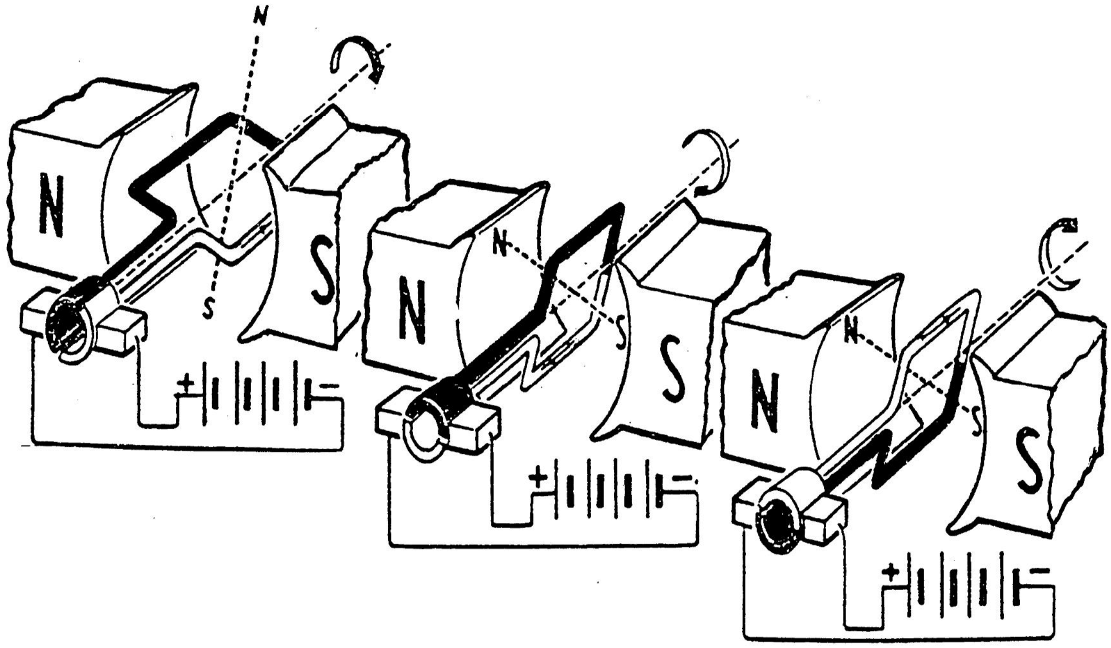
Chapter 6

MOTORS AND ACTUATORS

DC MOTOR THEORY

The DC motor is similar to the DC generator and electrical energy is used to make the mechanical rotation of the motor shaft.

The principle of electro-magnetic indication applies, but in the motor a current is used to create a magnetic field in the armature. This field reacts with the field set up by the stator windings. As like poles repel, the armature is forced to rotate. The armature rotates until the opposite poles of the armature and the stator are almost adjacent. The fields are now less effective and the brushes on the commutator switch to reverse the current flow. A new field of the opposite polarity is formed and the armature is again repelled by the stator field and continues to rotate in the same direction.



A DC MOTOR

BACK EMF

As the armature of the motor rotates, its windings are moving in the magnetic field of the stator. This induces a voltage into the armature windings in the same manner EMF is induced in a generator. This induced voltage is called back EMF and opposes the applied voltage that is already causing the current flow in the armature.

The amount of induced voltage (back EMF) in the armature depends on the same factors as electrical induction as described in generators, the:

- number of windings
- field of strength
- speed of rotation (rate of change)

Back EMF ***always opposes*** the applied EMF and consequently reduces the armature current. Back EMF is ***always less than*** the applied EMF.

This introduction to DC motor theory and back EMF has used a motor pictured with permanent magnets providing the stator field. Permanent magnets are rarely used in aircraft systems because they are heavy and lack control flexibility. As with generators, the magnetic field in a motor is very important. By taking control of the field winding design, the motor torque, speed and therefore its usefulness is determined.

As with DC generators, DC motors can have their field windings wound in series, parallel or a combination of series, parallel with the motor armature.

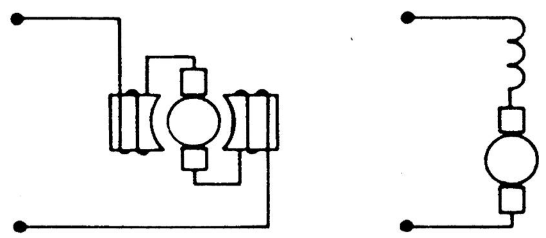
<u>Series Motors</u> - The field is connected in series with its armature.

In a series motor, as the armature and field windings are connected in series, the entire armature current flows through the field windings(stator). If the physical load on the motor increases, the motor slows down, the back EMF reduces, which allows the armature and field current to increase producing stronger fields thereby providing significantly more torque. The main features of this motor are:

-high starting torque
- good acceleration

Series motors tend to turn slowly with heavy loads and very rapidly with light loads. They are very high torque devices and must not be started without a load. Series DC motors are often used in:

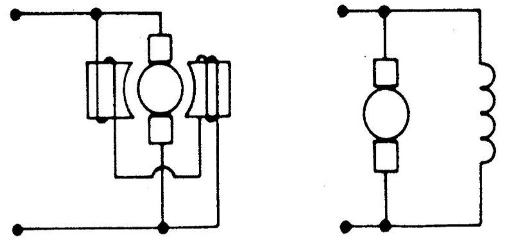
- starter motors
- Electric actuators



SERIES MOTOR

<u>Shunt Motors</u> - The field is connected in parallel with its armature.

In a shunt motor the same voltage that produces the armature current produces the field (stator) current. The armature current is therefore independent of the field current, allowing a constant field strength. The torque developed by the shunt motor varies directly with the armature current.

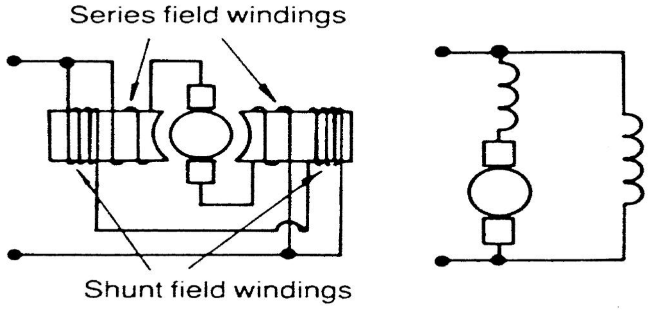


SHUNT MOTOR

The speed variation from the no load to the full load condition is only about 10%. **Shunt motors** are used where a constant motor speed (RPM) is required. Shunt motors need to start under light or no-load conditions as they have very low starting torque and are used in small fans and blowers.

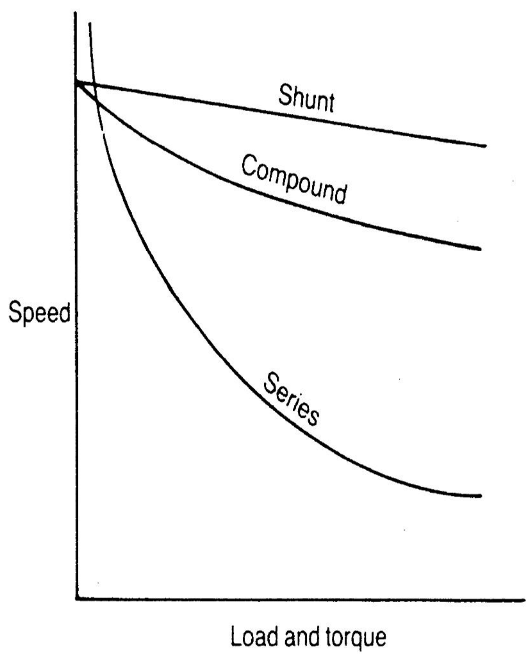
<u>Compound Motors</u> - A combination of series and parallel field windings.

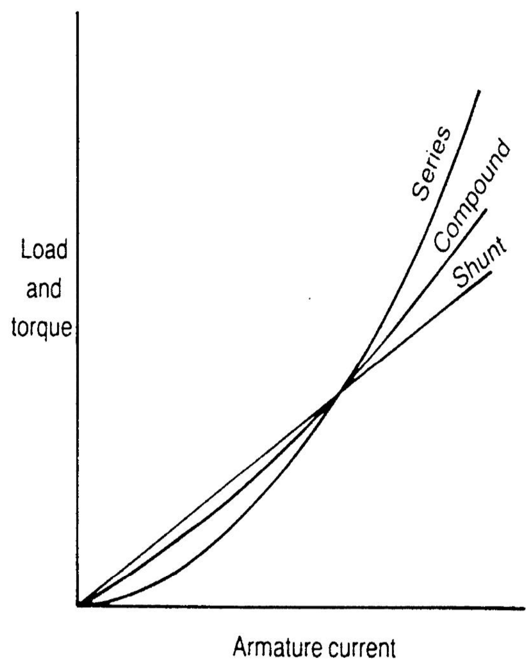
Compound motors feature the advantages of both series and shunt motors, with relatively constant speed with good starting torque and excellent power characteristics at high RPM.



COMPOUND MOTOR

The following graphs provide a comparison of series, shunt and compound wound DC motors





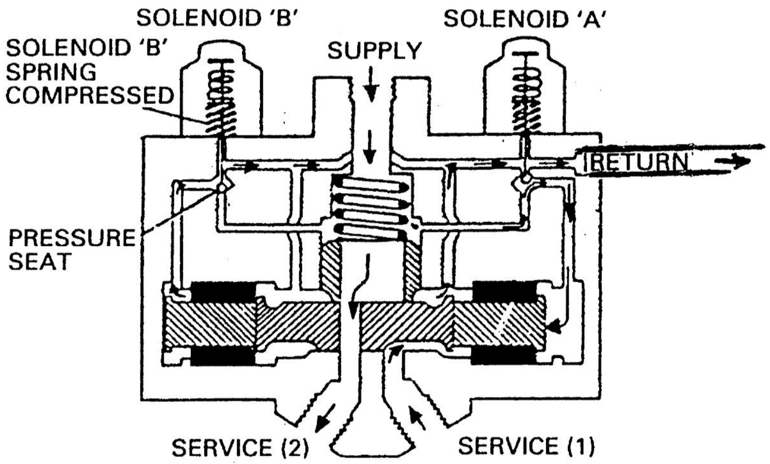
ELECTRICAL ACTUATORS

Actuators or servo's, are electro-mechanical devices which provide a physical output to operate valves, fuel cocks, doors and flaps etc.

Electrical actuators usually make use of a motor, which can be AC or DC, or solenoids to produce the required mechanical output. Solenoid types are used to control hydraulic or pneumatic valves which in turn provide the hydraulic or pneumatic power to complete a task. Motor actuators are generally self contained with a motor, driving through a gear box or worm gear to increase the torque output. Small aircraft autopilots use actuators or servos, to move control surfaces. Actuators can be designed to provide a rotary or linear output.

Solenoid Actuators

Solenoid actuators are used to control fluid systems, hydraulic or pneumatic, selectors. Switching on the DC control power to the solenoid coil, results in the magnetic field acting to withdraw the valve armature against spring tension and the fluid flow occurs. To stop the flow, the control power is switched OFF allowing the spring to force the valve closed.



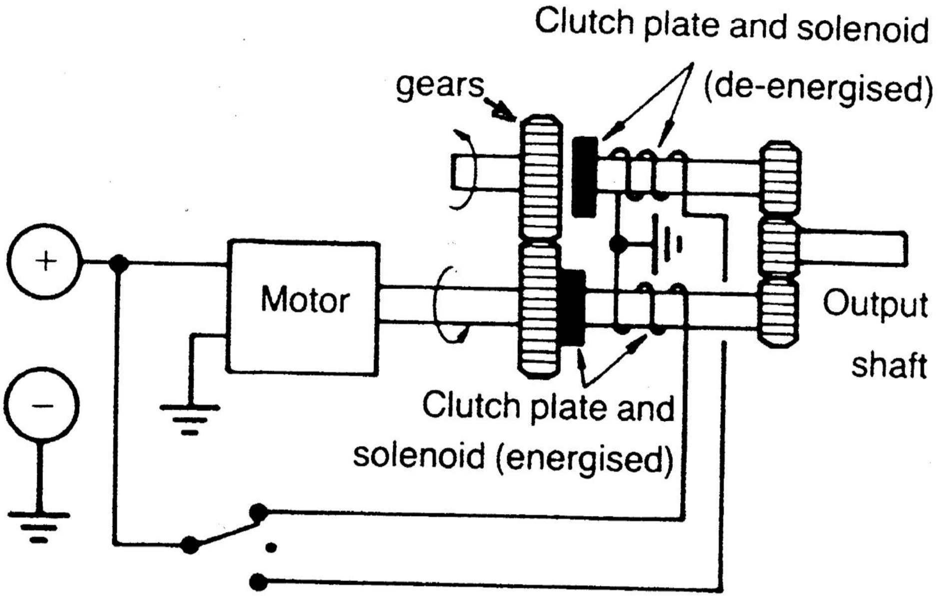
A SOLENIOD ACTUATOR - REMOTE VALVE OPERATION

Rotary Actuators

Rotary actuators are powered by small reversible motors. The amount of angular travel of the output shaft and its speed of rotation, depends on the design of the actuator. The output shaft of an actuator, designed for operation of fuel cocks may turn at just 3 r.p.m. and may be limited to an angular travel of 90°. The reduction gearing may be of the multi-stage spur type with a reduction ratio of as much as 20,000 : 1.

Rotary actuators used to position very light loads such as switches, would have a high ratio reduction gear linked to a small motor.

Limit switches are fitted to control the angular travel of the output shaft. An electro-magnetic brake is a common feature of rotary actuators; the brake solenoid is connected in series with the motor armature, so the brake is released when the motor is energised. Conversely, the brake is immediately applied, by spring action, when the motor is energised. The action of the brake, prevents over-run of the output shaft when the electrical supply to the actuator is switched off; it also prevents 'creep' of the motor when it should be stationary.



ROTARY ACTUATOR

LINEAR ACTUATORS

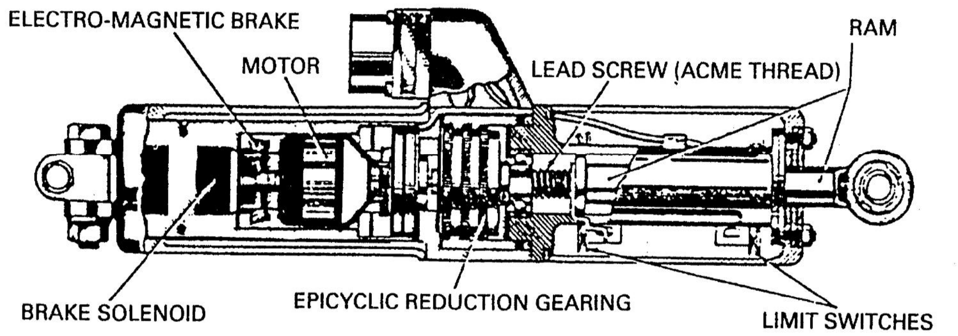
Linear actuators are designed to operate on the aircraft electrical power of 115VAC 1ϕ or 3ϕ 400HZ or 28VDC. These units can operate against loads of up to seven tons, to small mechanisms that are effective against maximum loads of only 50lb. This wide range of performance has led to variations in construction and appearance. All operate on the same basic principle. The operating ram, which produces the linear effort, is driven by a reversible motor through high-ratio gearing and a lead screw.

The size and power of the motor depends on the maximum designed load against which the actuator is intended to operate, and on the linear speed of the operating ram.

Limit switches are fitted, so that the motor stops automatically, when the operating ram has reached the permissible limits of its travel. Certain types of actuator have an intermediate limit switch, whereby the ram can be stopped automatically at a predetermined position other than the fully extended or fully retracted positions. This could apply to flaps selections.

The majority of linear actuators are fitted with electro magnetic brakes to prevent over travel of the operating ram when the motor is switched off. The brakes are spring loaded so that they are applied when the motor is not energised; the brake solenoid is connected in series with the armature of the motor, so that the brake is withdrawn immediately the motor is switched on.

Many types of linear actuators are protected from the effects of mechanical overloading, by the incorporation of friction clutches in the transmission system between the motor and the operating ram. These friction clutches are often referred to as ‘torque limiting’ devices. The principle is, that it is better to stop the action of the actuator than to cause structural damage or a problem like flaps asymmetry.



LINEAR ACTUATOR

STARTER GENERATORS

To save weight, some small and medium turboprop aircraft take advantage of the similarities of function between a DC Motor and a DC Generator.

A compound wound DC Motor is coupled via a gear box, to act as the starter motor powered from the battery. As the engine winds up and becomes self sustaining, the aircraft engine now drives the starter motor. The battery and field windings are switched so the motor now becomes the generator and is connected to the Bus Bar via a voltage regulator.

This DC system achieves both the ***starting*** and ***DC generating*** functions with one piece of equipment. Aircraft using starter generators usually require AC power too. One or two inverters are provided to ensure a suitable supply of constant frequency AC. Should there be a further power requirement, additional air driven generators can provide independent ‘frequency wild’ AC for heating, lighting and other non-frequency sensitive circuits. These AC aspects are presented later in this book.