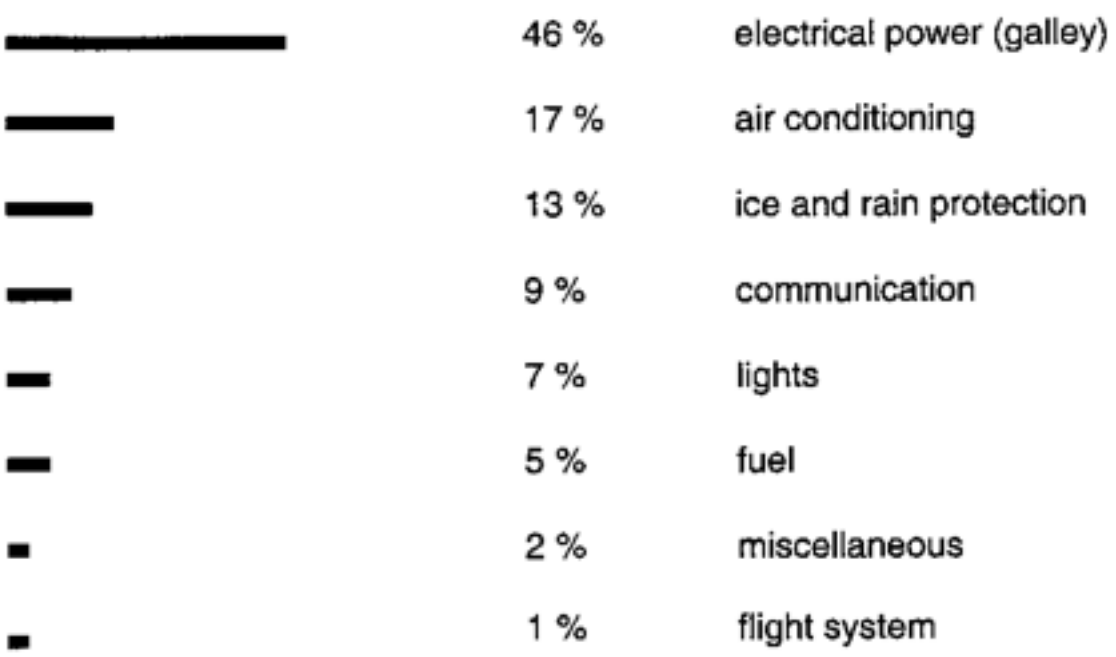
Electrical System: Load Analysis



A 380

DIFINITION AND FUNCTION continuation2

The share of electrical energy in cruise is: (Example A330)



46 %	electrical power (galley)
17 %	air conditioning
13 %	ice and rain protection
9 %	communication
7 %	lights
5 %	fuel
2 %	miscellaneous
1 %	flight system

- End of session,
- Thank you !
- Back up slides:

A320 Electrical Power system (1)

- There are two identical engine driven generators called Integrated Drive Generators (IDGs). They are used as the main power source to supply the A/C electrical network.
- The IDG basically contains, in a common housing, a generator and a Constant Speed Drive (CSD). The CSD gives a constant input speed to the generator, which is required for a constant output frequency.
- Each generator supplies 115V 400Hz AC to its own bus:
  - - generator 1 supplies AC bus 1,
  - - generator 2 supplies AC bus 2.
- This supply is known as split operation, which means that the AC power sources are never connected in parallel.
- Each AC bus supplies a Transformer Rectifier (TR):
  - - AC bus 1 supplies TR 1,
  - - AC bus 2 supplies TR 2.
- The TRs convert 115V AC into 28V DC to supply their associated DC buses, DC 1 and DC 2.

A320 Electrical Power system (2)

- DC bus 1 then supplies the DC BAT bus.
- The DC battery bus can charge the batteries or receive power from the batteries as a backup supply, if no other power sources are available.
- The electrical system also includes two ESSential (ESS) Buses. One is the AC ESS bus fed by AC bus 1 and the other is the DC ESS bus fed by DC bus 1. These buses are used to supply the most critical A/C systems.
- This is the basic electrical system.
- Other components which also supply the system.
  - The entire electrical network can also be supplied by the APU generator.
  - On the ground, the aircraft electrical network can be supplied by an external power source.
  - Any one of the power sources can supply the entire electrical network. As no parallel connection is allowed on this A/C (split operation), priorities have to be given to the different power sources in supplying the bus bars.
  - AC 1 and AC 2 buses are supplied in priority by their own side generator, then the external power, then the APU generator and then by the opposite generator.

PART5 WIRING SYSTEM continuation1

5.2 GENERAL RULES:

- Electric circuits which could, following an unexpected action, endanger flight safety, must be designed in such a way that such an action is inoperative or impossible.

- An electrical failure anywhere along the distribution line must not endanger the right operation of the line upstream.

-The supply of the electrical lines has to be done through circuits breakers or current limiters connected to the bus bars of the diverse subsystems.

- The electrical paths of the various distribution subsystems have to function so that the accidental cut of a wire strand of one subsystem does not affect the good functioning of the other subsystems.

- The isolation of the generation and distribution subsystems must be done for the whole system, from the generations supplies to the equipment and the command and control panels.

PART5 WIRING SYSTEM continuation2

SETTING IN REGARD TO THE SAFETY:

The safety requirements impose to have different sorts of distribution systems for the equipment according to their function:

NORMAL system

It supplies the equipment which are not essential for the safety in normal flight, that means without failure of electrical generation.The name of the bus bar can be NORMAL BUS BAR, MAIN BUS.

ESSENTIAL system

It supplies electricity, if the normal system is out of service, to the systems useful to fly with a total safety. The essential system has to be supplied through a selector switch, by every one electrical generation. The name of the bus is ESSENTIAL BUS BAR. Today this system is an emergency system.

PART5 WIRING SYSTEM continuation3

EMERGENCY system

This system supplies the equipment which are absolutely necessary in order to pursue the flight in a safe way.

This system has to be supplied by an on-board battery or emergency generator when all the generators are out of service. The name of the bus bar can be: EMERGECY BUS BAR, ULTIMATE EMERGENCY BUS BAR. In this case the equipment has to be supplied for about half an hour.

The HOT BUS is a bus which supplies equipment for which the current does not have to be cut (clock, fire-extinguisher …)

Remark: on board some aircraft (B 767, ATR 42…) we can find a STAND-BY BUSBAR or LAND RECOVERY BUSBAR. On this busbar are connected the equipment used for the take-off and the landing.

PART5 WIRING SYSTEM continuation4

5.4 DISTRIBUTION OF EQUIPMENT

The equipment are supplied according to their function in the aircraft:

- the equipment not essential for the flight safety are supplied by the **normal system** (automatic-pilot, galley, de-icing of the lateral windshield …)

- the equipment which enable the safety of the flight are supplied by the **essential system** (inertial platform, anti-collision light, temperature, frequency and voltage alternators…)

- the equipment essential for flight controls or the safety are supplied by the **emergency system** (public address, battery indicators, engine fire extinguisher...)

PART5 WIRING SYSTEM

5.1 REQUIREMENTS:

After the design of the system, the on-board setting of the wiring system has to respect some requirements:

- the structure is the electrical ground,
- the equipment have to be supplied by current is in accordance with the standards,
- the weight has to be minimum, and so must the cost be.

PART6 PROTECTION, WARNING AND INDICATING SYSTEM

6.1 PROTECTIONS

The goal of the protection is not to protect the equipment but to protect the system and specially the wiring system. The only existing problem is an over current due, for example, to a short-circuit on the wires or on the equipment itself.

The protections have to :

- protect the wires and the aircraft,

- avoid the disengagement of the protections upstream.

Every kind of wire, depending on its use, is defined with a density of current rating. Generally the wires can withstand an over current during a short time.

The 2 kinds of protection are:

- the fuses (quick-blow fuse, inertia fuse, current limited)

- the circuit breakers (thermal, magnetic, thermal and magnetic, reset circuit…)

Electrical Distribution Systems

Distribution System Equipments

Electrical center(s) made of

Busbars

Contactors

Controllers

Circuit Breakers (or SSPC)

Electrical Distribution Systems

Purpose of Electrical centers:

- Controls the reconfiguration of the network (especially under failure cases)
- « Split » high power provided by the sources into limited power for subbusbars
- Protect the sources
- Protect the loads

Therefore: contactors, busbars and C/B to be adapted to the power to be transmitted.

Electrical Distribution Systems

Distribution System Capacity

In case normal electrical network total loss probability is > 1.10-9, a segregated emergency generator/network is to be available induce having a emergency center fully independent of main centers and physically located at a different place

Electrical Distribution Network

Wire sizing

Network risks and mitigations

Electrical Distribution Network

Wire sizing

- Loads are supposed to work at nominal voltage +/- tolerances
  - Generator provides a nominal voltage +/- tolerances
  - Wires as no ideal component decrease voltage and induce heat
    - Gauge has to be chosen for minimizing voltage drop
      Wire duplication (for exchange surface increase) is to be considered to limit heat.

Electrical Distribution Network

Network risks and mitigation

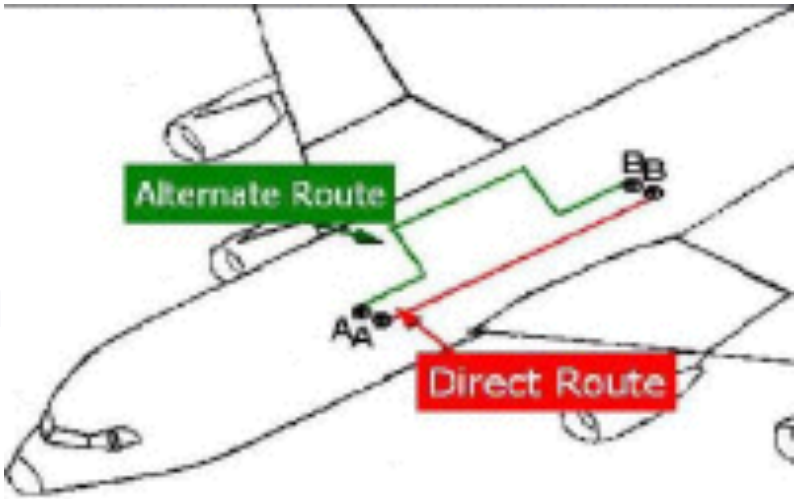
Network risks:

- Engine burst
- Tire burst
- Bird collision
- Short circuit
- Lightning
- EMI

Electrical Distribution Network

Network risks and mitigation

Network mitigation:



Segregation:

- Redundancy
- Signal independence
- Coherent harness signal

Protection:

- C/B, SSPC, RCCB, GFI, Fuse (it ensures crew protection as well)
- Shielded wire
- Physical structure/wire isolation

2.2 PRIMARY GENERATION SYSTEM continuation1

CONSTANT FREQUENCY

To supply a constant 400Hz frequency, 2 solutions are possible:

- to drive the alternator with a constant speed, and the constant speed is obtained thanks to a speed regulation, the name of this system is CSD. And today the alternator and the CSD are integrated in one equipment: the IDG. (CSCF)
- to supply a variable frequency and then change this variable frequency into a constant frequency with an electronic equipment (VSCF).

CSCF system

VSCF system

2.4 AIRCRAFT ON-BOARD BATTERY

FUNCTIONS:

A battery is a device which converts chemical energy into electrical energy.

In almost all aircraft electrical systems, a battery has the following principal functions:

- To help maintain the dc system voltage under transient conditions.

- To supply power for short term heavy loads when generator or ground power is not available, e.g. internal starting of an engine.

-Under emergency conditions, a battery is intended to supply limited amounts of power.

Two kinds of batteries are available:

- the lead-acid battery,

- the cadmium-nickel battery.

2.4 AIRCRAFT ON-BOARD BATTERY continuation1

LEAD-ACID BATTERY

These batteries are used generally for light aircraft.

- The nominal voltage is 12 V or 24 V (the electromotive force is 2.5 V by battery cell)
- The internal resistor is high : 30 mΩ for a 24 V battery
- The capacitor-weight ratio is poor : 38 kg for 30 Ah
- Problem: at the end of the charge vapours of hydrogen are emitted : risk of explosion

2.4 AIRCRAFT ON-BOARD BATTERY continuation2

CADMIUM-NICKEL BATTERY

- These batteries are used in commercial aviation every where in the world
- The nominal voltage is 24 V (the electromotive force is 1.4 V by battery cell)
- The internal resistor is low : 10 mΩ for a 24 V battery
- The capacitor-weight ratio is : 36 kg for 40 Ah

Two problems :

- It is not possible to know the charge level
- When the battery is old or in bad condition : risk of thermal runaway and explosion

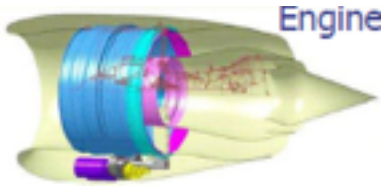
Electrical Generation Systems

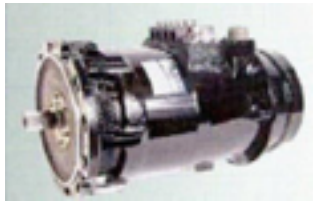
Generation System Equipments

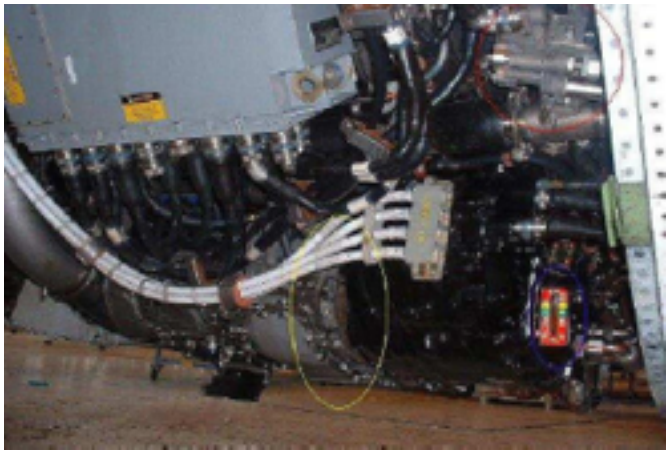
Generator (AC or DC) driven by (1/3):

Aircraft engine through a gear box

Engine







Electrical Generation Systems

Generation System Equipments

Generator (AC or DC) driven by (2/3):

- APU

Electrical Generation Systems

Generation System Equipments

Generator (AC or DC) driven by (3/3):

RAT

BENEFITS AND DRAWBACKS OF ALTERNATING CURRENT SYSTEM :

Benefits:

- The alternators do not have brush-ring, so no switching problems,
- Facility to change the voltage and to transform in direct current,
- The power-to-weight ratio is better than for the D.C. generators,
- Weight of wiring system light,
- Max power can reach up to 120kVA for one alternator.

Drawbacks:

- The parallel coupling for A.C. generators is complicated and difficult,
- Use of a speed regulator to drive the alternator to constant speed in order to generate a constant frequency,
- The starting torque of asynchronous motors is lower than those of direct current motors and the torque decreases when the frequency increase,
- Impossibility to stock alternative energy.