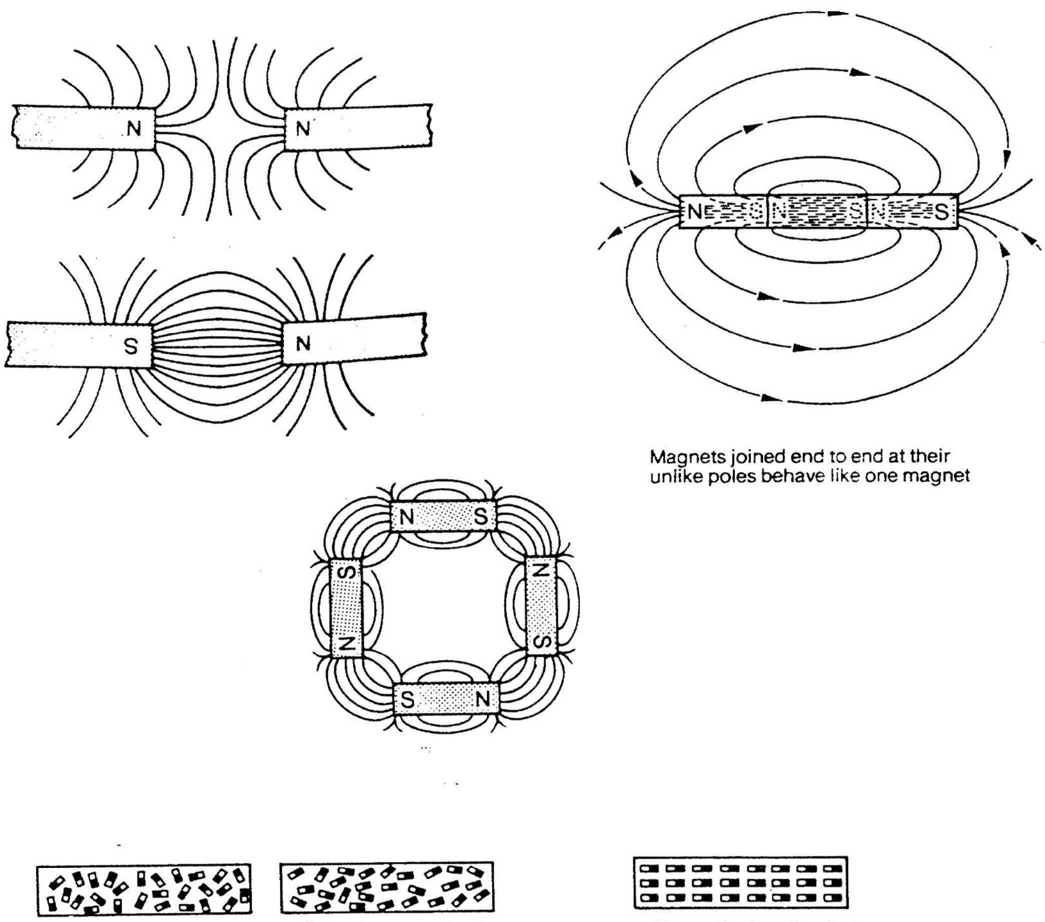
GENERATION OF ELECTRICAL ENERGY

MAGNETISM

Some understanding of the fundamentals of magnetism is important to help comprehend the production of electricity. Behaviours such as like poles repel and opposites attract, are a function of the interaction of invisible magnetic fields.

The following diagrams are provided to help review some of the principles of magnetism.



MAGNETIC FIELD PATTERNS

Permanent magnets are formed when a ferromagnetic material has its molecular structure forced into alignment by some external activity. Hammering (vibration) or the influence of another magnetic field, can cause this molecular alignment to occur.

The quality and retentivity of the magnetism is a property of the magnetized material. The term HARD magnetism is used when a material has permanent or highly retentive magnetic characteristics. SOFT magnetism is temporary magnetism of low retentive materials. There are separate uses for permanent or temporary magnetic materials.

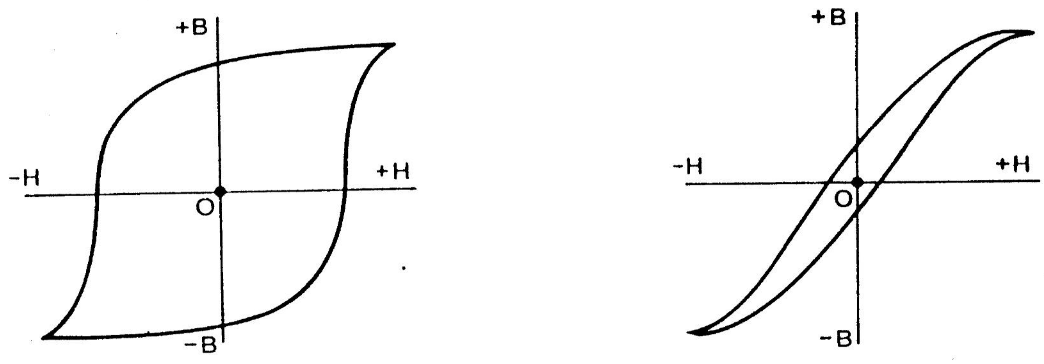
The magnet in a permanent magnet generator (PMG) needs to retain its magnetism for a long time, so that the generator will function for many years and this requires a high retention magnetic core.

In a relay or solenoid however, the core must be made of soft iron to provide temporary magnetism only. When current is switched ON, magnetism will close the main contacts of a relay and these will open again when the current is switched OFF. Should the core of the relay remain magnetised when the current is switched OFF, the main contacts may remain closed and the relay would obviously not achieve its design function.

Hysteresis

The ability of a material to change its magnetic state is known as hysteresis or lag effect. A material that is fully magnetized is said to be magnetically SATURATED and no further effort would improve the magnet. Most magnetic materials have some difficulty losing all their magnetism and this is known as residual magnetism.

The hysteresis loop is the graphical indication of the flux density (B) response of different magnetic core materials that have been placed in a magnetizing field (H). This magnetizing force field is designated +H or -H for its tendency to polarize north or south. The hysteresis loop on the left represents a material suitable for use as a permanent magnet (HARD), as it is slow to become magnetically saturated but then retains its flux for a long time, even when the magnetizing force is reversed. The loop on the right, indicates a soft magnetic material which quickly saturates and loses its flux.



HYSTERESIS LOOPS

ELECTRO-MAGNETIC INDUCTION

The principle of electro-magnetic induction involves :

1. A magnetic field.
2. A conductor, or set of conductors.
3. Movement of that field or conductor, (or change of the magnetic field).

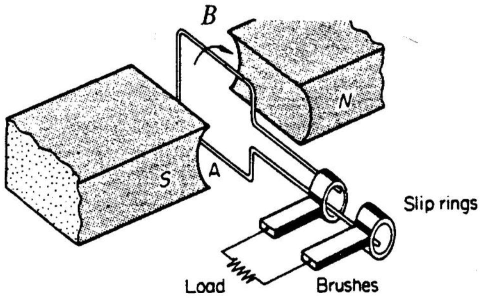
The amount of energy generated by this process depends on the interaction of these three elements :

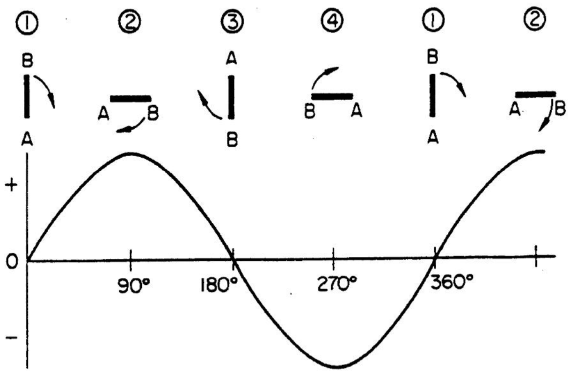
- strength of magnetic field
- number of conductors
- rate of movement of conductors in that field.

The proximity of the field to the conductors is also a factor of inductive efficiency. In a generator, this distance is set by the manufacturer. Generating electricity is converting mechanical energy to electrical energy.

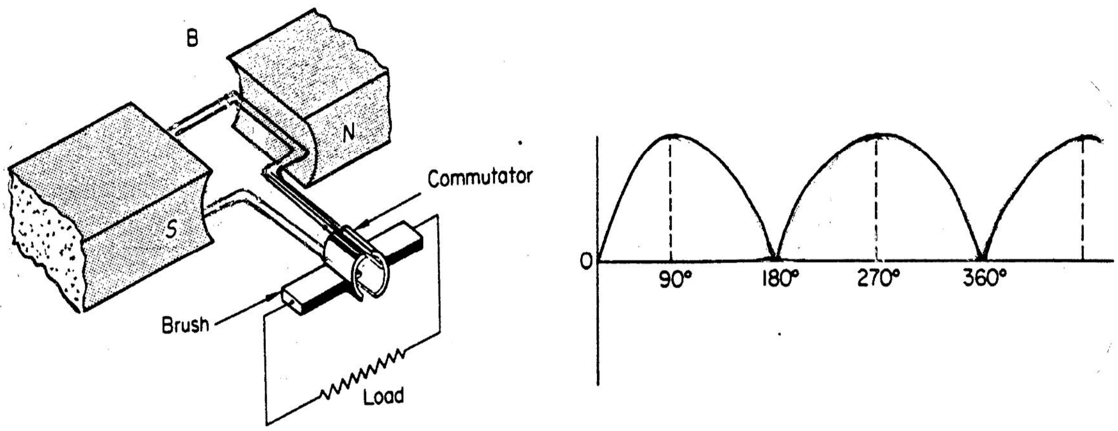
In the diagrams below, the generating process occurs as mechanical (rotary motion) is used to turn a conductor inside a magnetic field, alternatively, a magnet could be turned inside a set of conductors (a coil).

The graphical representation shows the wave form of the type of current generated.





BASIC ALTERNATING CURRENT PRODUCTION



BASIC DIRECT CURRENT PRODUCTION

Generator, is a generic term as in generating electricity. In modern aircraft, a generator can be an AC or a DC device. An AC generator is sometimes referred to as an alternator.

DC GENERATORS

Generators are classified by the method used to make their magnetic fields. The three types are :

1. Permanent Magnet Generators
2. Separately Excited Generators
3. Self Excited Generators

Permanent Magnet Generators (PMG)

These devices are not common as they are generally very heavy. Some modern generators do incorporate a permanent magnet to allow the device to 'SELF START'. All permanent magnets reduce in strength with age, consequently these generators become less productive as they get older.

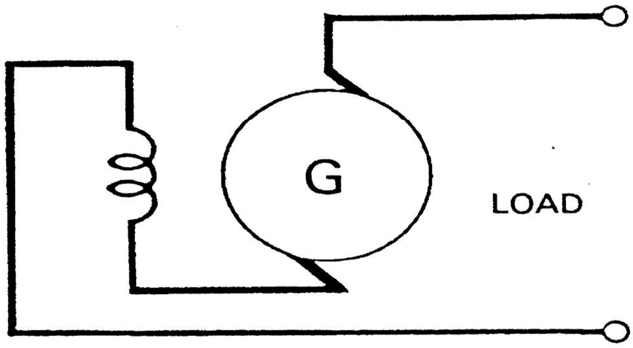
Self Exited Generators

Once the mechanical rotation is commenced, a small permanent magnet or residual magnetism can be used to make the initial field to get the generator started. Now that electricity is being produced it can supply its own field. It is therefore considered self excited.

If the generator is self exciting it needs some residual magnetism in its core to initiate electricity production. If this magnetism is lost through age, mistreatment or heat, it can be restored by 'Flashing the Field'. This is done by connecting a battery to the field for a few seconds to remagnetise the core.

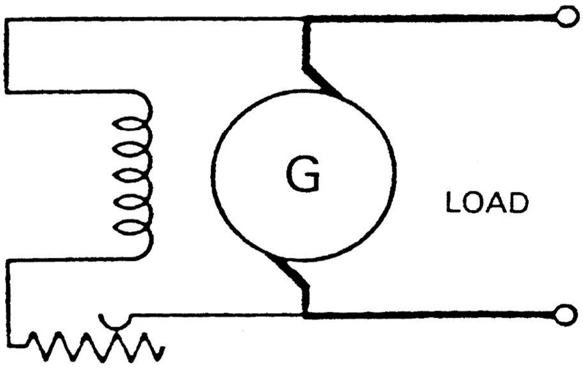
DC Generator 'Field Winding' Arrangements

The field windings in a DC generator are usually built into the stator and produce a magnetic field through which the armature coils are forced to rotate producing its DC output via the commutator and brushes. This field can be connected in series with the armature and its load, in parallel with the armature and its load or a compound field can be formed with part of the windings in series and part of the windings in parallel.



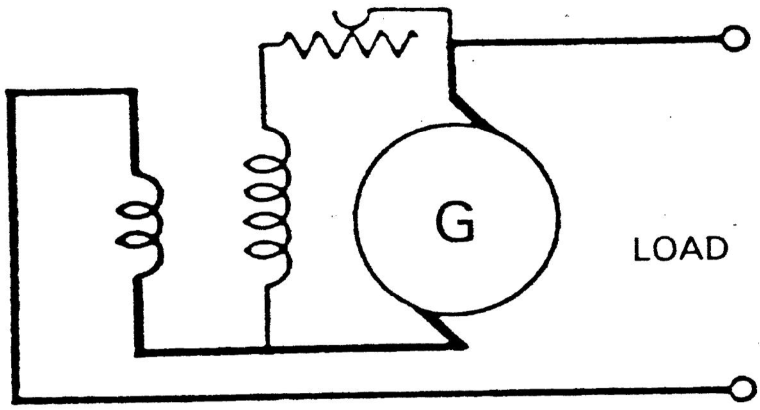
SERIES FIELD

In a series wound generator, the higher the load current, the greater the field strength, and this tends to increase the voltage output. Conversely, if the load decreases the output voltage decreases. It is possible to provide some control of the out voltage by using a rheostat, but generally this type of generator has poor control characteristics and is rarely used.



PARALLEL FIELD (SHUNT WOUND)

In the parallel wound generator, the field is parallel with or across the armature and the load. The field current is directly proportional to the applied voltage (generator output) which decreases as the load increases. While this device is more stable its output does decrease as load increases.



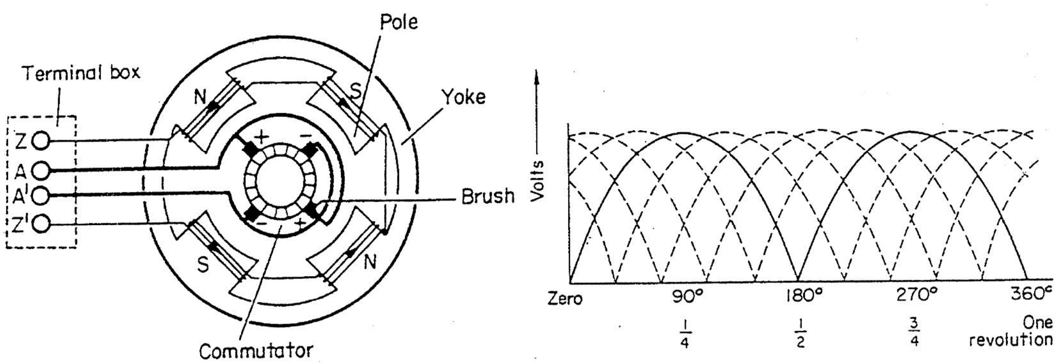
THE COMPOUND WOUND GENERATOR

The combination of the series and parallel field windings captures the most desirable characteristics of the series and parallel wound generator. As load current increases, the voltage drop in the shunt field is offset by the increased current in the series field.

DC generators are no longer common on light aircraft. However, the compound wound generator is a useful device and is sometimes found on the medium size turboprop aircraft where it can be used to double as a starter motor.

These devices are more complex than the preceding simple diagrams indicate. The DC generator below uses four magnetic poles and two sets of brushes onto a sixteen step commutator.

The output characteristics of a compound wound generator are determined by the manufacturer.

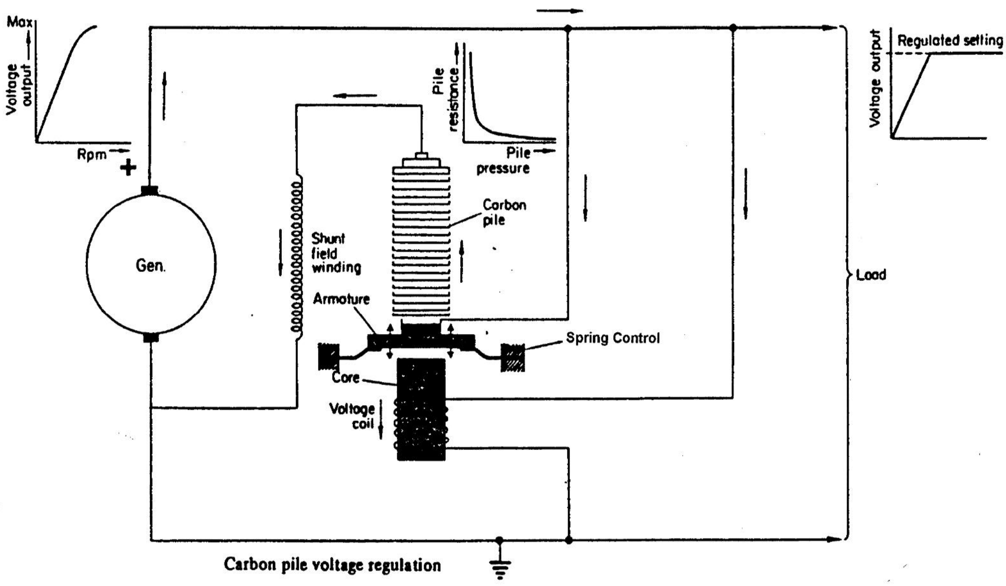


DC GENERATOR MULTIPLE POLES

This results in a multiple of the wave form energy being produced. Which means a high current flow is available (a large electrical load) and a good quality DC voltage is produced.

VOLTAGE REGULATION - DC

Electrical equipment requires the supply voltage to be within a fairly small operational range for it to be useful and reliable. Vibrating contact regulators and the carbon pile regulators were originally used for this basic regulating function. They sense the output voltage from the generator, then control the amount of current flowing in the generator field windings. A change in the field current causes a change in the field strength hence the generator output is regulated.



BASIC VOLTAGE REGULATOR

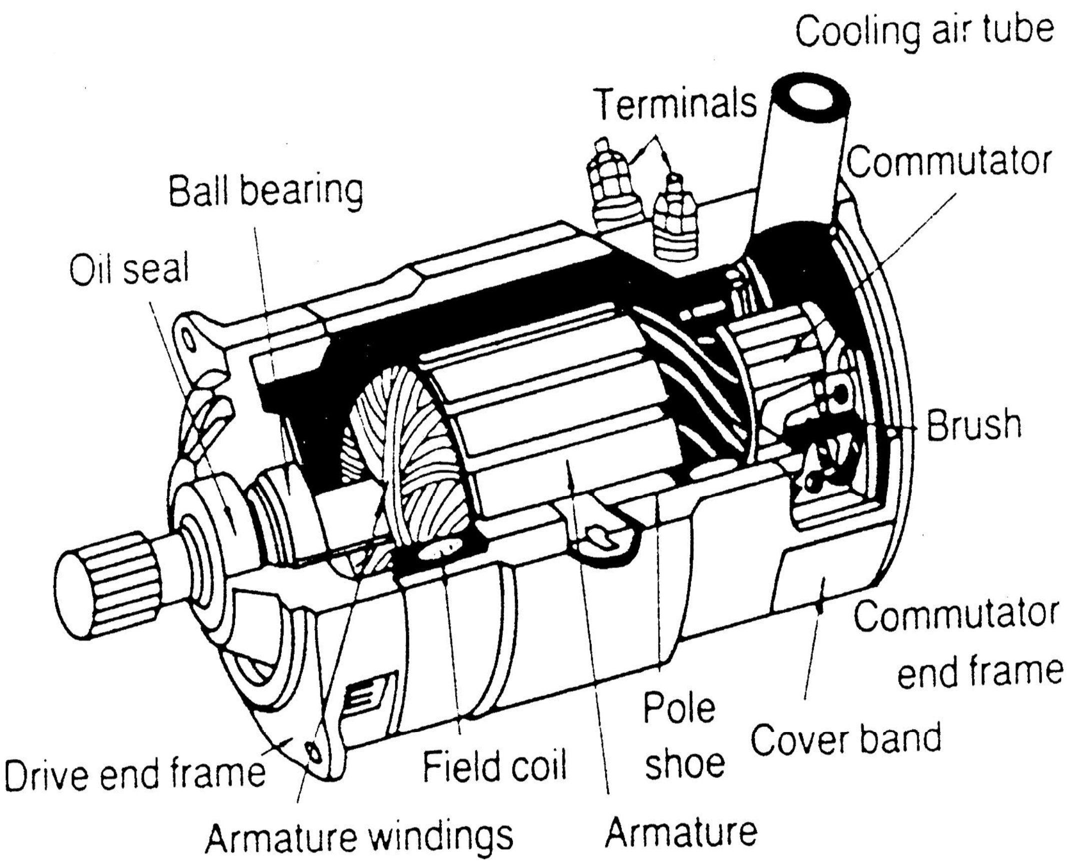
The use of "Direct Current only" systems is common in light aircraft. Through the years, as technology has progressed, the Alternator (AC) has been developed and has proved to be significantly more efficient and lighter than the older DC generator.

Because the generator was a self-starting device, it contained some permanent magnets which added weight to the unit. Another problem with the older DC generators was the inefficiency of the commutator. No energy was made as the brushes crossed the gaps in commutator. While the regulating device controlled the voltage well at high RPM, a DC generator had difficulty sustaining its system voltage below about 1500 RPM. Brush and commutator wear was an ever-present maintenance problem. Arcing between the brushes and the commutator caused energy transmissions, known as Radio Frequency Interference (RFI), that could affect other equipment.

The Basic DC Generator

Small DC generators are no longer common on light aircraft. However, some aircraft still have them and medium weight aircraft use a type of generator that doubles as a started motor.

In the diagram below the field windings are wound on a magnetic core called pole shoes, these are fixed to the generator housing and together form the stator. The armature core is mounted on the generator drive shaft. The commutator is also mounted on the drive shaft. Each armature winding starts and ends at opposite contacts on the commutator, with many windings wound around the core. The brushes are made of carbon and are spring loaded to keep them in good contact with the commutator. The brushes are internally connected to the generator terminals, which in turn allow external generator connection to the electrical system.



A LIGHT AIRCRAFT DC GENERATOR

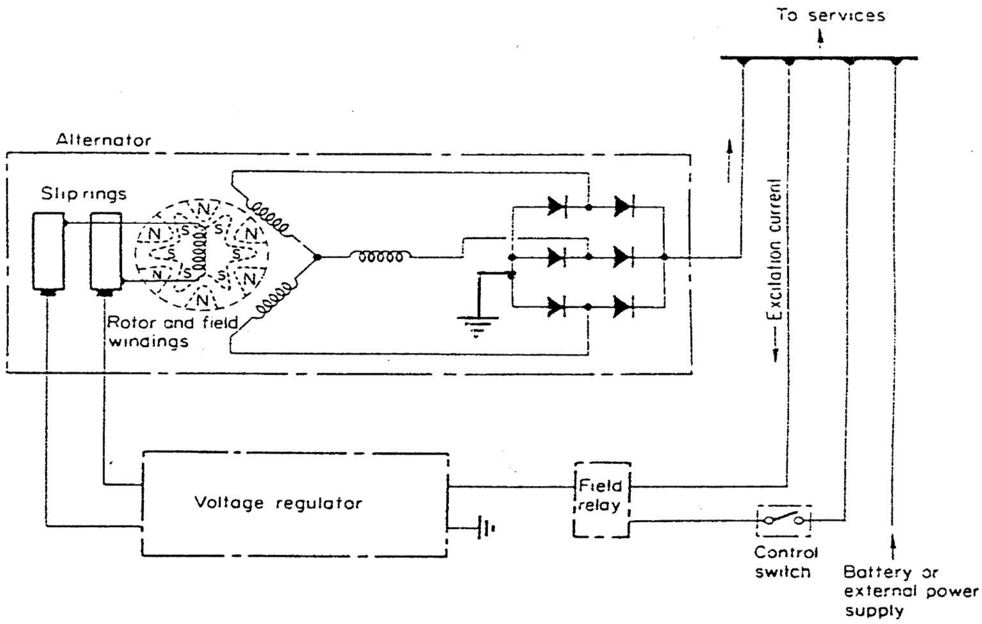
The Alternator (AC GENERATOR) in the DC Electrical System

The primary product of an alternator is alternating current. However, many modern light aircraft use direct current only systems. The alternating current is rectified by diodes mounted on the back of the alternator so the system outputs DC.

Large modern aircraft have AC systems and use very large AC generators to supply the power needed. When DC is required a transformer-rectifier unit is used.

Aircraft DC electrical systems are regulated at either 14 volts DC or 28 volts DC. To regulate the output voltage from an alternator, a regulating device is used, similar to the voltage regulator used for DC generators. Modern regulators are solid state electronic devices that very accurately sense a change in 'line' voltage and cause a change in the alternator field current to regulate the output voltage over a wide engine RPM range. The current from the regulator that creates the magnetic field, is always DC.

The alternator is usually 'on line' at 1000 RPM.



ALTERNATOR : PROVIDING A REGULATED DC OUTPUT

The DC generator has some disadvantages when compared to an alternator in a DC system :

1. Energy losses because of arcing and wear occur at the commutator.
2. Usually heavier
3. Unreliable at low RPM.

NB The Alternator has one disadvantage, in that it is not self exciting and requires a battery supply to provide field current to the rotor.

Aircraft DC electrical systems are regulated at either 14 volts or 28volts DC.