Prepared by :Ponnidevi.J

UNIT 3 AC POWER GENERATION DC POWER GENERATION BASICS 12 Hrs.

Types of alternator – alternator rectifier unit – constant speed alternator – wild frequency alternator – brush less alternator – alternator control unit - synchronizing of alternator – charging and cooling - Disconnection and connection GCU: - Line contactors/ Transfer contactors Static invertors- testing the operation. Auto transformers. Current transformers- differential protection APU – purpose – operation – starting of engine– precautions to be observed before starting –– limitations of starting APU. DC generators – construction – Starter generator – checking and testing of generator parts – functional check of generator on aircraft. Paralleling of DC buses. TRUs and DC power generation.

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Alternators

• Three-phase AC generators called alternators provide most of the electrical power we use today.

• Electrical power companies use alternators rated in gigawatts. • 1 gigawatt = 1,000,000,000 watts

- Alternators use the same operating principle as direct-current generators.
- However, alternators have no commutator to change the armature AC into DC.
- Most alternators are three-phase

Construction

• There are two basic types of alternators

– revolving-armature-type alternators

– Revolving-field-type alternators

Revolving-Armature-Type Alternators

• The revolving-armature type is the least used of the two basic types

• This type uses sliprings instead of a commutator.

• The armature windings are rotated inside a magnetic field.

• This type has very limited output power.

Revolving-Field-Type Alternators

• The revolving-field type uses a stationary armature called a stator and a rotating magnetic field.

• This design permits much higher power output.

3.2 Constant speed drive/integrated drive generator

As an example we may consider the constant speed drive unit (C.S.D.) which is based on Sundstrand design and is in use in several current types of turbojet-powered aircraft. It employs a hydro-mechanical variable-ratio drive which, in its basic form, consists of a variable-displacement swash plate type of hydraulic pump and a constant displacement swash plate type of motor. The oil for system operation is supplied by charge pumps and governor systems fed from a reservoir which is pressurized by air tapped from the low-pressure compressor of the engine. Power from the engine is transmitted through an input shaft and gears, to a hydraulic cylinder block common to both pump and motor, and by the action of the internal hydraulic system, is finally transmitted tothe motor and output gears and shaft coupled to the generator. The principle is illustrated very simply in Fig. 3.3.

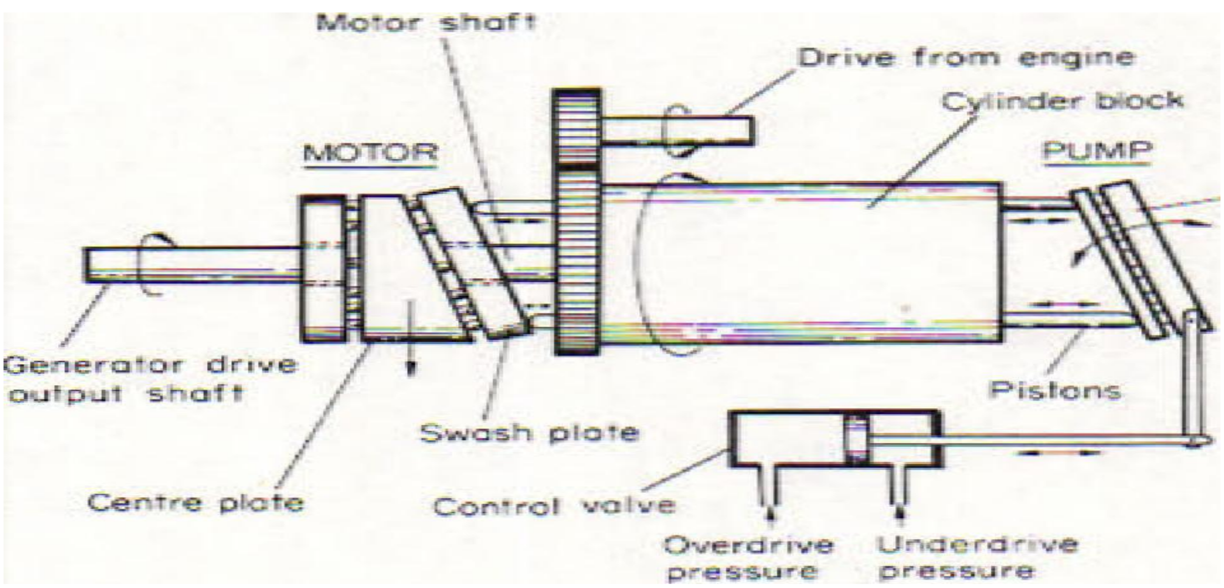

Fig 3.3 Principle of constant speed drive unit

When the engine output is exactly equal to the required generator speed, the oil pressure and flow within the hydraulic system are such that the motor is hydraulically locked to the cylinder block and they rotate together; thus, the whole transmission system acts as a fixed coupling. If, however, there is a change in engine and input shaft speed, the governor system senses this and applies a greater or smaller pressure to the pump to vary the angle of its swash-plate.

For example, if engine output is slower than the required generator speed, called an "overdrive" condition, the pressure increases; conversely, in an "underdrive" condition when engine output is faster, the pressure decreases.

Variations in the angle of the swash-plate also varies the stroke of the pump pistons as they go round with the cylinder block, so that either a greater or smaller (underdrive) pressure is transmitted to the motor pistons. The motor pistons in turn exert a greater or smaller pressure on the motor swash-plate assembly made up of two stationary plates which sandwich an eccentric centre plate coupled to the output shaft, and free to rotate against ball bearings.

Thus, assuming that an overdrive condition arises an increased pressure will be exerted by the motor pistons on the centre plate and there will be a tendency for it to be squeezed out from between the plates. However, since the plate is restrained to rotate independently about a fixed axis it will do so relative to the cylinder block, and at a faster rate, thereby overcoming the tendency for the engine to slow the generator down. In an under drive condition, the pressure on the eccentric centre plate is decreased so that it will rotate at a slower rate relative to the cylinder block

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FREQUENCY-WILD SYSTEMS

A frequency-wild system is one in which the frequency of its generator voltage output is permitted to vary with the rotational speed of the generator.

Although such frequency variations are not suitable for the direct operation of all types of a.c. consumer equipment, the output can (after constant voltage regulation) be applied directly to resistive load circuits such as electrical de-icing systems, and can also be transformed and rectified to provide medium-or low-voltage d.c. Several types of aircraft currently in service employ frequency-wild generators in either or both of the foregoing applications, and some details of the construction and operation of two representative machines are given in the following paragraphs.

Generator Construction

The construction of a typical generator utilized for the supply of heating current to a turbo-propeller engine de-icing system is illustrated in Fig. 3.7.

It has a three-phase output of 22 kVA at 208 volts and it supplies full load at this voltage through a frequency range of 280 to 400 Hz. Below 280 Hz the field current is limited and the output relatively reduced.

The generator consists of two major assemblies: a fixed stator assembly in which the current is induced, and a rotating assembly referred to as the rotor.

The stator assembly is made up of high permeability laminations and is clamped in a main housing by an end frame having an integral flange for mounting the generator at the corresponding drive outlet of an engine-driven accessory gear-box.

The stator winding is star connected, the star or neutral point being made by linking three ends of the winding and connecting it to ground The other three ends of the winding are brought out to a three-way output of the winding are brought out to a three-way output

The rotor assembly has six salient poles of laminated construction; their series-connected field windings terminate at two slip rings secured at one end of the rotor shaft

Three spring-loaded brushes are equispaced on each slip ring and are contained within a brush-gear housing which also forms a bearing support for the rotor.

The brushes are electrically connected to d.c. input terminals housed in an excitation terminal box mounted above the brush-gear housing.

The terminal box also houses capacitors which are connected between the terminals and frame to suppress interference in the reception of radio signals.

At the drive end, the rotor shaft is serrated and an oil seal, housed in a carrier plate bolted to the main housing, is fitted over the shaft to prevent the entry of oil from the driving source into the main housing

The generator is cooled by ram air passing into the main housing via an inlet spout at the slip ring end, the air escaping from the main housing through ventilation slots at the drive-end.

An air-collector ring encloses the slots and is connected to a vent through which the cooling air is finally discharged. Provision is made for the installation of a thermally-operated switch to cater for an overheat warning requirement

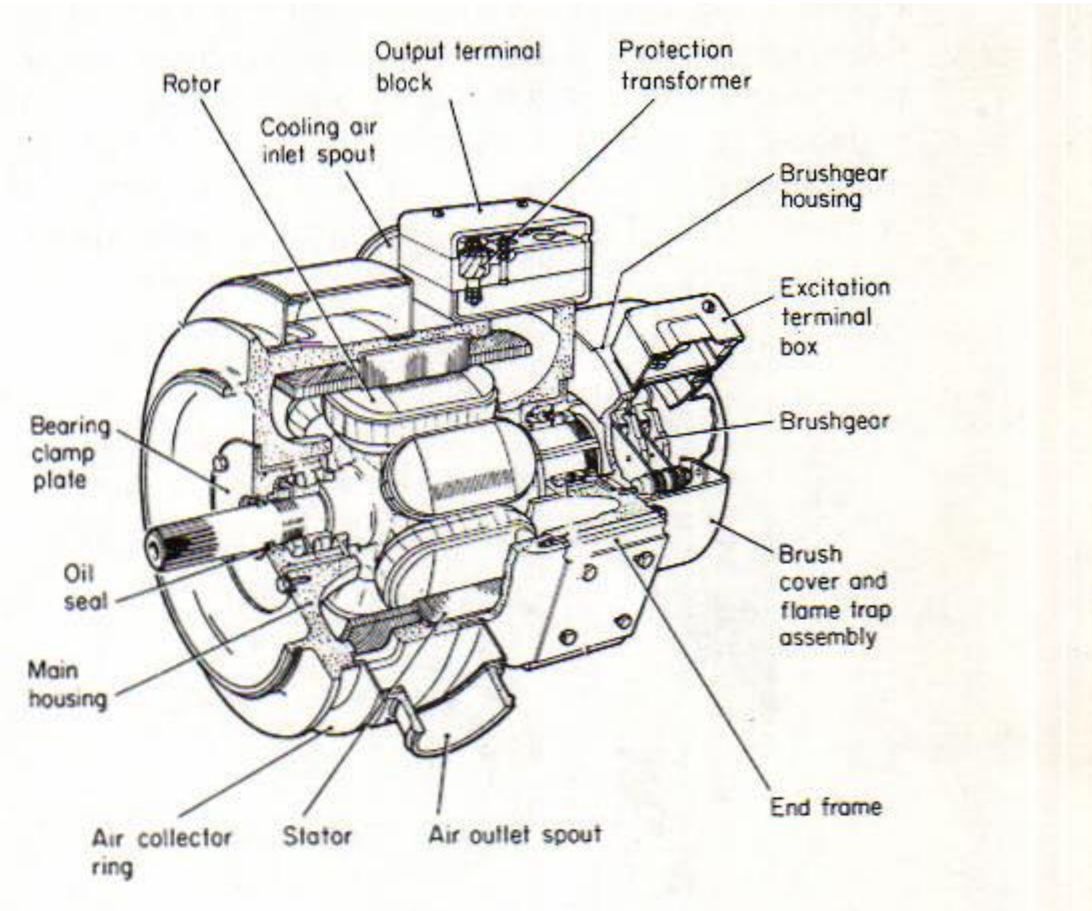


Fig. 3.7 construction of a typical generator

The basic construction of the generator follows the general pattern in that it consists of a rotor, stator, slip-ring and brush assembly and end frames. In addition six silicon diodes are carried in an end frame and are connected as a bridge rectifier to provide the d.c. for the aircraft's system.

The principal constructional features are

The rotor is formed by two extruded steel pole pieces which are press-fitted on to the rotor shaft to sandwich a field coil and thus form the core of the electromagnet.

Each pole piece has six "fingers" which, in position, mesh but do not touch. The field coil is connected to the slip rings which are also press-fitted on to the rotor shaft and supplied, via the brushes, with direct current from the aircraft's system.

The stator is made up of a number of steel stampings riveted together to form the core around which the three star-connected phase coils are wound. One end of each winding is connected to the bridge rectifier assembly while the other ends are joined together to form the neutral point. The stator assembly is clamped between the end frames.

Cooling of the generator is provided by a fan at the driving end and by air passing through slotted vents in the slip-ring end frame. Heat at the silicon diodes is dissipated by mounting them on steel plates known as "heat sinks".

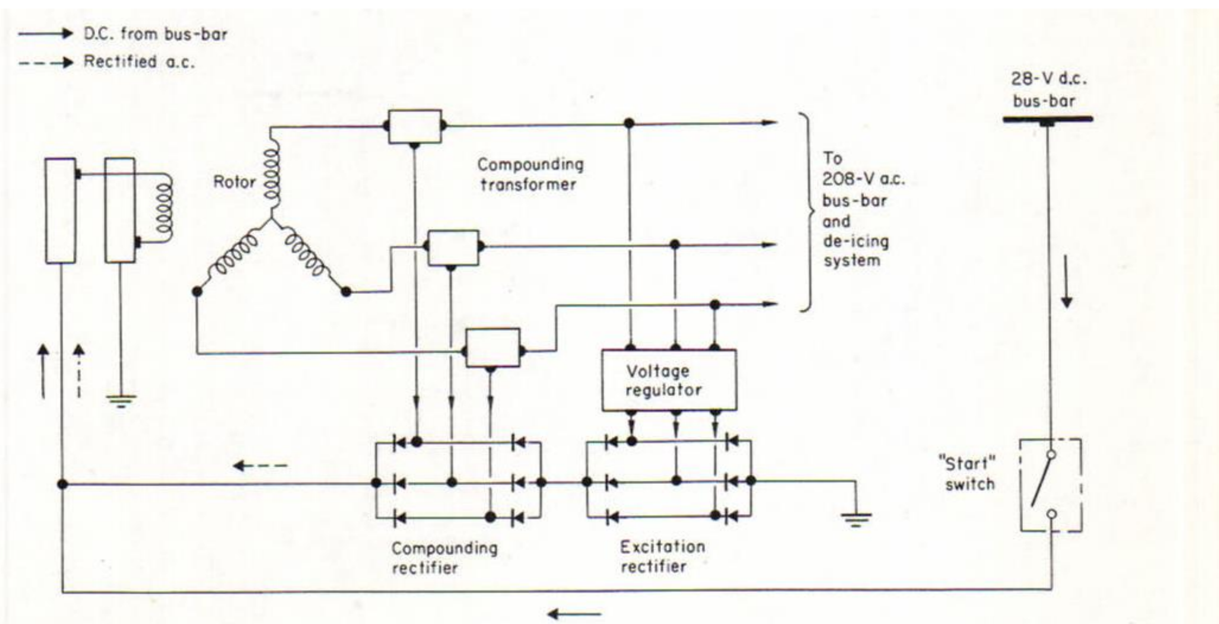


Fig 3.9 wild frequency generator excitation

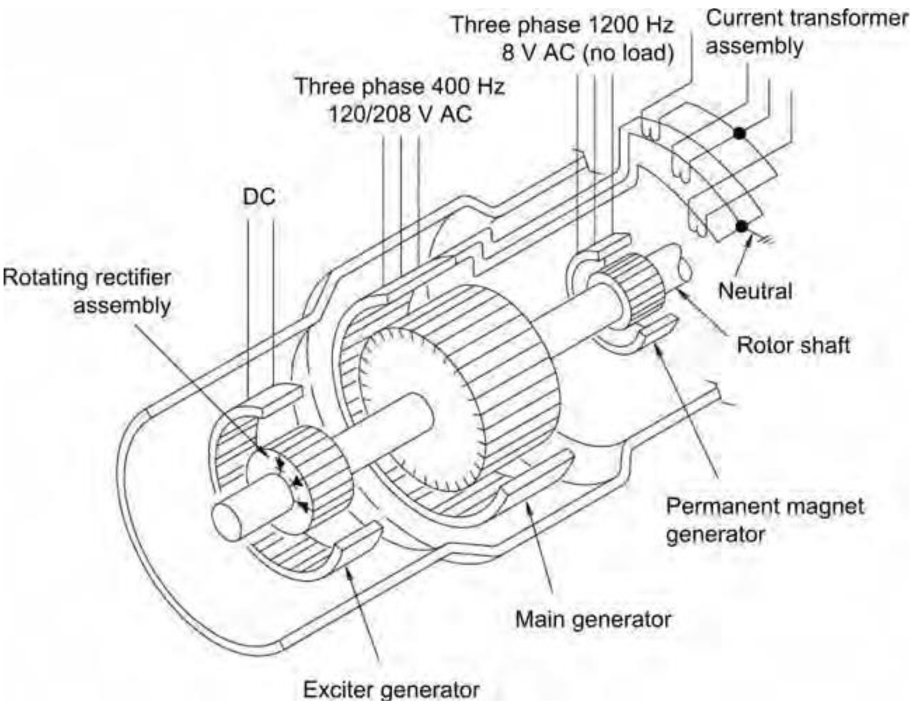
Figure is th schematic representation of the method adopted for the generator illustrated in figure in this case , excitation of the rotor field is provided by d.c from the main busbar and by rectified a.c . the principal components and sections of the control system associated with excitation are : the contol switch , voltage regulation section , field excitation rectifier and current compounding section consisting of a three phase current transformer and rectifier.

The primary windings of the compounding transformer are in series with the three phases of the generator and the secondary windings in series with the compounding rectifier.

When the control switch is in the "start" position, d.c. from the main busbar is supplied to the slip-rings and windings of the generator rotor; thus, with the generator running, a rotating magnetic field is set up to induce an alternating output in the stator. The output is tapped to feed a magnetic amplifier type of voltage regulator which supplies a sensing current signal to the excitation rectifier (see p. 38). When this signal reaches a pre-determined off-load value, the rectified *a.c.* through the rotor winding is sufficient for the generator to become self-excited and independent of the main bulbar supply which is then disconnected.

The maximum excitation current for wide-speed range high-output generators of the type shown in Fig. 3.7 is quite high, and the variation in excitation current necessary to control the output under varying "load" conditions is such that the action of the voltage regulator must be supplemented by some other medium of variable excitation current. This is provided by the compounding transformer and rectifier, and by connecting them in the manner already described, direct current proportional to load current is supplied to the rotor field windings.

BRUSHLESS GENERATORS



Basic Theory

an electric current is passed through a coil of wire, a magnetic field is produced (an electromagnet). Conversely, when a magnetic field is moved through a coil of wire, a voltage is induced in the wire. The induced voltage becomes a current when the electrons have some place to go such as into a battery or other load. [See Word~Power in issue ___] Both of these actions take place in alternators, motors and generators or dynamos. Voltage is generated when a coil of wire is moved through a magnetic field. It doesn't matter whether the coil is moving or the magnetic field is moving. Either configuration works equally well and both are used separately or in combination depending on mechanical, electrical and other objectives. The old DC generators (dynamos) used a stationary field and rotating armature. Automotive alternators use the opposite configuration with a rotating field and stationary armature. In a brushless alternator, both configurations are used in one machine

Terminology

The stationary part of a motor or alternator is called the stator and the rotating part is called the rotor. The coils of wire that are used to produce a magnetic field are called the field and the coils that produce the power are called the armature. This can be confusing because most of us equate the armature with the rotor. Traditionally, the armature was on the rotor but this is not necessarily the case. The two terms are not synonymous. For example, in the common automotive alternator, the field is on the rotor and the armature is on the stator. The rotor and stator are the mechanical configuration. The field and the armature are the electrical components. Either electrical component can be located on either of the two mechanical parts. The coils of wire that are used to create the field and the armature are sometimes referred to as the “windings”.

Construction

A brushless alternator is composed of two alternators built end-to-end on one shaft. Smaller brushless alternators may look like one unit but the two parts are readily identifiable on the large versions. The larger of the two sections is the main alternator and the smaller one is the exciter. The exciter has stationary field coils and a rotating armature (power coils). The main alternator uses the opposite configuration with a rotating field and stationary armature.

Exciter

The exciter field coils are on the stator and its armature is on the rotor. The AC output from the exciter armature is fed through a set of diodes that are also mounted on the rotor to produce a DC voltage. This is fed directly to the field coils of the main alternator, which are also located on the rotor. With this arrangement, brushes and slip rings are not required to feed current to the rotating field coils. This can be contrasted with a simple automotive alternator where brushes and slip rings are used to supply current to the rotating field.

Main Alternator

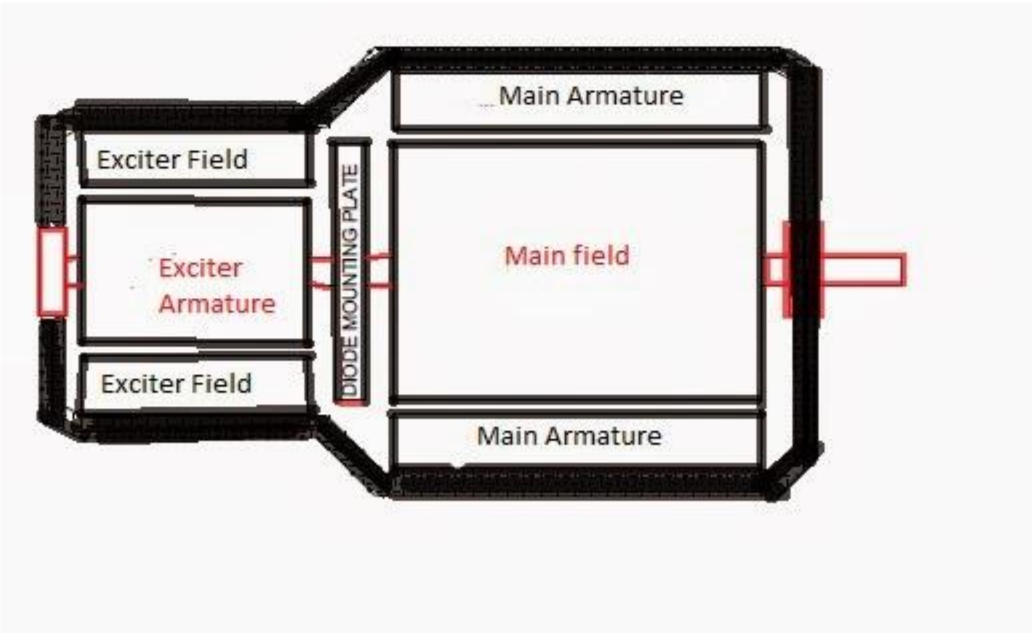
The main alternator has a rotating field as described above and a stationary armature (power generation windings). This is the part that can be confusing so take note that in this case, the armature is the stator, not the rotor. With the armature in the stationary portion of the alternator, the high current output does not have to go through brushes and slip rings. Although the electrical design is more complex, it results in a very reliable alternator because the only parts subject to wear are the bearings.

Control System

Varying the amount of current through the stationary exciter field coils controls the strength of the magnetic field in the exciter. This in turn controls the output from the exciter. The exciter output is fed into the rotating field of the main alternator to supply the magnetic field for it. The strength of the magnetic field in the main alternator then controls its output. The result of all this is that a small current, in the field of the exciter indirectly controls the output of the main alternator and none of it has to go through brushes and slip-rings.

AVR

In many diagrams and explanations, you will encounter the term “AVR”, with no explanation of what it is. AVR is an abbreviation for Automatic Voltage Regulator. An AVR serves the same function as the “voltage regulator” in an automobile or or the “regulator” or “controller” in a home power system.



Brushless generator

The excitation circuit arrangement for the generator is shown schematically in Fig. 3.15. When the generator starts running, the flux from the permanent magnets of-the a.c. exciter provides the initial flow of current in its rotor windings. As a result of the initial current flow, armature reaction is set up, and owing to the position of the permanent magnetic poles, the reaction polarizes the main poles of the exciter stator in the proper direction to assist the voltage regulator in taking over excitation control.

The three-phase voltage produced in the windings is supplied to the rectifier assembly, the d.c. output of which is, in turn, fed to the field coils of the main generator rotor as the required excitation current. A rotating magnetic field is thus produced which induces a three-phase voltage output in the main stator windings. The output is tapped and is fed back to the shunt field windings of the exciter, through the voltage regulator system, in order to produce a field supplementary to that of the permanent magnets. In this manner the exciter output is increased and the main generator is enabled to build up its output at a faster rate. When the main output reaches the rated value, the supplementary electromagnetic field controls the excitation and the effect of the permanent magnets is almost eliminated by the opposing armature reaction. During the initial stages of generator operation, the current flow to the exciter only passes through one of the two shunt field windings, due to the inverse temperature/ resistance characteristics of the thermistor. As the temperature of the winding increases, the thermistor resistance decreases to allow approximately equal current to flow in both windings, thus maintaining a constant effect of the shunt windings.

In the event that excitation current should suddenly increase or decrease as a result of voltage fluctuations due, for example, to switching of loads, a current will be induced in the stabilizing winding since it acts as a transformer secondary winding. This current is fed into the voltage regulator as a feedback signal to so adjust the excitation current that voltage fluctuations resulting from any cause are opposed and held to a minimum

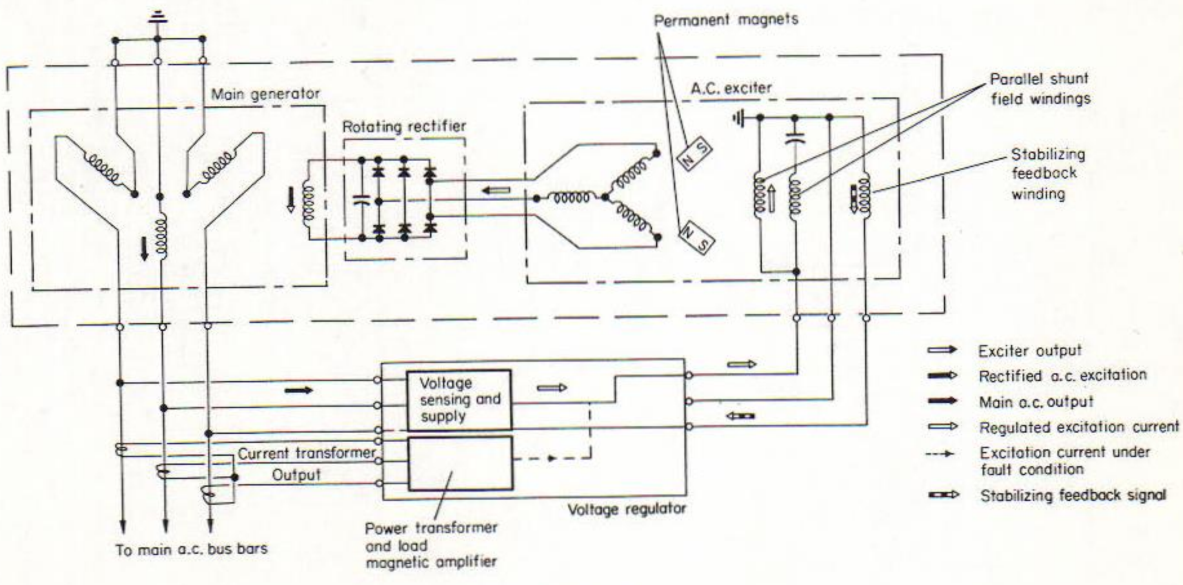


Fig 3.15
Circuit diagram of brushless generator

ALTERNATOR CONTROL UNIT ;

The alternator control unit is a solid state voltage regulator with an overvoltage sensor and low-voltage sensor incorporated in the unit. The control unit is not adjustable and is a remove-and-replace item.

The solid-state control for an alternator that contains the voltage and current sensors and controls the alternator field current to maintain the correct voltage and current within the alternator rating.

the Generator Control Unit (GCU) is built into a cast aluminum housing; the unit is water-cooled. The main task of the GCU is to convert the generator's variable frequency and variable voltage into a stabilized 750VDC voltage bus.

The DC outputs are protected against electrical surge. The converter is equipped with various safety features: for instance in case of an electrical fault the main output of the high voltage bus can be completely disconnected by an internal circuitbreaker

Basic Functions of a Generator Control Unit

The generator control unit (GCU) is more commonly found on turbine power aircraft. The most basic generator control units perform a number of functions related to the regulation, sensing, and protection of the DC generation system.

Voltage Regulation

The most basic of the GCU functions is that of voltage regulation. Regulation of any kind requires the regulation unit to take a sample of an output and to compare that sample with a controlled reference. If the sample taken falls outside of the limits set by the reference, then the regulation unit must provide an adjustment to the unit generating the output so as to diminish or increase the output levels. In the case of the GCU, the output voltage from a generator is sensed by the GCU and compared to a reference voltage. If there is any difference between the two, the error is usually amplified and then sent back to the field excitation control portion of the circuit. The field excitation control then makes voltage/excitation adjustments in the field winding of the generator in order to bring the output voltage back into required bus tolerances.

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Overvoltage Protection

Like the voltage regulation feature of the GCU, the overvoltage protection system compares the sampled voltage to reference voltage. The output of the overvoltage protection circuit is used to open the relay that controls the output for the field excitation. These types of faults can occur for a number of reasons. The most common, however, is the failure of the voltage regulation circuit in the GCU

Two alternators are paralleled whenever the power demand of the load circuit's greater than the power output of a single alternator. it's necessary to match the output voltage and electrical polarity of the machines with the voltage and polarity of the line.

The output voltage of an alternator is continuously changing in both magnitude and polarity at a definite frequency. Thus, when two alternators are paralleled, not only must the rate of the rise and fall of voltage in both alternators be equal, but the rise and fall of voltage in one machine must be exactly in step with the rise and fall of voltage in the other machine. When two alternators are in step, they are said to be in synchronism.

Alternators cannot be paralleled until their voltages, frequencies, and instantaneous polarities are exactly equal.

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LOAD SHARING AND PARALLEING

PRINCIPLE

In multi-generator systems, it is necessary for the generators to operate in parallel, and in order to ensure that they carry equal shares of the system load, their output voltages must be as near equal as possible under all operating conditions. As we have already learned, generators are provided with a voltage regulator which exercises independent control over voltage output, but as variations in output and electrical loads can occur, it is essential to provide additional voltage regulation circuits having the function of maintaining balanced outputs and load sharing. The method most commonly adopted for this purpose is that which employs a "load-equalizing circuit" to control generator output via the voltage regulators.

The principle as applied to a twin-generator system is illustrated in much-simplified form by Fig. 1.13(a). The generators are interconnected on their negative sides, via a series "load-sharing" or "equalizing" loop containing equalizing coils (CO each coil forming part of the individual voltage regulator electromagnetic circuits. The resistances RI and R2 represent the resistances of the negative sections (interpole windings) of the generators, and under balanced load-sharing conditions the volts drop across each section will be the same,i.e. Vi = 11 R1 and V2 = 12 R2 . Thus, the net volts drop will be zero and so no current will flow through the equalizing coils.

Let us now assume that generator No. 1 tends to take a somewhat larger share of the total load than generator No. 2. In this condition the volts drop V1 will now be greater than V2 and so the negative section of generator No. 1 will be at a lower potential. As a result, a current Ic will flow through the equalizing coils which are connected in such a manner that the effect of 1e is to raise the output voltage of generator No. 2 and reduce that of No. 1, thereby effectively reducing the unbalance in load sharing.

SHARING OF REAL LOAD BETWEEN PARALLELED GENERATORS

The sharing of real load between paralleled generators is determined by the real relative rotational speeds of the generators which in turn influence the voltage phase relationships. the speed of a generator is determined by the initial setting of the governor on its associated constant speed drive. It is not possible, however, to attain exactly identical governor settings on all constant speed drives employed in any one installation, and so automatic control of the governors becomes necessary.

A.C. generators are synchronous machines. There-fore when two or more operate in parallel they lock together with respect to frequency and the system frequency established is that of the generator whose output is at the highest level. Since this is controlled by speed-governing settings then it means that the generator associated with a higher setting will carry more than its share of the load and will supply energy which tends to motor the other machines in parallel with it. Thus, sharing of the total real load is unbalanced, and equal amounts of energy in the form of torque on the generator rotors must be supplied.

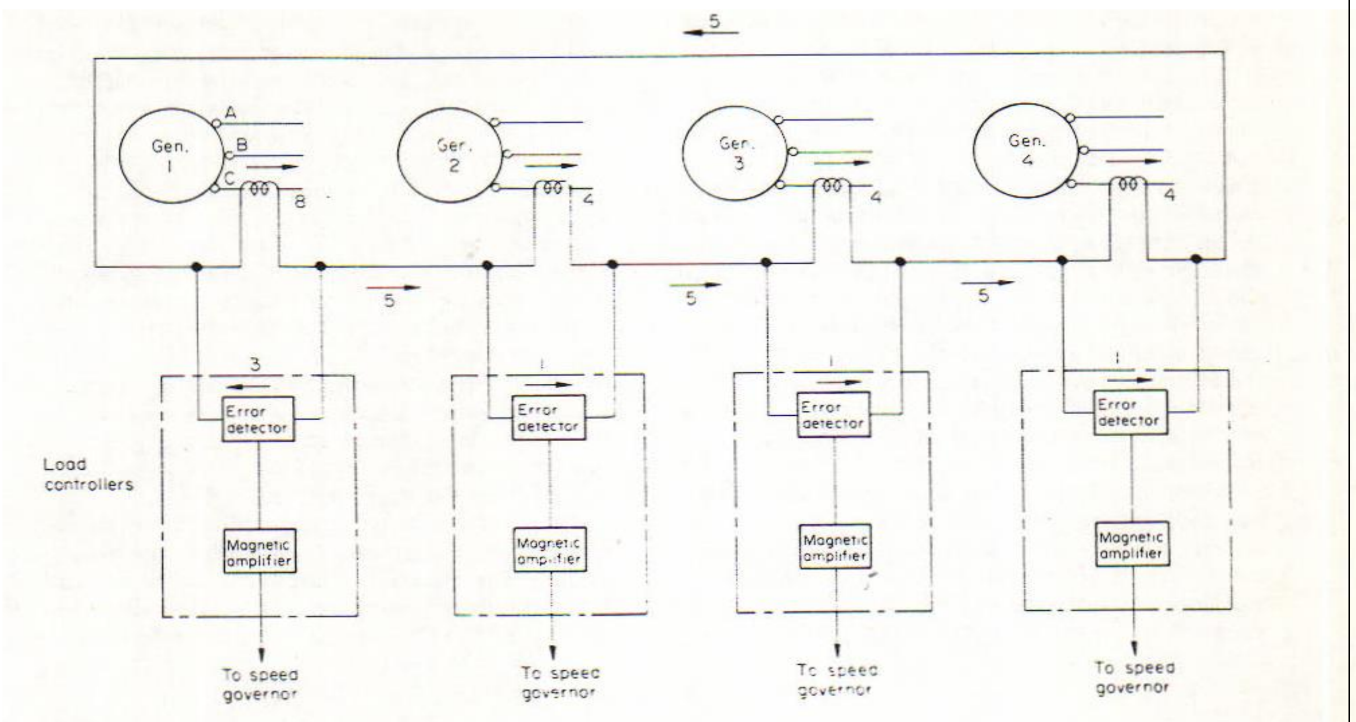
Fundamentally, a control system is comprised of two principal sections: one in which the unbalance is determined by means of current transformers, and the other (load controlling section) in which torques are established and applied. A circuit diagram of the system as applied to a four-generator installation is shown schematically in Fig. 3.20.

The current transformers sense the real load distribution at phase "C" of the supply from each generator, and are connected in series and together they form a load sharing loop. Each load controller is made up of a two-stage magnetic amplifier controlled by an error sensing element in parallel with each current transformer. The output side of each load controller is, in turn, connected to a solenoid in the speed governor of each constant speed unit.

When current flows through phase "C" of each generator a voltage proportional to the current is induced in each of the current transformers and as they are connected in series, then current will flow in the load sharing loop. This current is equal to the average of the current produced by all four transformers.

Let us assume that at one period of system operation, balanced load sharing conditions are obtained under which the current output from each transformer is equal to five amps, then the average flowing in the load sharing loop will be five amps, and no current circulates through the error sensing elements. If now a generator, say No. 1, runs at a higher speed governor setting than the other three generators, it will carry more load and will increase the output of its associated current transformer.

The share of the load being carried by the other generators falls proportionately, thereby reducing the output of their current transformers and the average current flowing in the load sharing loop remains the same, i.e. five amps. If, for example, it is assumed that the output of No. 1 generator current transformer is increased to eight amps a difference of three ampswill flow through the error sensing element of its relevant load controller. The three amps difference divides equally between the other generators and so the output of each corresponding current transformer is reduced by one amp, a difference which flows through the error sensing elements of the load controllers. The error signals are then applied as d.c. control signals to the two-stage magnetic amplifiers .



SYNCHRONIZATION OF ALTERNATOR

Synchronization of alternator means connecting an alternator into grid in parallel with many other alternators, that is in a live system of constant voltage and constant frequency. Many alternators and loads are connected into a grid, and all the alternators in grid are having same output voltage and frequency (whatever may be the power). It is also said that the alternator is Connected to a infinite busbar

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A stationary alternator is never connected to live bus-bars, because it will result in short circuit in the stator winding (since there is no generated emf yet). Before connecting an alternator into grid ,following conditions should be satisfied

Equal voltage: The terminal voltage of incoming alternator must be equal to the bus-bar voltage.

1. Similar frequency: The frequency of generated voltage must be equal to the frequency of the bus-bar voltage.
2. Phase sequence: The phase sequence of the three phases of alternator must be similar to that of the grid or bus-bars.
3. Phase angle: The phase angle between the generated voltage and the voltage of grid must be zero.

SYNCHRONIZING LIGHTS

In some power-generating systems a method of indicating synchronization between generator out- output forms part of the paralleling system, and consists if lights and frequency adjustment controls. this schematic diagram of the method based on that dopted for the triple generator system of the Boeing

The lights are connected into phase A and C of each generator between the generator breakers and synchronizing busbar via selector switch . the switch is also used for connecting a voltmeter and a frequency meter to each generator output phase B . the frequency adjustment controls are connected into the circuit of the load controller . the generators are connected to their resprctive load busbar and the synchronizing busbar via generator breaker and bus tie breaker resp.

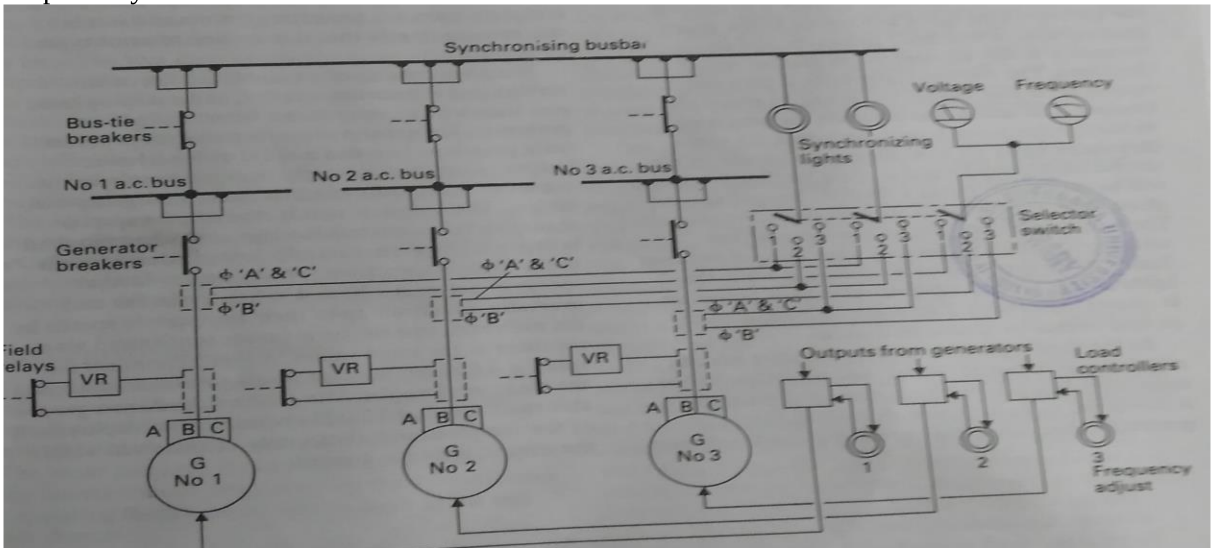

Fig 2.22
Synchronizing

each breaker being closed or tripped by manual operation of switches on a panel at the flight engineer station . the breaker also trip automatically in the event of faults detected by the generator control and protection system . the field relays are similarly operated . indicator light are located adjacent to all the switches to indicate either of the closed or tripped condition .

Prior to engine starting, the bus-tie breakers and field relays are closed (indicator lights out) and the generator breakers are tripped (indicator lights on). As the first engine is started, the meter selector switch is positioned at GEN I to connect phases "A" and "C" of this generator to the synchronizing busbar via the synchronizing lights. Phase bin" is connected to both the voltmeter and frequency meter the readings of which are then checked. Since at this moment, only the number I generator is in operation, then with respect to the other two, it will of course, produce maximum voltage and phase difference and both synchronizing lights will flash at a high frequency as a result of the current flow through them. The frequency control knob for the generator is then adjusted until its load controller has trimmed the CSD/generator speed to produce a "master" frequency of about 403 Hz, and simultaneous flashing of both synchronizing lights.

When the second engine is started, the meter selector switch is positioned at GEN 2 to connect the synchronizing lights and meters to the appropriate phases of number 2 generator, and its frequency is also adjusted in the manner just described. The number I generator is then connected to its load busbar by closing its generator breaker. This action also connects the generator to the synchronizing busbar, and since the synchronizing lights are now sensing the output of the second on-corning generator, their flashing frequency will be very much less as a result of less voltage and phase difference between the two generator outputs.

The frequency of the second generator is then adjusted to obtain the greatest time interval between flashes of the synchronizing lights, and while the lights are out (indicating both sources of power are in phase) the number 2 generator is connected to its load busbar by closing its breaker.

As the third engine is started, the meter selector ;switch is positioned at GEN 3, and by following the same procedure just outlined, number 3 generator is connected to its load busbar. With all three generators thus connected their subsequent operation is taken of automatically by the load sharing sensing circuits of the associated control and protection circuit unit .

it is Important to note that a generator must n ever be connected to its load busbar when the synchronizing lights are on .such action would impose heavy load on generators and possibly cause damage to them . if at any time synchronizing lights flash alternately a phase reversal is indicated and appropriate generator should not be used

Cooling of Generators

The maximum output of a generator, assuming no Limit to input mechanical power, is largely determined by the ease with which heat (arising from hysteresis, thermal effect of current in windings, etc.) can be iissipated. With large-bulk generators of relatively low output the natural processes of heat radiation from the extensive surfaces of the machine car case may well provide sufficient cooling, but such "natural" cooling s inadequate for the smaller high-output generators iced for the supply of electrical power to aircraft, and must, therefore, be supplemented by forced cooling.

The most commonly accepted method of cooling s that which utilizes the ram or blast effect resulting loin either the slipstream of a propeller or the air-stream due to the aircraft's movement. A typical coolng system is shown in a basic form in Fig. 1.8. The air s forced at high speed into an intake and is led through ight-alloy ducts to a collector at the commutator end of the generator .the air discharges over the brush gear and commutator to cool this natural area of high temperature , and then passes through the length of the machine to exhaust through aperture, surrounded by a perforated strap, at the drive end. In order to assist in ram air cooling and also to provide some cooling when the aircraft is on the ground , many types o generator have a fan fitted at the drive end of the armature shaft .

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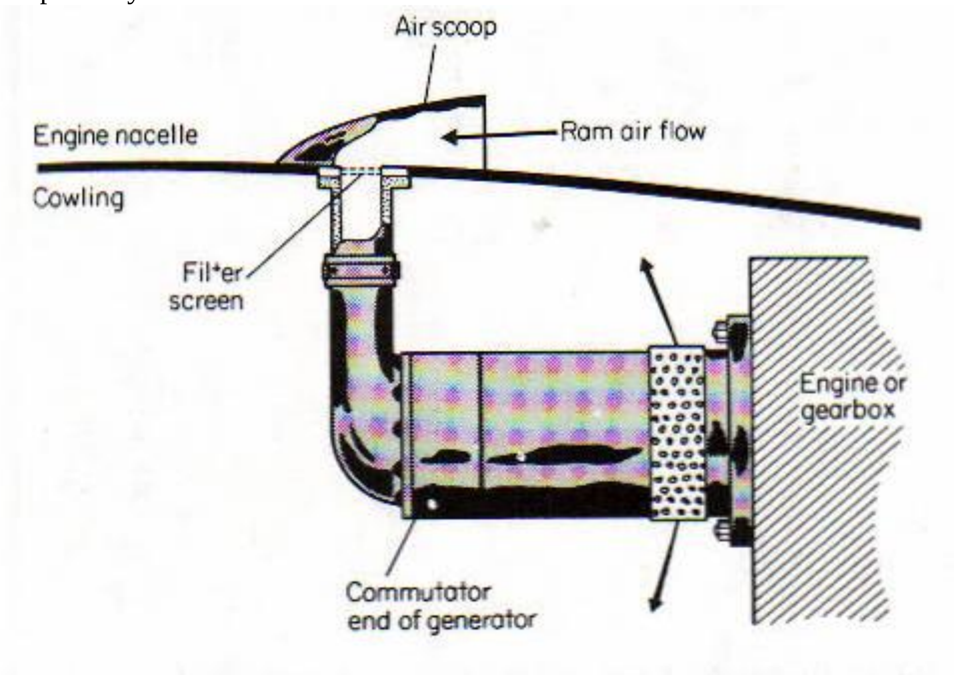


Autotransformers

Auto transformer is kind of electrical transformer where primary and secondary shares same common single winding. So basically it's a one winding transformer.

Theory of Auto Transformer

In Auto Transformer, one single winding is used as primary winding as well as secondary winding. But in two windings transformer two different windings are used for primary and secondary purpose. A diagram of auto transformer is shown below. The winding AB of total turns N_1 is considered as primary winding. This winding is tapped from point ′C′ and the portion BC is considered as secondary. Let's assume the number of turns in between points ′B′ and ′C′ is N_2.

If V_1 voltage is applied across the winding i.e. in between ′A′ and ′C′.

$$So\ voltage\ per\ turn\ in\ this\ winding\ is\ \frac{V_1}{N_1}$$

Hence, the voltage across the portion BC of the winding, will be,

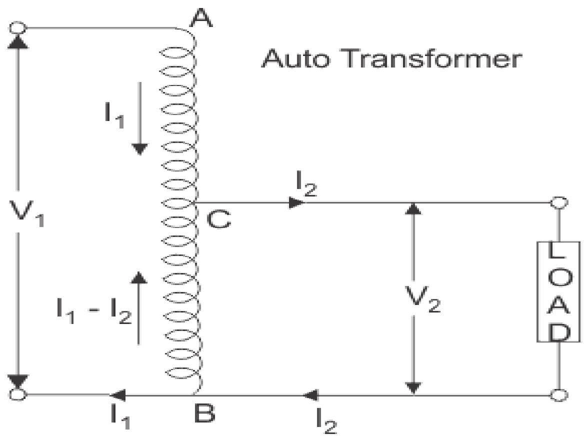
$$\frac{V_1}{N_1} X N_2 \text{ and from the figure above, this voltage is } V_2$$

$$Hence,\ \frac{V_1}{N_1} X N_2 = V_2$$

$$\Rightarrow \frac{V_2}{V_1} = \frac{N_2}{N_1} = Constant = K$$

As BC portion of the winding is considered as secondary, it can easily be understood that value of constant ′k′ is nothing but turns ratio or voltage ratio of that auto transformer.

When load is connected between secondary terminals i.e.between ′B′ and ′C′, load current I_2 starts flowing. The current in the secondary winding or common winding is the difference of I_2 & I_1.



Advantages ofAutotransformers

1. Its efficiency is more when compared with the conventional one.
2. Its size is relatively very smaller.
3. Voltage regulation of autotransformer is much better.
4. Lower cost
5. Low requirements of excitation current.

6. Less copper is used in its design and construction
7. In conventional transformer the voltage step up or step down value is fixed while in autotransformer, we can vary the output voltage as per out requirements and can smoothly increase or decrease its value as per our requirement.

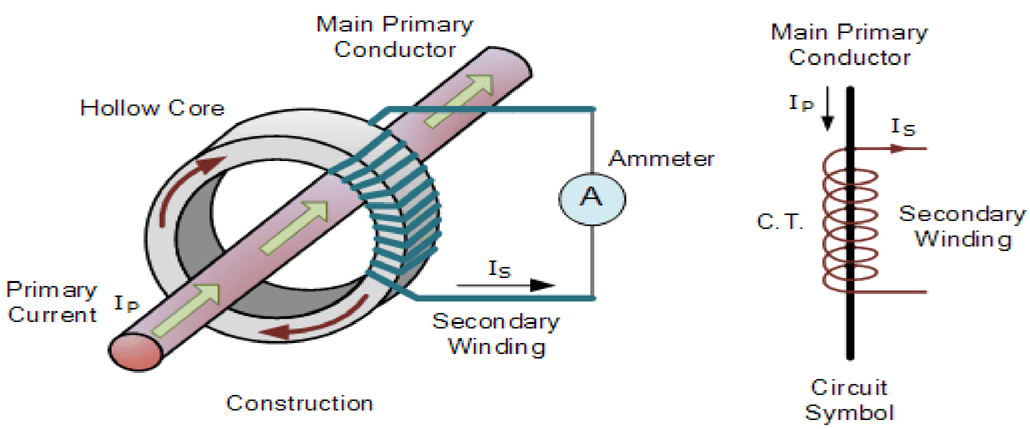
Applications of Auto Transformers

1. Compensating voltage drops by boosting supply voltage in distribution systems.
2. Auto transformers with a number of tapping are used for starting induction and synchronous motors.
3. Auto transformer is used as variac in laboratory or where continuous variable over broad ranges are required.

The Current Transformer

The **Current Transformer** (C.T.), is a type of “instrument transformer” that is designed to produce an alternating current in its secondary winding which is proportional to the current being measured in its primary current transformers are generally used to measure currents of high magnitude. These transformers step down the current to be measured, so that it can be measured with a normal range ammeter. A Current transformer has only one or very few number of primary turns.

The primary winding may be just a conductor or a bus bar placed in a hollow core (as shown in the figure). The secondary winding has large number turns accurately wound for a specific turns ratio. Thus the current transformer steps up (increases) the stepping voltage while down (lowering) the current. Now, the secondary current is measured with the help of an AC ammeter. The turns ratio of a transformer is $N_P / N_S = I_S / I_P$



Generally, current transformers are expressed in their primary to secondary current ratio. A 100:5 CT would mean the secondary current of 5 amperes when primary current is 100 amperes. The secondary current rating is generally 5 amperes or 1 ampere, which is compatible with standard measuring instrument

$$\text{Turns Ratio} = \frac{N_P}{N_S} = \frac{V_P}{V_S} = \frac{I_S}{I_P}$$

Differential current protection

Merz-Price Protection of Alternator Stator Windings

This is most commonly used protection scheme for the alternator stator windings. The scheme is also called biased differential protection and percentage differential protection.

In this method, the currents at the two ends of the protected section are sensed using current transformers. The wires connecting relay coils to the current transformer secondaries are called pilot wires.

Under normal conditions, when there is no fault in the windings, the currents in the pilot wires fed from C.T. secondaries are equal. The differential current $i_1 - i_2$ through the operating coils of the relay is zero. Hence the relay is inoperative and system is said to be balanced.

When fault occurs inside the protected section of the stator windings, the differential current $i_1 - i_2$ flows through the operating coils of the relay. Due to this current, the relay operates. This trips the generators circuit breaker to isolate the faulty section. The is also disconnected and is discharged through a suitable impedance.

The Fig.1 shows a schematic arrangement of Merz-Price protection scheme for a star connected alternator.

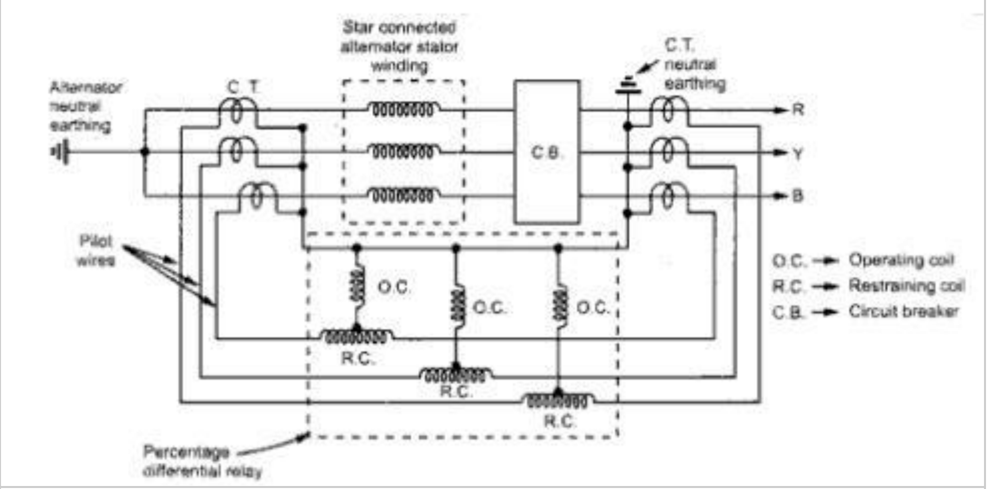


Fig. 1 Merz-Price protection for star connected alternator

The differential relay gives protection against short circuit fault in the stator winding of a generator. The C.T.s are connected in star and are provided on both, the outgoing side and machine winding connections to earth side. The restraining coils are energized from the secondary connection of C.T.s in each phase, through pilot wires. The operating coils are energized by the tappings from restraining coils and the C.T. neutral earthing connection.

The similar arrangement is used for the delta connected alternator stator winding. as shown in the Fig. 2.

The C.T.s on the delta connected machine winding side are connected in delta while the C.T.s at outgoing ends are connected in star. The restraining coils are placed in each phase, energized by the secondary connections of C.T.s while the operating coils are energized from the restraining coil tappings and the C.T. neutral earthing

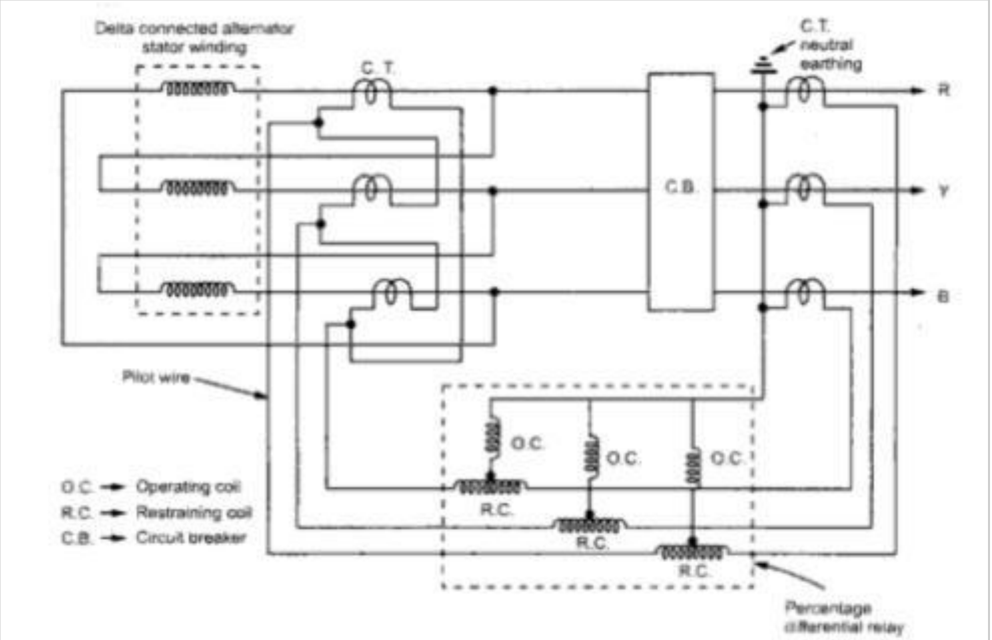


Fig. 2 Merz-Price protection for delta connected alternator

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If there is a fault due to a short circuit in the protected zone of the windings, it produces a difference between the currents in the primary windings of C.T.s on both sides of the generator winding of the same phase. This results in a difference between the secondary currents pf the two currents transformers. Thus, under fault conditions, a differential current flows through the operating coils which is responsible to trip the relay and open the circuit breaker. The differential relay operation depends on the relation between the current in the operating coil and that in the restraining coil. In addition to the tripping of circuit breaker, the percentage differential relay trip a hand reset multicontact auxiliary relay.

- This auxiliary relay simultaneously initiates the following operations,
- Tripping of the main circuit breaker of generator
- Tripping of the field circuit breaker

- Tripping of neutral circuit breaker if it is present
- Shut down of the prime mover
- Turn on of CO_2 gas if provided for safety of generator under faulty conditions
- Operation of alarm and / or annunciator to indicate the occurrence of the fault and the operation of the relay the field must be opened immediately otherwise it starts feeding the fault.

When differential relaying is used for the protection, C.T.s at both the ends of generator must be of equal accuracy otherwise if the error is excessive, wrong operation of the relay may result. The cause of unequal currents on both the sides of C.T.s without any fault are ratio errors, unequal lengths of the leads, unequal secondary burdens etc.

This scheme provides very fast protection to the stator winding against phase to phase faults and phase to ground faults. If the neutral is not grounded or grounded through resistance then additional sensitive earth fault relay should be provided.

The advantages of this scheme are,

1. Very high speed operation with operating time of about 15 msec.
2. It allows low fault setting which ensures maximum protection of machine windings.
3. It ensures complete stability under most severe through and external faults.
4. It does not require current transformers with air gaps or special balancing features.

Prepared by :Ponnidevi.J

Auxiliary Power Units

The Auxiliary Power Unit (APU) is a small jet engine housed in the tail of theaircraft used to provide a source of electricity to power the aircraft on the ground when the engines are switched off and as a source of air in order to start the engines.

Auxiliary Power Unit. It provides power to the aircraft when the engines are shut off, and can provide the power to start the engines. On some aircraft, it also doubles as backup power incase of engine failure.

Auxiliary Power Units (APUs) are gas turbine engines used primarily during aircraft ground operation to provide electricity, compressed air, and/or shaft power for main engine start, air conditioning, electric power and other aircraft systems. APUs can also provide backup electric power during in-flight operation.

IN general an APU consists of a small gas turbine engine , a bleed air,control and supply system and an accessory gear box.

The gas turbine comprises a two stage centrifugal compressor connected to a single stage turbine . the bleed air control and supply system automatically regulates the amount of air bleed from the compressor for delivery to the cabin air conditioning system.

In addition to those accessories essential for engine operation. E.g fuel pump control unit and oil pumps, the accessory gear box drives a generator which is of same type as those driven by the main engines and having the same type of control and protection unit

A motor for starting the APU is also secured to the gear box and is operated by the aircraft battery system or, when available ,from a ground power unit . in some types of APU , the functions of engine starting and power generation are combined in a starter /generator unit .in order to record th hours run an hour meter is automatically driven by APU

The APU is a small jet engine that is used to start the larger jet engines. In airliners it's usually at the very rear of the aircraft, below the tail. Large engines are heavy and require a lot of torque to spin up, more than a starter battery can generate. So, the battery spins up a much smaller APU jet engine. High-speed bleed air from the APU is used to spin up the main engine.

Once the engines are started, the APU is no longer required, but it does provide a couple of secondary function

It provides cabin air and electric power before the engines are started (saving battery power).

It provides an emergency source of electric power in the event of engine failure.

It can start the aircraft engines mid-flight in an emergency.

If the APU fails before engine start, the engines cannot be started without an external "start cart" to provide a source of bleed air. If the APU fails mid-flight, there will be no immediate effect. Even without the APU, there are two additional ways to restart an aircraft engine in flight:

a cross-bleed start, where bleed air from a working engine is used to start a dead engine, ora windmill start, where the aircraft dives and attains enough speed that ram air spins the turbine fast enough to allow a relight.APU is normally left off in flight, but may be turned on for certain long-haul overwater flights as an extra precaution.

Purpose of APU

The primary purpose of an aircraft APU is to provide power to start the main engines. Turbine engines have large, heavy rotors that must be accelerated to a high rotational speed in order to provide sufficient air compression for self-sustaining operation. This process takes significantly longer and requires much more energy than starting a reciprocating engine. Smaller turbine engines are usually started by an electric motor, while larger turbine engines are usually started by an air turbine motor. Whether the starter is electrically or pneumatically powered, however, the amount of energy required is far greater than what could be provided by a storage device (battery or air tank) of reasonable size and weight.

An APU solves this problem by powering up the aircraft in two stages. First, the APU is started by an electric motor, with power supplied by a battery or external power source (ground power unit). After the APU accelerates to full speed, it can provide a much larger amount of power to start the aircraft's main engines, either by turning an electrical generator or by providing compressed air to the air turbine of the starter motor.

APUs also have several auxiliary functions. Electrical and pneumatic power are used to run the heating, cooling, and ventilation systems prior to starting the main engines. This allows the cabin to be comfortable while the passengers are boarding without the expense, noise, and danger of running one of the aircraft's main engines. Electrical power is also used to power up systems for preflight checks. Some APUs are also connected to a hydraulic pump, allowing maintenance and flight crews to operate the flight controls and power equipment without running the main engines. This same function is also used as a backup in flight in case of an engine failure or hydraulic pump failure

To start, a jet engine requires pneumatic rotation of the turbine, AC-electrical fuel pumps, and an AC-electrical "flash" that ignites the fuel. As the turbine (behind the combustion chamber) is already rotating, the front inlet fans are also rotating. After the ignition, both fans and turbine speed up their rotation. As combustion stabilizes, the engine thereafter only needs the fuel to run at idle. The started engine can now replace the APU when starting up further engines. During flight the APU and its generator are not needed

APUs are also used to run accessories while the engines are shut down. This allows the cabin to be comfortable while the passengers are boarding before the aircraft's engines are started. Electrical power is used to run systems for preflight checks. Some APUs are also connected to a hydraulic pump, allowing crews to operate hydraulic equipment (such as flight controls or flaps) prior to engine start. This function can also be used, on some aircraft, as a backup in flight in case of engine or hydraulic failure]

Aircraft with APUs can also accept electrical and pneumatic power from ground equipment when an APU has failed or is not to be used. Some airports reduce the use of APUs due to noise and pollution, and ground power is used when possible.

APUs fitted to extended-range twin-engine operations (ETOPS) aircraft are a critical safety device, as they supply backup electricity and compressed air in place of the dead engine or failed main engine generator. While some APUs may not be startable in flight, ETOPS-compliant APUs must be flight-startable at altitudes up to the aircraft service ceiling. APUs providing electricity at 400 Hz are smaller and lighter than their 50/60 Hz counterparts, but are costlier; the drawback being that such high frequency systems suffer from voltage drops.[1]

General aviation aircraft use electrical starter motors for both piston and gas turbine engines; larger transport aircraft use an air-start system(controlled electrically) derived from ground support equipment or by air cross-fed from another engine. Electrical starting systems on piston and gas turbine engines are very different. The trend towards the all-electric aircraft will see more aircraft types using electrical starting methods. The engine also requires electrical power for the ignition system.

10.1.5 Main engine start

The main engines are normally started via air-driven motors; there are three sources of air for starting the main engines:

- APU
- ground air supply cart
- another engine.

A typical air distribution system is illustrated in Fig. 10.11 .Valves, controlled either manually or automatically, are operated by motors. With the APU started and running at normal speed, a switch on the start control panel opens the APU bleed valve. Air is directed through the isolation valve and engine bleed valve to the engine start valve.

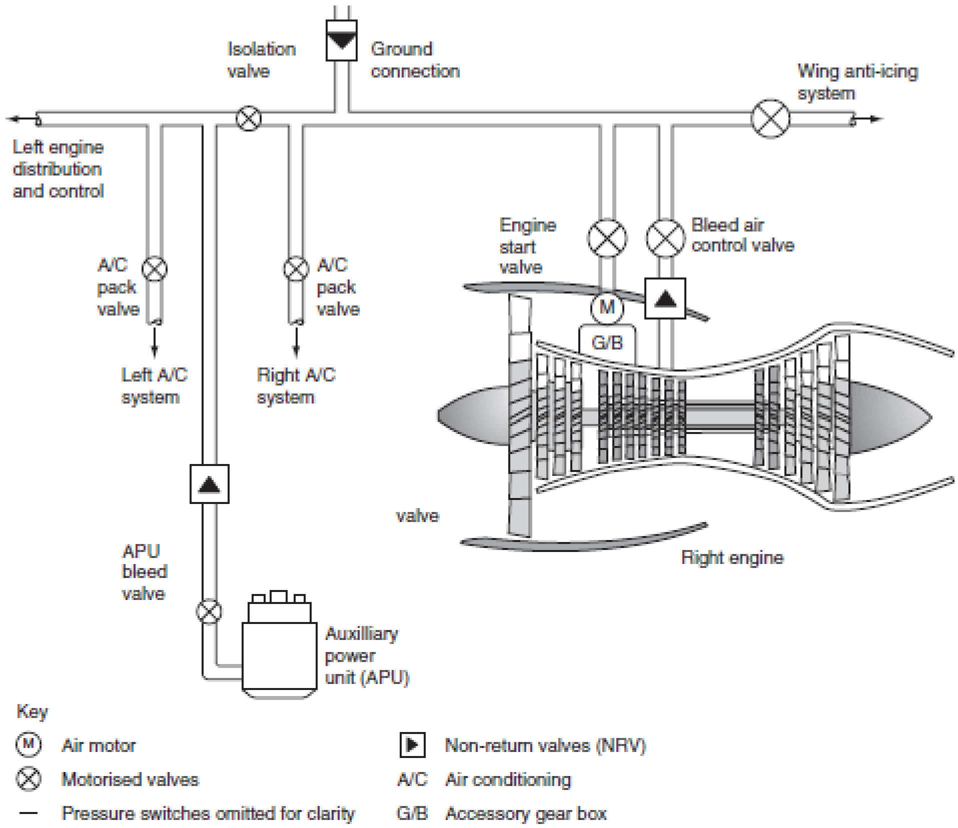


Figure 10.11 Typical air distribution system

When using the ground air supply cart, an external connection is made and air is directed through the engine bleed valve to the start valve, or through the isolation valve and engine bleed valve to the start valve. When using another engine (that is already running), air is supplied from its bleed valve, through the isolation and bleed valves of the engine to be started and through to the start valve.For illustration purposes, a twin-engined aircraft starting and ignition system is described; refer to Fig.10.12 . There is a combined start and ignition control panel located in the overhead panel; in the illustration, this is fitted with a rotary switch for each engine.

The operation and functions of this switch are identical for each engine. The switch has to be pushed in before any selections can be made; this is to prevent accidental movement of the switch. Selecting ground (GRD) connects 28 V DC to energize the start switch holding coil. The circuit is completed through the cut-out contacts in the engine starter valve. The start switch is now held in the GRD position and the ground start sequence is initiated. The 28 V DC supply also energizes the start valve solenoid and this opens the valve,

supplying air to drive a small turbine in the starter motor. The turbine connects through an accessory gearbox onto the engine's HP compressor shaft.

At approximately 16% of maximum rotational speed, the start lever is moved from the cut-off position to ‘ idle ’ . This applies 28 V DC through a second pair of contacts of the start switch and ignition switch to supply the HEIU. Each igniter plug discharges at a high level, typically 20 joules of energy, at 60–90 discharges per minute. (This can be heard outside

the engine as an audible ‘ clicking ’ sound.) At a predetermined

cut-out speed, the centrifugal switch in the starter motor opens: the start switch is de-energized and returns (under spring force) to the off position.

The 28 V DC power supply is removed from the HEIU and the start valve motor drives to its closed position. The engine continues to accelerate to the **ground idle** speed; this is slightly above self-sustaining speed and occurs when the engine has stabilized. For a twin-shaft axial flow engine, ground idle is typically 60% of the high-pressure (HP) compressor speed.

Low-energy ignition (typically 4 joules of energy, at 30 discharges per minute) is used in certain phases of fl ight including take-off, turbulence and landing. Furthermore, if the aircraft is fl ying through clouds, rain or snow, continuous low-energy ignition is selected on the control panel. This closes a contact on the rotary switch and applies power to a second HEIU input.

In the event of an engine **flameout** during flight, the crew will attempt an in-fl ight start of the engine; this requires a modified procedure to that of the ground start. The engine will be wind-milling due to the forward speed of the aircraft. The starter valve and motor are not selected as with the ground start.

Low ignition (LOW IGN) and flight (FLT) are manually selected on the control panel until the engine reaches **flight idle** speed. In-flight restarts can only be attempted within certain airspeed and altitude limits.

Gas turbine engines sometimes suffer from a starting problem that results in fuel entering the combustion chamber, but no ignition; this is sometimes referred to as a **wet start** . Engine indications would be the engine turning at the correct starter speed, with indications of fuel fl ow, but no increase in exhaust gas temperature (EGT). Observers outside the aircraft could see atomized fuel or vapour from the engine exhaust.

The cause of a wet start is most likely to be a defective HEIU and/or igniter plug. The net result is no ignition in the combustion chamber and the accumulation of fuel. If compressor outlet air gets hot enough, it could ignite the fuel, causing a rapid expansion of the fuel/air mix (effectively an explosion) that could lead

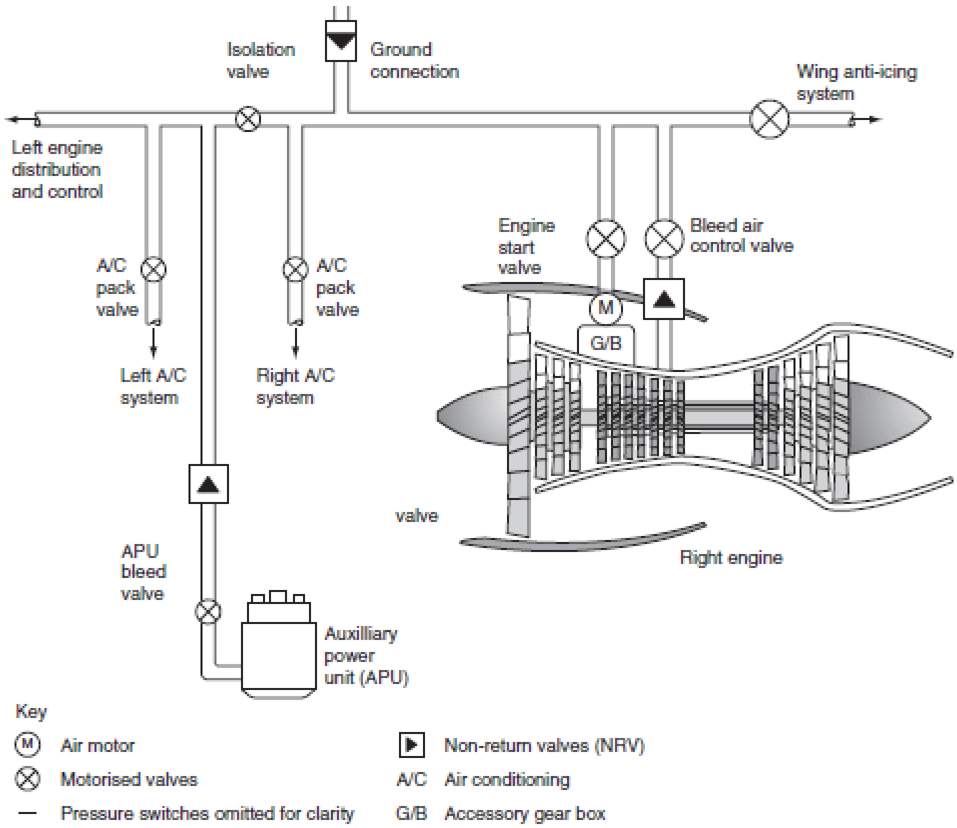


Figure 10.11 Typical air distribution system

damage of the turbine section and eject fl ames fromthe engine exhaust. The procedure is to shut off the fuel supply to the engine and continue turning over the engine with the starter motor to clear (or blow out) out

the fuel. Some starter panels have a selectable **blow out** position to achieve this procedure.

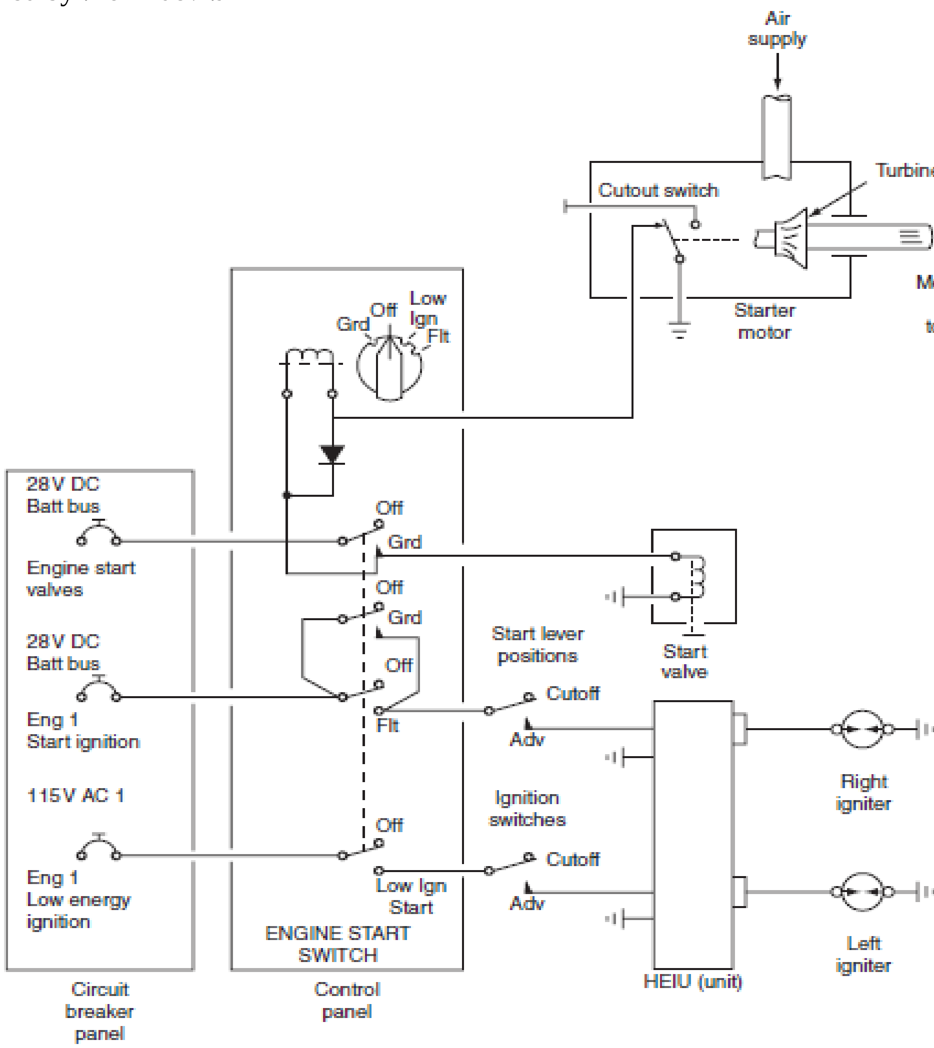


Figure 10.12 Turbine starting and ignition system

Precaution Starting the Engine

The before starting and starting checklist provided for the particular airplane being used should always be followed. There are, however, certain precautions pointed out here that apply to all airplanes.

Too many careless pilots start the engine with the tail of the airplane pointed toward an open hangar door, toward parked automobiles, or toward a group of bystanders. This is not only discourteous, thoughtless, and in violation of Federal

Aviation Regulations, but often results in personal injury and serious damage to the property of others.

When ready to start the engine, the pilot should look around in all directions to be sure that nothing is or will be in the vicinity of the propeller, and that nearby persons and aircraft will not be struck by the propeller blast or the debris it might pick up from the ground.

If an electric starter is used, the pilot should always call "all clear," and wait for a response from persons who may be nearby before turning the ignition switch ON or activating the starter. While activating the starter, one hand should be kept on the throttle, to be ready to advance the throttle if the engine falters while starting or to prevent excessive RPM just after starting. A low power setting is recommended until the engine temperatures and oil pressure starts increasing.

As soon as the engine is operating smoothly, the oil pressure should be checked. If it does not rise to the manufacturer's specified value in about 30 seconds in summer or 60 seconds in winter, the engine is not receiving proper lubrication and should be shut down immediately to prevent internal damage.

Even though most airplanes are equipped with electric starters, every pilot should be familiar with the procedures and dangers involved in starting an engine by turning the propeller by hand (hand propping). Due to the associated hazards, this method of starting should be used only when absolutely necessary and when proper precautions have been taken. There have been many fatalities, serious injuries, and substantial property damage caused by the rotating propeller blades when the airplane suddenly moved forward, uncontrolled under its own power after hand starting.

It is recommended that an engine never be "hand propped" unless a qualified person thoroughly familiar with the operation of all the controls is seated at the controls and the brakes set. As an additional precaution, chocks should be placed in front of the main wheels. If this is not feasible, the airplane's tail should be securely tied down.

NEVER ALLOW A PERSON WHO IS UNFAMILIAR WITH AIRPLANE CONTROLS TO HANDLE THE CONTROLS WHEN THE ENGINE IS STARTED BY AN OUTSIDE SOURCE.

When hand propping is necessary, the ground surface near the propeller should be firm and free of debris. Loose gravel, slippery grass, mud, or grease might cause the person "propping" the airplane to slip or fall into the rotating propeller as the engine starts.

First the ignition switch should be checked to be sure it is OFF. Then the blade to be swung should be rotated so that it is slightly above the horizontal position. The person doing the hand propping should face the blade squarely and stand close but not too close to the propeller blade. If standing too far away, it would be necessary to lean forward in an unbalanced position to reach the blade. This may cause the person to fall forward into the revolving blades when the engine starts.

After the throttle is set to the start position and the ignition switch is turned ON, the propeller is swung by forcing the blade downward rapidly, pushing with the palms of both hands. If the blade is gripped tightly with the fingers, the person's body may be drawn into the propeller blades should the engine misfire and rotate in the opposite direction. As the blade is pushed down, the "hand propper" should step backward away from the propeller. If the engine does not start, the propeller should not be repositioned for another attempt until it is certain the ignition switch is turned OFF.

When removing the wheel chocks after the engine starts remember that the propeller is almost invisible. There have been cases of serious injuries and fatalities because the person reached into the whirling propeller to remove the chocks. Before they are removed, the throttle should be set to idling and the chocks approached from the rear of the propeller - never from the front or the side.

As stated previously, the procedure for starting should always be in accordance with the manufacturer's recommendations or checklist. Nonetheless, the following are

LIMITATIONS OF STARTING APU

warning : Do not touch the APU until it is sufficiently cool to prevent burns when you do the maintenance task

warning : while the APU operates, do not go into these areas:
- the area behind the APU exhaust duct: 25m (82ft.) rearward of the duct, more than 3m (10ft.) above the ground, and the width of the horizontal stabilizer
-the area around the APU air-intake: 2m (7ft) around the intake
-the area of the oil-cooler outlet.
there is a risk of injury if you go into these areas.
caution : do not use the APU during fluid de-icing operations. de-icing fluid can contaminate the inside of the APU.
caution : do not start or try to start the APU more than three times, one after the other. after the third time, there must be a minimum of one hour before you start or try to start the APU again. this makes sure that the temperature of the starter

motor decreases sufficiently.
caution : do not start the APU with access doors 315al and 316ar open/removed. the APU fire extinguisher system is not sufficient to extinguish a fire if the access doors 315al and 316ar are open/removed.
caution : do not try to start the APU again during a refuel/defuel procedure after an automatic shutdown or failed APU start. if you do, there is a risk of injury and/or
damage.
caution : obey the safety precautions

Static Inverters

A power **inverter**, or **inverter**, is an electronic device or circuitry that changes direct current (DC) to alternating current (AC). The input voltage, output voltage and frequency, and overall power handling depend on the design of the specific device or circuitry.

In many applications where continuous dc voltage must be converted to alternating voltage, static inverters are used in place of rotary inverters or motor generator sets. The rapid progress being made by the semiconductor industry is extending the range of applications of such equipment into voltage and power ranges which would have been impractical a few years ago. Some such applications are power supplies for frequency sensitive military and commercial ac equipment, aircraft emergency ac systems, and conversion of wide frequency range power to precise frequency power.

The use of static inverters in small aircraft also has increased rapidly in the last few years, and the technology has advanced to the point that static inverters are available for any requirement filled by rotary inverters. For example, 250 VA emergency ac supplies operated from aircraft batteries are in production, as are 2,500 VA main ac supplies operated from a varying frequency generator supply. This type of equipment has certain advantages for aircraft applications, particularly the absence of moving parts and the adaptability to conduction cooling.

Static inverters, referred to as solid state inverters, are manufactured in a wide range of types and models, which can be classified by the shape of the ac output waveform and the power output capabilities. One of the most commonly used static inverters produces a regulated sine wave output. A block diagram of a typical regulated sine wave static inverter is shown in figure 9-65. This inverter converts a low dc voltage into higher ac voltage. The ac output voltage is held to a very small voltage tolerance, a typical variation of less than 1 percent with a full input load change. Output taps are normally provided to permit selection of various voltages; for example, taps may be provided for a 105, 115, and 125 volt ac outputs. Frequency regulation is typically within a range of one cycle for a 0 - 100 percent load change.

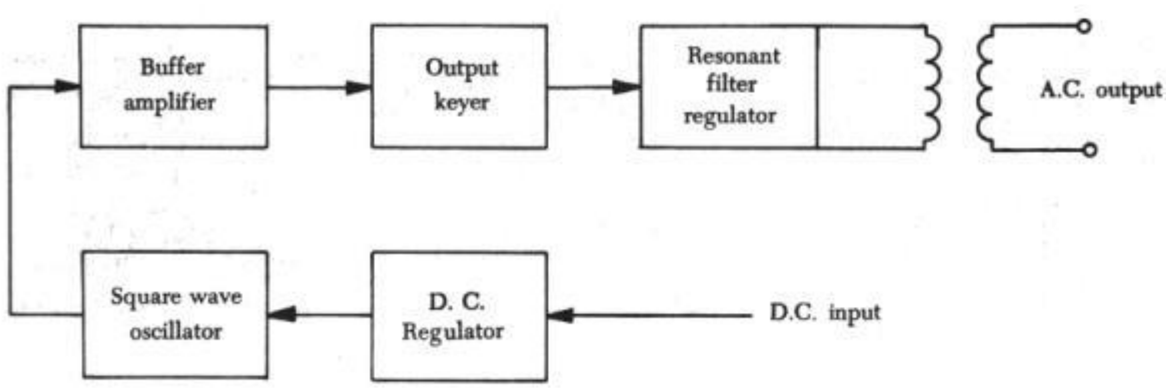


FIGURE 9–65. Regulated sine wave static inverter.

Variations of this type of static inverter are available, many of which provide a square wave output.

Since static inverters use solid state components, they are considerably smaller, more compact, and much lighter in weight than rotary inverters. Depending on the output power rating required, static inverters that are no larger than a typical airspeed indicator can be used in aircraft systems. Some of the features of static inverters are:

1. High efficiency.
2. Low maintenance, long life.
3. No warmup period required.
4. Capable of starting under load.
5. Extremely quiet operation.
6. Fast response to load changes.

Static inverters are commonly used to provide power for such frequency sensitive instruments as the attitude gyro and directional gyro. They also provide power for autosyn and magnesyn indicators and transmitters, rate gyros, radar, and other airborne applications.

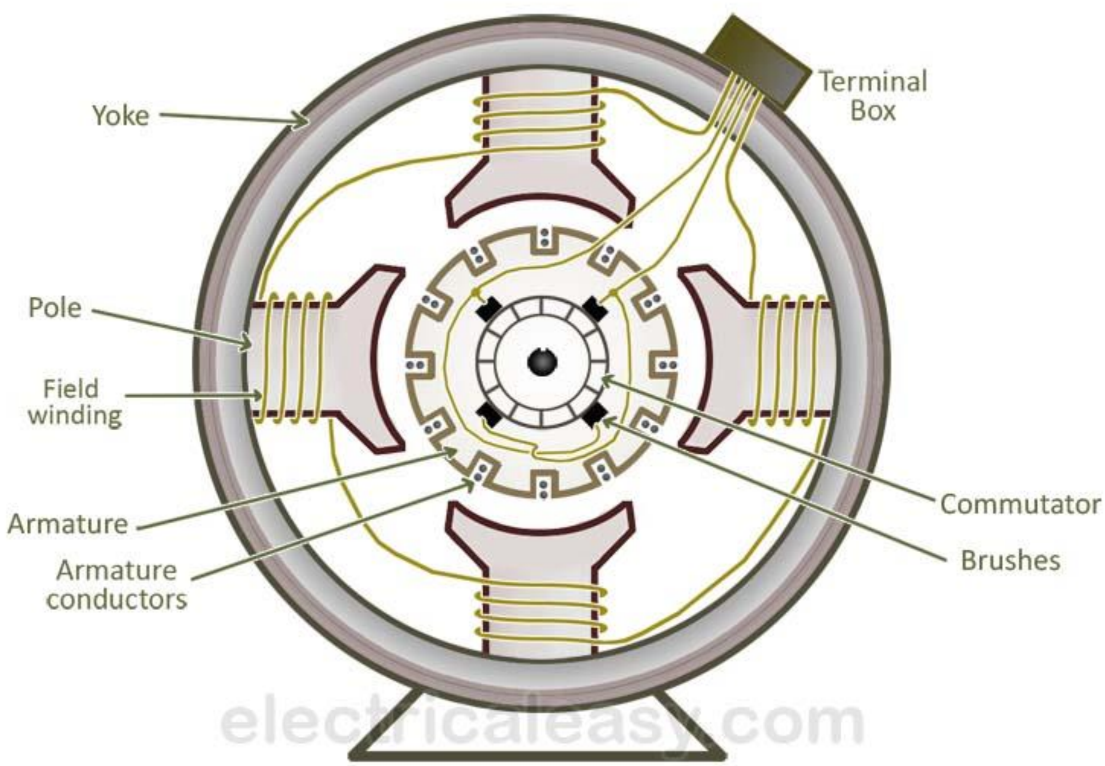
DC Generator

A dc generator is an electrical machine which converts mechanical energy into **direct current electricity**. This energy conversion is based on the principle of production of dynamically induced emf.

Construction Of A DC Machine:

Note: A DC generator can be used as a DC motor without any constructional changes and vice versa is also possible. Thus, a DC generator or a DC motor can be broadly termed as a **DC machine**. These basic constructional details are also valid for the **construction of a DC motor**. Hence, let's call this point as **construction of a DC machine** instead of just 'construction of a dc ge nerator'.

The figure shows the constructional details of a simple **4-pole DC machine**. A DC machine consists two basic parts; stator and rotor. Basic constructional parts of a DC machine are described below. The figure shows the constructional details of a simple **4-pole DC machine**. A DC machine consists two basic parts; stator and rotor. Basic constructional parts of a DC machine are described below.



1. **Yoke:** The outer frame of a dc machine is called as yoke. It is made up of cast iron or steel. It not only provides mechanical strength to the whole assembly but also carries the magnetic flux produced by the field winding.
2. **Poles and pole shoes:** Poles are joined to the yoke with the help of bolts or welding. They carry field winding and pole shoes are fastened to them. Pole shoes serve two purposes; (i) they support field coils and (ii) spread out the flux in air gap uniformly.
3. **Field winding:** They are usually made of copper. Field coils are former wound and placed on each pole and are connected in series. They are wound in such a way that, when energized, they form alternate North and South poles.

Armature core (rotor)

4. **Armature core:** Armature core is the rotor of the machine. It is cylindrical in shape with slots to carry armature winding. The armature is built up of thin

laminated circular steel disks for reducing eddy current losses. It may be provided with air ducts for the axial air flow for cooling purposes. Armature is keyed to the shaft.

5. **Armature winding:** It is usually a former wound copper coil which rests in armature slots. The armature conductors are insulated from each other and also from the armature core. Armature winding can be wound by one of the two methods; lap winding or wave winding. Double layer lap or wave windings are generally used. A double layer winding means that each armature slot will carry two different coils.

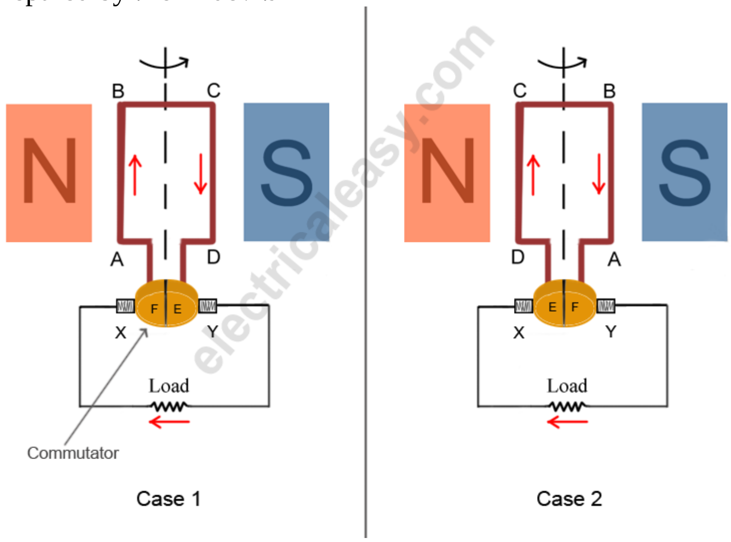
6. **Commutator and brushes:** Physical connection to the armature winding is made through a commutator-brush arrangement. The function of a commutator, in a dc generator, is to collect the current generated in armature conductors. Whereas, in case of a dc motor, commutator helps in providing current to the armature conductors. A commutator consists of a set of copper segments which are insulated from each other. The number of segments is equal to the number of armature coils. Each segment is connected to an armature coil and the commutator is keyed to the shaft. Brushes are usually made from carbon or graphite. They rest on commutator segments and slide on the segments when the commutator rotates keeping the physical contact to collect or supply the current.

Commutator

Working Principle Of A DC Generator:

According to Faraday's laws of electromagnetic induction, whenever a conductor is placed in a varying magnetic field (OR a conductor is moved in a magnetic field), an emf (electromotive force) gets induced in the conductor. The magnitude of induced emf can be calculated from the emf equation of dc generator. If the conductor is provided with the closed path, the induced current will circulate within the path. In a DC generator, field coils produce an electromagnetic field and the armature conductors are rotated into the field. Thus, an electromagnetically induced emf is generated in the armature conductors. The direction of induced current is given by Fleming's right hand rule.

Need of a Split ring commutator:



According to Fleming's right hand rule, the direction of induced current changes whenever the direction of motion of the conductor changes. Let's consider an armature rotating clockwise and a conductor at the left is moving upward. When the armature completes a half rotation, the direction of motion of that particular conductor will be reversed to downward. Hence, the direction of current in every armature conductor will be alternating. If you look at the above figure, you will know how the direction of the induced current is alternating in an armature conductor. But with a split ring commutator, connections of the armature conductors also gets reversed when the current reversal occurs. And therefore, we get unidirectional current at the terminals.

Types Of A DC Generator:

DC generators can be classified in two main categories, viz;

(i) Separately excited and (ii)Self-excited.

(i) **Separately excited**: In this type, field coils are energized from an independent external DC source.

(ii) **Selfexcited**: In this type, field coils are energized from the current produced by the generator itself. Initial emf generation is due to residual magnetism in field poles. The generated emf causes a part of current to flow in the field coils, thus strengthening the field flux and thereby increasing emf generation. Self excited dc generators can further be divided into three types -

(a) Series wound - field winding in series with armature winding

(b) Shunt wound - field winding in parallel with armature winding

(c) Compound wound - combination of series and shunt winding

TRANSFORMER-RECTIFIER UNITS

Transformer-rectifier units (T.R.U.) are combinations of static transformers and rectifiers, and are utilized in some a.c. systems as secondary supply units, and also as the main conversion units in aircraft having rectified a.c. power systems.

Fig. 4.16 illustrates a T.R.U. designed to operate on a regulated three-phase input of 200 volts at a frequency of 400 Hz and to provide a continuous d.c. output of 110 A at approximately 26 volts. The circuit is shown schematically in Fig. 4.17. The unit consists of a transformer and two three-phase bridge rectifier assemblies mounted in separate sections of the casing. The transformer has a conventional star-wound primary winding and secondary windings wound in star and delta. Each secondary winding is connected to individual bridge rectifier assemblies made up of six silicon diodes, and connected in parallel. An ammeter shunt (dropping 50 mV at 100 A) is connected in the output side of the rectifiers to enable current taken from the main d.c.

output terminals to be measured at ammeter auxiliary terminals. These terminals, together with all others associated with input and output circuits, are grouped on a panel at one end of the unit. Cooling of the unit is by natural convection through gauze-covered ventilation panels and in order to give warning of overheating conditions, thermal switches are provided at the transformer and rectifier assemblies, and are connected to independent warning lights. The switches are supplied with d.c. from an external source (normally one of the busbars) and their contacts close when temperature conditions at their respective locations rise to approximately 150°C and 200°C.