

## UNIT II

### STARTING SYSTEM & CHARGING SYSTEM

#### **The starting system:**

The starting system includes the battery, starter motor, solenoid, ignition switch and in some cases, a starter relay. An inhibitor or a neutral safety switch is included in the starting system circuit to prevent the vehicle from being started while in gear.

When the ignition key is turned to the **start** position, current flows and energizes the starter's solenoid coil. The energized coil becomes an electromagnet which pulls the plunger into the coil. The plunger closes a set of contacts which allow high current to reach the starter motor.

#### **The charging system:**

The charging system consists of an alternator (generator), drive belt, battery, voltage regulator and the associated wiring. The charging system, like the starting system is a series circuit with the battery wired in parallel. After the engine is started and running, the alternator takes over as the source of power and the battery then becomes part of the load on the charging system.

The alternator, which is driven by the belt, consists of a rotating coil of laminated wire called the rotor. Surrounding the rotor are more coils of laminated wire that remain stationary (called stator) just inside the alternator case. When current is passed through the rotor via the slip rings and brushes, the rotor becomes a rotating magnet having a magnetic field. When a magnetic field passes through a conductor (the stator), alternating current (A/C) is generated.

This A/C current is rectified, turned into direct current (D/C), by the diodes located within the alternator.

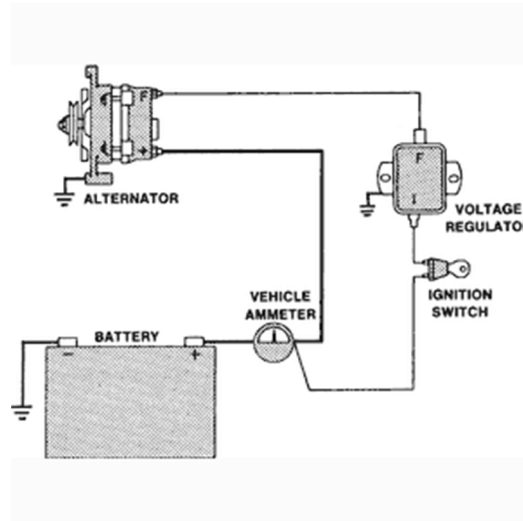


Fig 2.1: Common Charging system schematic diagram.

### 1. Condition at starting:

The starting torque should be very high and the speed should be very low while starting the starter motor of a automobile.

### 2. Behavior of starter during starting.

The starter motor is a dc series motor which has the high starting torque characteristics.

### 3(a) DC machines:

D.C. machines are electro mechanical energy converters which work from a d.c. source and generate mechanical power (called as motor) or convert mechanical power into a d.c. power(called as generator).

### **DC Motor:**

A motor is an electrical machine which converts electrical energy into mechanical energy.

### **Principle of DC Motor:**

Whenever a current carrying conductor is placed in a magnetic field, it experiences a mechanical force. The direction of this force is given by Fleming's left hand rule and it's magnitude is given by  $F = BIL$ . Where, B = magnetic flux density, I = current and L = length of the conductor within the magnetic field.

### **Fleming's left hand rule:**

Stretch the fore finger, middle finger and thumb of left hand to be perpendicular to each other, the direction of magnetic field is represented by the fore finger, direction of the current is represented by middle finger then the thumb represents the direction of the force experienced by the current carrying conductor.

### **Types Of DC Motors:**

DC motors are usually classified on the basis of their excitation configuration, as given below.

- Separately excited (field winding is fed by external source)
- Self excited -

- Series wound (The field winding is connected in series with armature winding)
- Shunt wound (The field winding is connected in parallel with armature wdg)
- Compound wound -
  - Long shunt
  - Short shunt

The Classification chart of DC machine is given in fig.2.2

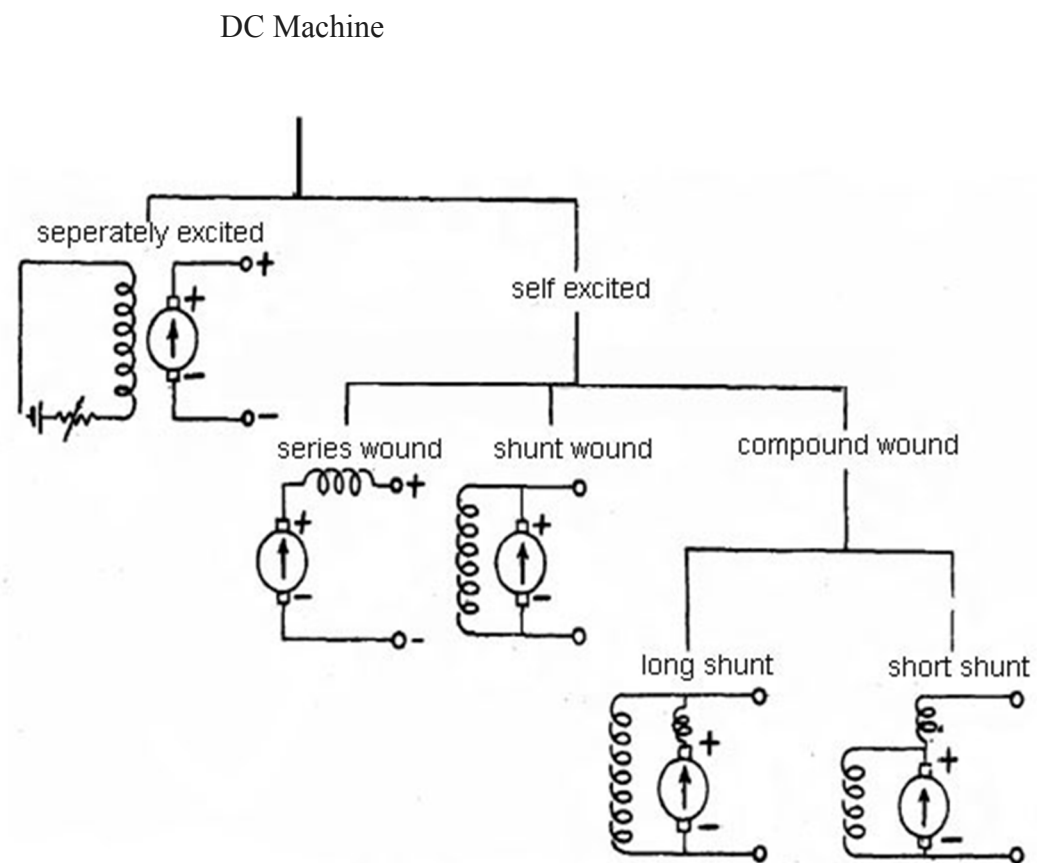


Fig 2.2 Dc machine classifications

References:

1. <http://www.electricaleasy.com/2012/12/classifications-of-dc-machines.html>
2. <http://www.electricaleasy.com/2012/12/basic-construction-and-working-of-dc.html>

### **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:**

A DC generator can be used as a DC motor without any constructional changes and vice versa is also possible. Hence a DC generator/DC motor can be termed as a **DC machine**. The basic constructional details are valid for both of them.

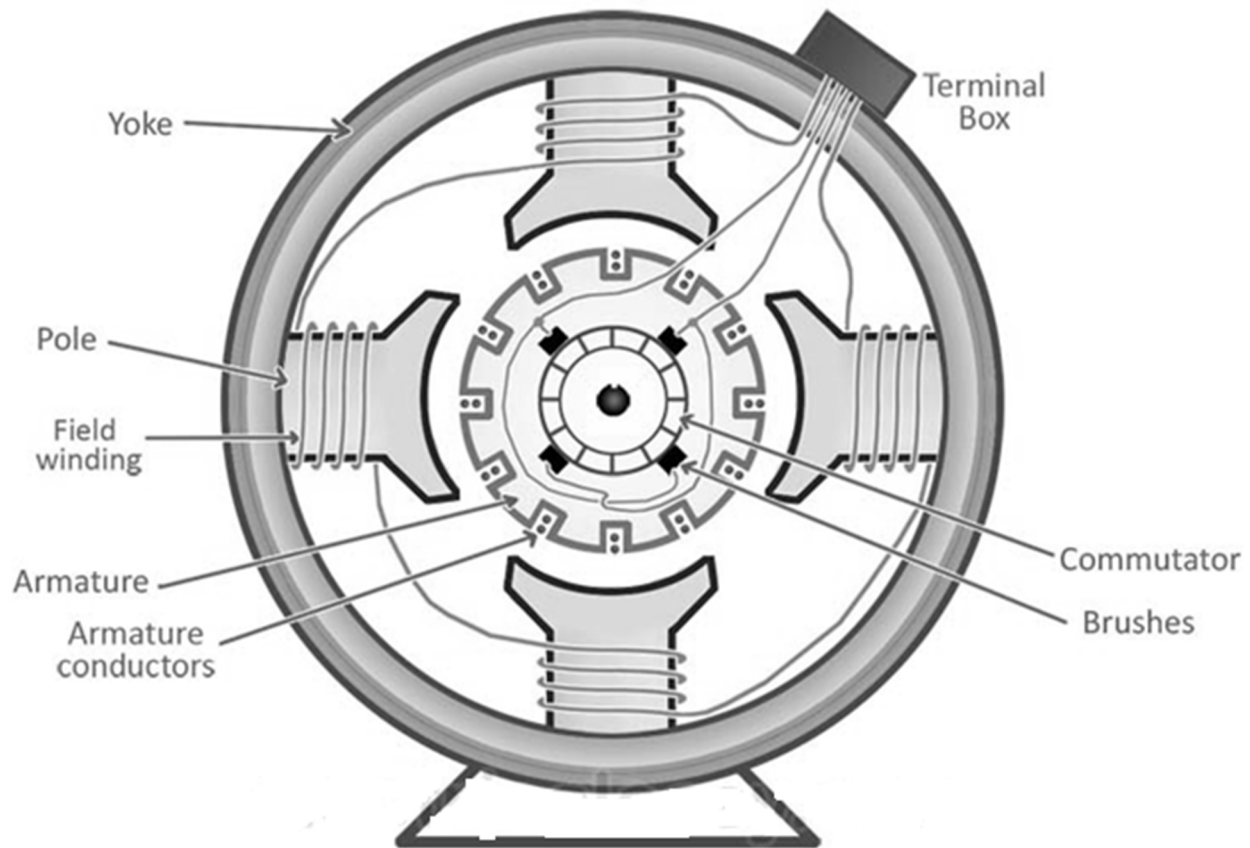


Fig.2.3 Construction of a simple 4-pole DC machine.

The above figure shows the constructional details of a simple 4-pole DC machine. A dc machine(motor/generator) consists of two basic parts named as stator and rotor.

The basic constructional parts of a DC machine are briefed 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.



Fig 2.4 Armature core and winding coil (rotor)

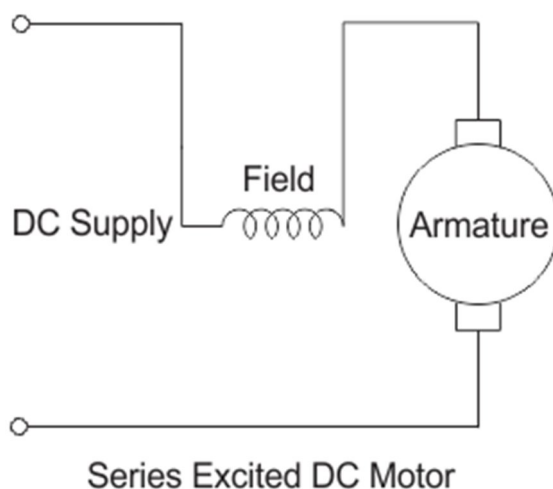
4. **Armature core:** Armature core is the rotor of the machine. It is cylindrical in shape with slots to carry armature winding. The armature is built up of thin laminated circular steel disks for reducing eddy current losses. It may be provided with air ducts for the axial air flow for cooling purposes. 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 consists of radial copper bars separated by an insulating material, usually mica. The number of coils in the armature, the number of poles, and the type of winding determine the number of commutator bars

### 3(b).Series motor and its characteristics:

This motor has field coil connected in series to the armature winding.

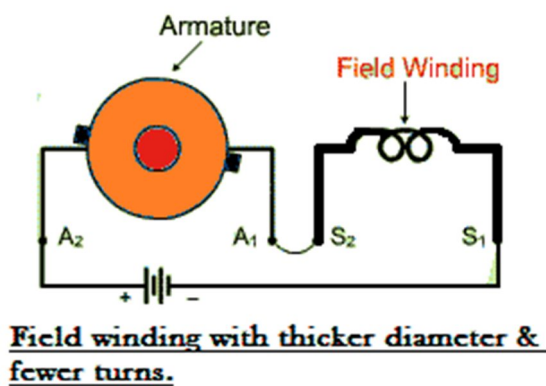




For this reason relatively higher current flows through the field coils, it is designed accordingly as mentioned below.

1. The field coils of DC series motor are wound with relatively fewer turns as the current through the field is its armature current and hence for required mmf less numbers of turns are required.

2.



3. The wire is heavier, as the diameter is considerable increased to provide minimum electrical resistance to the flow of full armature current.
4. In spite of the above mentioned differences, about having fewer coil turns the running of this DC motor remains unaffected, as the current through the field is reasonably high to produce a field strong enough for generating the required amount of torque.

#### **Torque Vs. Armature Current ( $T_a$ - $I_a$ ):**

This characteristic is also known as **electrical characteristic**. We know that torque is directly proportional to the product of armature current and field flux,  $T_a \propto \phi \cdot I_a$ .

In DC series motors, field winding is connected in series with the armature, i.e.  $I_a = I_f$ . Therefore, before magnetic saturation of the field, flux  $\phi$  is directly proportional to  $I_a$ . Hence, before magnetic saturation  $T_a \propto I_a^2$ . Therefore, the  $T_a$ - $I_a$  curve is parabola for smaller values of  $I_a$ .

After magnetic saturation of the field poles, flux  $\phi$  is independent of armature current  $I_a$ . Therefore, the torque varies proportionally to  $I_a$  only,  $T \propto I_a$ . Therefore, after magnetic saturation,  $T_a$ - $I_a$  curve becomes a straight line. The shaft torque ( $T_{sh}$ ) is less than armature torque ( $T_a$ ) due to stray losses. Hence, the curve  $T_{sh}$  vs  $I_a$  lies slightly lower.

In DC series motors, (prior to magnetic saturation) torque increases as the square of armature current, these motors are used where high starting torque is required.

### **Speed Vs. Armature Current (N- $I_a$ )**

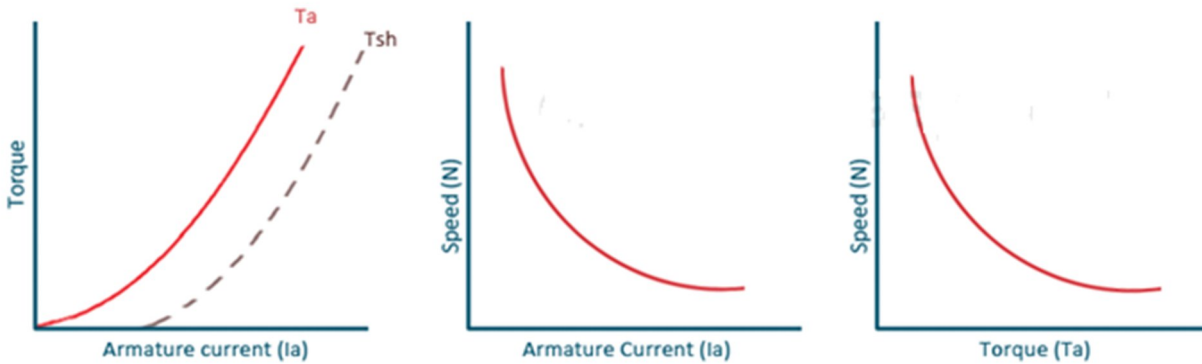
As per the relation,  $N \propto E_b / \phi$

For small load current (and hence for small armature current) change in back emf  $E_b$  is small and it may be neglected. Hence, for small currents speed is inversely proportional to  $\phi$ . As we know, flux is directly proportional to  $I_a$ , speed is inversely proportional to  $I_a$ . Therefore, when armature current is very small the speed becomes dangerously high. Hence a series motor should never be started at no load.

But, at heavy loads, armature current  $I_a$  is large and hence the speed is low which results in decreased back emf  $E_b$ . Due to decreased  $E_b$ , more armature current is allowed.

### Speed Vs. Torque (N-Ta)

This characteristic is also called as **mechanical characteristic**. From the below two **characteristics of DC series motor**, it can be found that when speed is high, torque is low and vice versa.



Ref: <http://what-when-how.com/automobile/starter-motor-construction-automobile/>

### 4. Principle & construction of starter motor.

**The starter motor or Self Starter or Self Motor** is used to crank the engine for starting. It utilizes the electrical energy stored in the battery and converts into mechanical energy. It is a powerful electric motor with a small gear type arrangement (pinion) attached to the end. When it gets activated, the gear is meshed with a larger gear (ring) that is attached to the engine. The starter motor then spins the engine over so that the piston can absorb in a fuel/ air mixture, which is then ignited to start the engine. When the engine starts to spin faster than starter, a device called an overrunning clutch (Bendix drive) automatically disengages the starter gear from the engine gear.

Working of different starter drive units:

There are four different main types of starter drives generally in use. They are given below.

1. The inertia drive (shock drive)
2. The pre-engaged drive
3. The single stage sliding gear drive and
4. The sliding armature drive.

STARTER TYPES ARE THREE "with light vehicles only." there are some other starter motors but for the heavy duties like bulldozer.

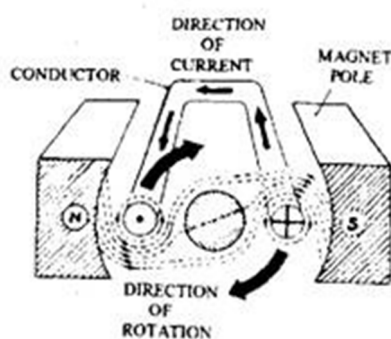
1. INERTIA.
2. PRE-ENGAGED.
3. GEAR REDUCTION.

### **1) INERTIA**

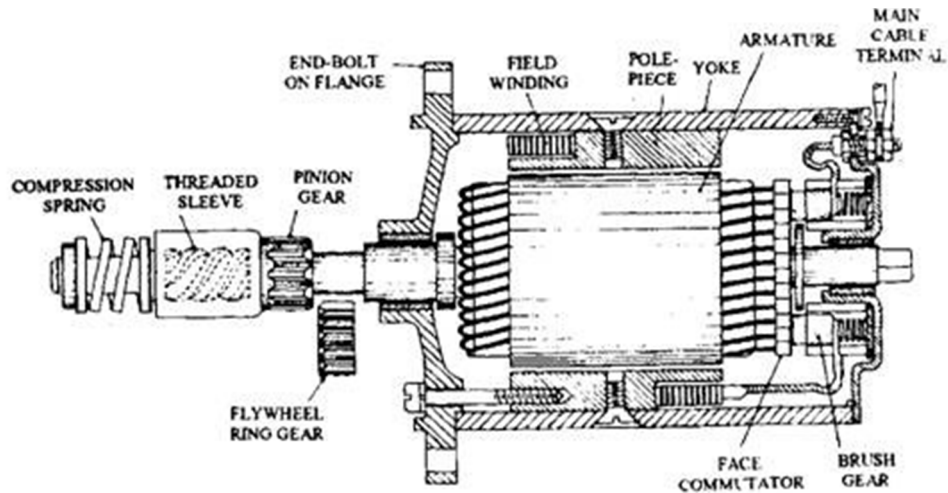


## Magnetic-torque Production

When the current flows through the yoke field windings, it converts the yoke into an electromagnet due to which a magnetic field or flux is created between the pole-pieces (Fig. 15.15). Similarly, due to the flow of current through the armature loop, concentric rings of magnetic flux are established around the two half-conductor cores. This magnetic flux flows anticlockwise around the left-hand conductor and clockwise around the right-hand conductor. It can be seen from the figure that the magnetic lines of force between the yoke poles and those for the armature conductors travel in the same direction, and the two sets of lines merge and strengthen each other. This is indicated below the left-hand conductor and above the right-hand conductor. Conversely, where the yoke and armature magnetic fields travel in opposite directions, they neutralise each other. Hence, the field strength above the left-hand conductor and below the right-hand conductor is very weak. The difference in the magnetic field strengths above and below each conductor gives rise to a net upward force, exerted on the left-hand conductor and a net downward force, on the right-hand conductor so that a clockwise-rotating torque is applied to the armature loop.



**Fig. 15.15. Production of a magnetic torque.**

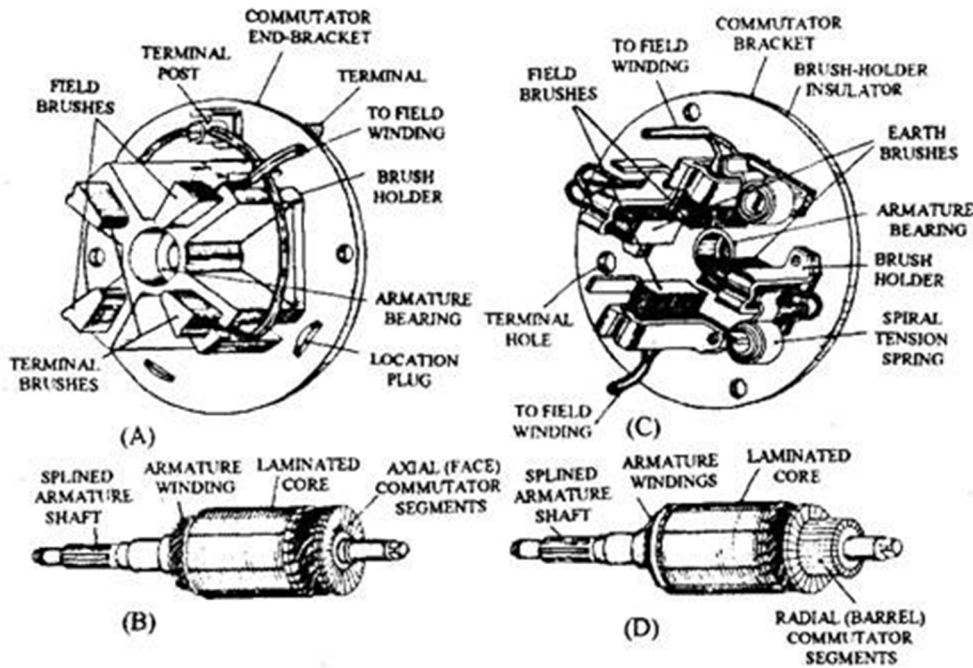


**Fig. 15.16. Inertia starter motor.**

### **Commutation**

When battery supplies power to the armature loop, the magnetic-field interaction rotates the loop causing the two half-conductors to change places with each other. Also this alters the direction of the current flowing in the conductor relative to the North and South Poles of the yoke. As a result the loop reverses its direction of rotation and turns backward.

To have the continuous rotation of armature loop in only one direction, the direction of current flowing in each half-loop is required to be reversed every half-revolution, called commutation. This is achieved by connecting the armature-loop ends to a split-ring (Fig. 15.14). As a result each half-ring segment comes in contact with a different brush during every half revolution of the armature, so that the direction of the current flow within the armature loop repeatedly reverses.



## Permanent-magnet Starter Motor

Permanent magnet starters were introduced on the vehicles in the late 1980s. Less weight and small size are the two advantages of these motors, compared to conventional types. This causes the permanent magnet starter to be more popular as less space is available for engine electrical in modern cars. The reduction in weight also contributes towards reduction in fuel consumption. The standard permanent magnet starters produced are suitable for spark ignition engines up to about 2L capacity and are rated in the capacity of 1 kW or less. Some examples are the Bosch DM range (Fig. 15.23) and the Lucas Models M78R / M80R (Fig. 15.24)

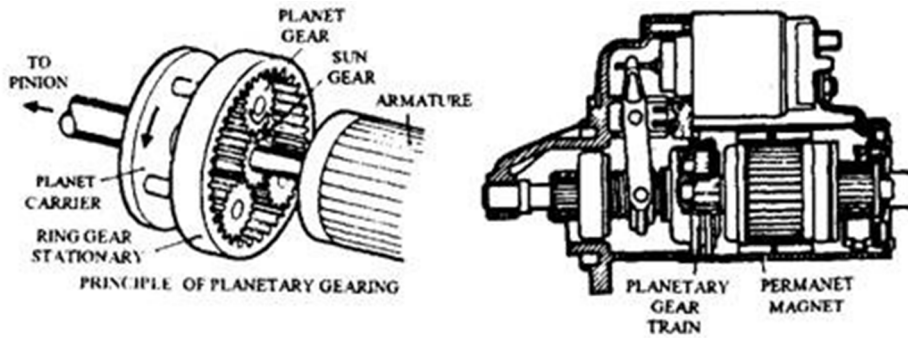


Fig. 15.23. Bosch permanent magnet starter.

#### SERVICE PARTS

- 1 - SOLENOID
- 2 - BRUSH BOX ASSEMBLY
- 3 - BRUSH KIT
- 4 - ARMATURE
- 5 - RETENTION KIT
- 6 - PIVOT AND GROMMET KIT
- 7 - DRY SHAFT AND BEARING BRACKET ASSEMBLY KIT
- 8 - DRIVE ASSEMBLY
- 9 - BUSH KIT
- 10 - MOTOR ASSEMBLY  
DRIVE SHAFT  
SUNDRY KIT  
SUNDRY PARTS KIT

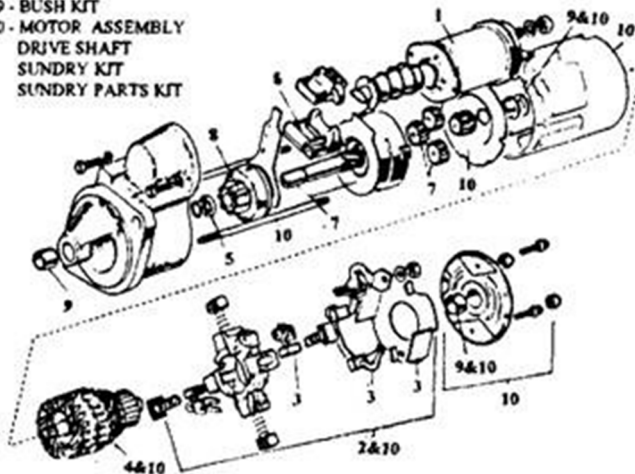


Fig. 15.24. Lucas M78R I M80R starter.

The principle of operation is almost similar to the conventional pre-engaged starter motor, in which the field windings and pole shoes are replaced with high quality permanent magnets. This provides a reduction in weight up to 15 percent. The diameter of the yoke can also be reduced by a similar value. Permanent magnets provide constant excitation due to which the speed and torque characteristic is expected to be constant. However, due to the fall in battery voltage under load and the low resistance of the armature windings, the characteristic is

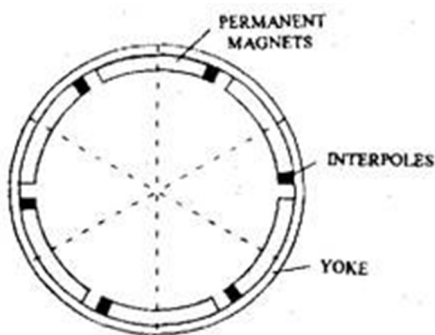


comparable to that of series wound motors. Sometimes flux concentrating pieces or inter-poles are installed between the main magnets (Fig. 15.25). The warping effect of the magnetic field causes the characteristic curve to be very similar to that of the series motor.

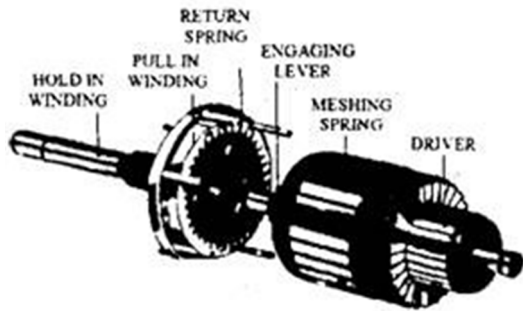
Considerable improvement in the construction of the brushes has taken place. A copper and graphite mix is used to make the brushes in two parts, so that higher copper content is in the power zone and higher graphite content is in the commutation zone. This provides an increase in the service life and a reduction in voltage drop, giving higher starter power output.

Permanent magnet motors for a higher power application, have been developed with intermediate transmission of generally epicyclic type (Fig. 15.26). These enable the armatures to rotate at a higher and more efficient speed while delivering the torque, due to the gear reduction.

Permanent magnet starters with intermediate transmission are available with power outputs of about 1.7 kW, suitable for spark ignition engines up to about 5 L or compression ignition engines up to about 1.6 L. The principle of operations of this type of permanent magnet motor is again similar to the conventional pre-engaged starter, but can provide a weight saving of up to 40 percent.



**Fig. 15.25. Permanent magnet fields with inter-poles.**



**Fig. 15.26. Starter motor intermediate transmission.** In the epicyclic type intermediate transmission, the sun gear is on the armature shaft and the pinion is driven by the planet carrier. The ring gear or annulus remains stationary acting as an intermediate bearing. This arrangement of gears provides a reduction ratio of about 5:1, which can be calculated by the simple formula;

$$\text{Reduction Ratio} = (A + S)/S$$

where, A = number of teeth on the annulus

S – number of teeth on the sun gear.

### 3) GEAR REDUCTION

#### Construction

This type of starter motor contains a magnetic switch, A compact high-speed motor, Several reduction gears, A pinion gear, A starter clutch etc. The extra gears reduce the motor speed by a factor of one to three or four and transmit it to the pinion gear. The plunger of the magnetic switch directly pushes the pinion gear, Which is located on the same axis, Causing it to mesh

with the ring gear. This type of starter motor generates much greater torque, In proportion to size and weight, Than the conventional type.

When the ignition switch has been turned to the START position, Terminal 50 passes electrical current from the battery to the hold-in and pull-in coils. From the pull-in coil, The current then flows to the field coils and armature coils via Terminal C. The motor rotates at a lower speed at this point, Since the energized pull-in coil causes a voltage drop which limits the supply of current to the motor components (The field coils and the armature). The hold-in and pull-in coils, At the same time, Set up a magnetic field which pushes the plunger to the left against the return springs. The pinion gear therefore shifts to the left until it engages with the ring gear. The low motor speed at this stage means that both gears mesh smoothly. The screw splines also help the pinion and ring gears to engage more smoothly.

### ***Pinion And Ring Gears Engaged***

When the magnetic switch and the screw splines have pushed the pinion gear to the position where it meshes completely with the ring gear, The contact plate attached to the plunger turns the main switch on by short-circuiting the connection between terminals 30 and C. The resulting connection allows the larger electrical current to pass through the starter motor, Which causes the motor to rotate with a greater torque. The screw splines help the pinion gear mesh more securely with the ring gear. At the same time, The voltage levels at both ends of the pull-in coil become equal so that no current flows through this coil. The plunger is therefore held in position by the magnetic force exerted by the hold-in coil.

### ***Ignition Switch In ON Position***

Turning the ignition switch back to the ON position from START cuts off the voltage being applied to terminal 50. The main switch remains closed, However, Some current flows from Terminal C to the hold-in coil via the pull-in coil. Since current flows through the hold-in coil in the same direction as when the ignition switch is in the START position, It generates a magnetic force which pulls the plunger. In the pull-in coil on the other hand, Current flows in the opposite direction, Generating a magnetic force which attempts to return the plunger to its original position. The magnetic fields set up by these two coils cancel each other out, So the plunger is pulled backward by the return springs. Therefore, The heavy current which has been supplied to the motor is cut off and the plunger disengages the pinion and ring gears at about the same time. The armature used in the reduction type starter motor has less inertia than the one in the conventional type, So friction soon brings it to a stop. This type of starter motor therefore does not require the brake mechanism used in the conventional type starter motor.

### **Care and maintenance of starter motor.**

The most important component of a starting system is the battery, and until this is in sound condition, the speed of starter motor remains low and possibly with a limited duration of cranking. However, a battery may be faulty due to other factors like, a defective charging system, a short to earth in another system, or overload of the battery due to driving or seasonal conditions. Indications from warning instruments and observation of the engine's starting performance, enable the driver to identify the initial conditions that may lead a major fault. A battery supplies a very large current to the starting motor, and hence a drop in the battery p.d.

takes place. When this drop is very high, the ignition system does not receive sufficient power to provide suitable spark at the plugs, although the starting motor is still functioning at a low speed. This condition is confirmed when an engine fails to start with the motor, but starts easily by “bump starting” (rolling the vehicle in top gear and suddenly releasing the clutch). Normally this problem is attributed to a battery fault, but on many modern engines the problem is resolved by installing cold-start ballast resistor in the ignition supply lead. In addition to the resistor lead, a separate lead is used between a terminal on the starter solenoid and the ignition coil so that the resistor is bypassed when the starter is operated.

### **Maintenance.**

Routine maintenance work should be attended to the battery, especially the terminals. All terminals and connectors in the starter circuit should be maintained clean and secure.

### **Fault Diagnosis.**

If the probable defects of each component of the system are considered, along with the possible symptoms indicated by each defect, then it is possible for the electrician to find a likely cause of a particular fault. The main problems, and the possible faults, faced by various components of the starting system, are presented below.

**Battery :**            **Low state of charge or defective.**

**Terminals**        **High resistance due to corrosion or slackness.**

**Cables :**            **Broken or partially broken, especially the earth-bonding strap**

**between the engine and frame.**

**Solenoid :**        **Dirty contacts or faulty connection between windings and terminals.**

**Starter switch :** **High resistance at contacts or broken cables.**

**Motor**            **Poor bedding of brushes or dirty commutator.**

**Pinion :**        **Not meshing or jammed due to a worm flywheel ring gear.**

**Ref:**            **<http://what-when-how.com/automobile/starter-motor-maintenance-and-fault-diagnosis-automobile>**

## **6. Starter Switches.**

There are two types, one is manually operated starter switch and the other is solenoidal starter switch

## **7. Generation of direct current.**

### **Direct current (DC):**

It is the unidirectional flow of electric charge(current) which is generated by sources like dynamo or dc generators, batteries, power supplies, thermocouples, solar cells etc.

### **Alternating current (AC):**

It is the bidirectional flow of current and is generated by sources called ac generator or alternator

### 8(a) Types of 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

### 9. Armature reaction.

In a DC machine(motor/generator), the main field is produced by field coils. In both the generating and motoring modes, the armature carries current and a magnetic field is established, which is called the armature flux. The effect or reaction of armature flux on the main field is called the **armature reaction**.

In the fig.X below shows the main field flux being distorted by the armature flux.

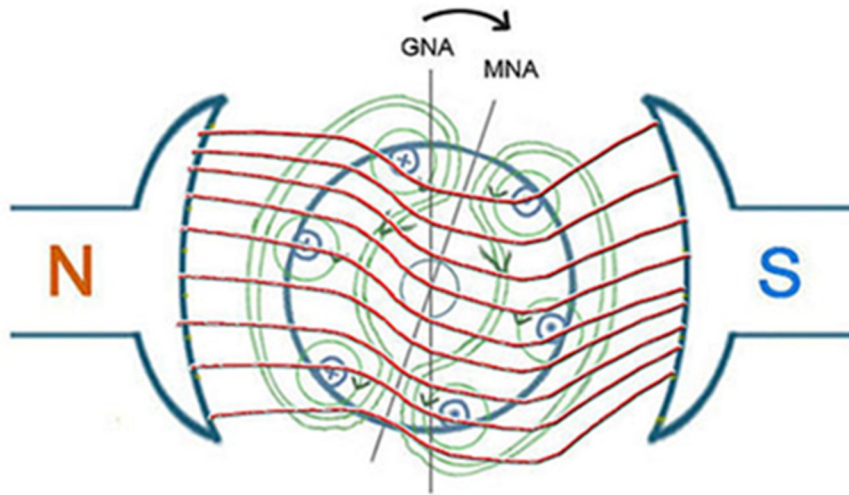


Fig.XX Shows armature reaction.

Ref:

[https://en.wikipedia.org/wiki/Armature\\_\(electrical\\_engineering\)#Armature\\_reaction\\_in\\_a\\_DC\\_machine](https://en.wikipedia.org/wiki/Armature_(electrical_engineering)#Armature_reaction_in_a_DC_machine)

### **Third brush regulation.**

Third-brush regulation is simpler in operation and cheap to manufacture than other methods of control. However it can be used for some special and limited applications. Generators with this type of control have an additional brush called the third brush which is located between the two main brushes.

Construction:

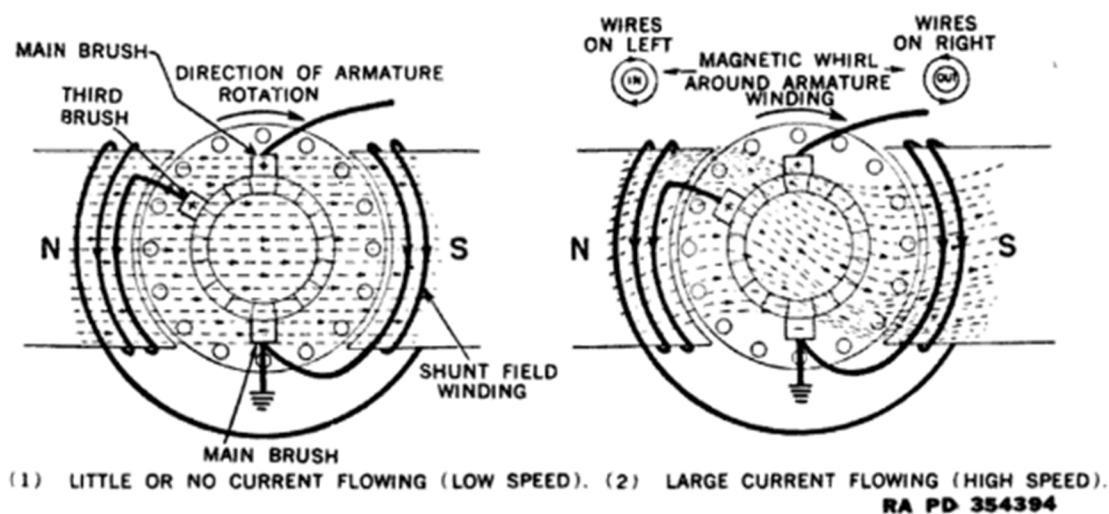
The arrangement of a typical two-pole, third brush type of generator is shown in figure xx. One end of the shunt field winding is connected to the third brush, the other end is grounded. Only a part of the total voltage generated is supplied to the field by the third brush.

Working:



(1) When the generator is running at a low speed and little or no current is flowing in the armature winding, the magnetic field produced by the field winding is approximately straight through the armature from one pole piece to the other (fig. 148 (1)). The voltage generated by each armature coil is then practically uniform during the time the coil is under the pole pieces.

(2) As the generator speed and charging current increase, the armature winding acts like a solenoid coil to produce a cross magnetic field. The magnetic whirl around the armature winding distorts the magnetic field produced by the shunt field winding, so that the magnetism is not equally distributed under the pole pieces (fig. 148 (2)). With this distortion of the magnetic field, the armature coils no longer generate a uniform voltage while passing under the different parts of the pole. Although the voltage across the main brushes remains nearly the same, a greater proportion of this voltage is generated by the coils between the positive brush and the third brush than was generated between them when little current was flowing through the armature winding. This is due to the distortion of the magnetic field which crowds more magnetic lines of force between the positive and third brush.



*Figure 148. Third Brush Generator Regulation.*

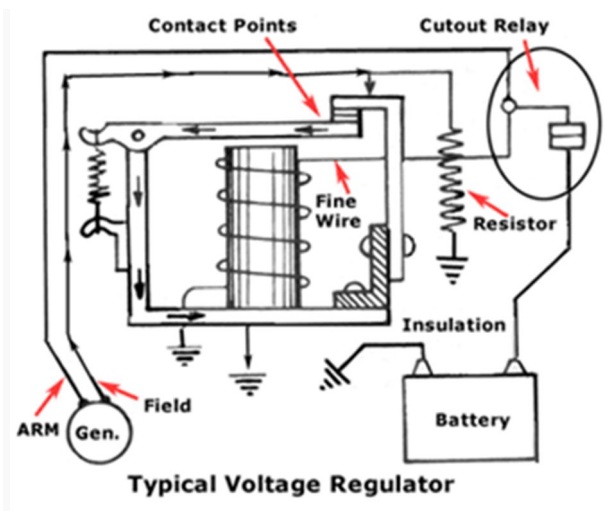
(3) The coils which connect the commutator between the negative and third brushes are in the region of the weakened field and generate a lower proportion of the voltage. The result is a dropping off of the voltage between the negative and third brushes, which is applied to the shunt field winding, thereby weakening the field strength. As the field strength decreases with increased generator current, the result will be an automatic regulation of the current output.

**Ref:** Principles of automotive vehicles, By United States. Dept. of the Army

<https://books.google.co.in/books?id=CZg7AAAAMAAJ&pg=PA198&lpg=PA198&dq=third+brush+regulation&source=bl&ots=D-n4Uu81JL&sig=LiDNThxyK7dxbnNMOhVT526iDiU&hl=en&sa=X&ved=0ahUKewirgvjlvrboAhXMMY8KHdoWCKs4ChDoAQgpMAM#v=onepage&q=third%20brush%20regulation&f=false>

## **Voltage Regulators**

In the function of generators, there is no means of internally controlling the output of one. In other words, the faster it spins the more voltage goes into the car's electrical system. If this weren't controlled the generator would damage the battery and burn out the car's lights. Also, if the generator weren't cut out from the car's circuitry when not running, the battery would discharge through its case.

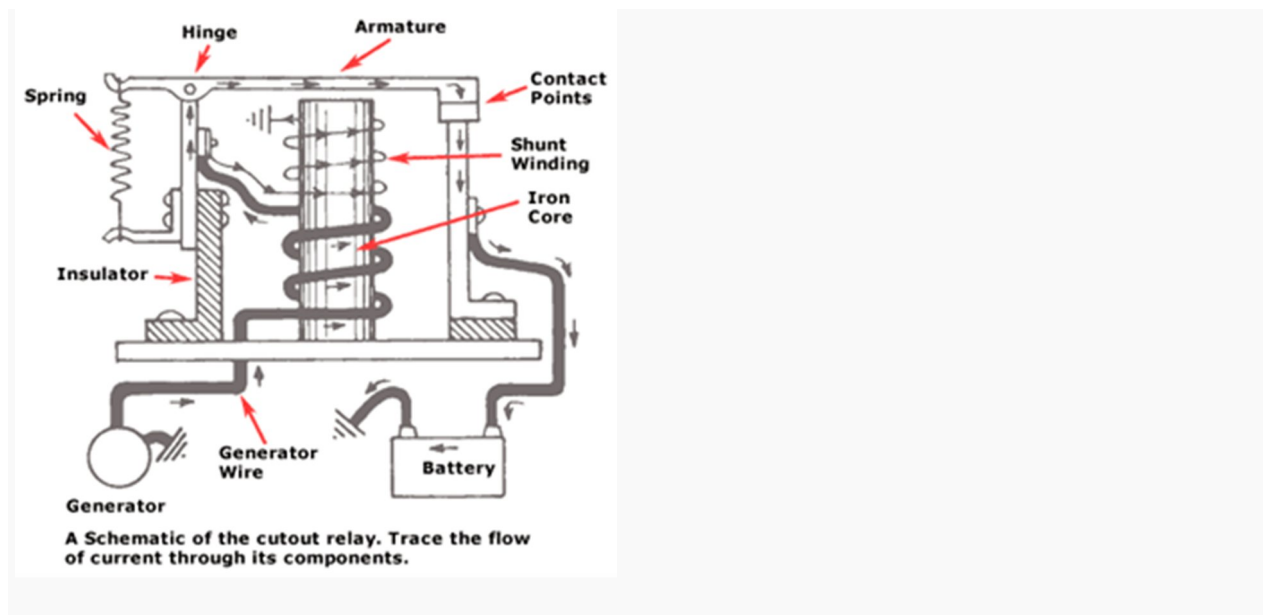


That's where the REGULATOR (commonly called the Voltage Regulator, but that's only one component of the system) comes in. Regulators have seen many design improvements over the decades, but the most commonly used electro-mechanical regulator is the three-control units in one box type. Let's look at how these things work...

### Cutout Relay

Sometimes called the circuit breaker, this device is a magnetic "make-and-break" switch. It connects the generator to the battery (and therefore the rest of the car) circuit when the generator's voltage builds up to the desired value. It disconnects the generator when it slows down or stops.

The relay has an iron core that is magnetized to pull down a hinged armature. When the armature is pulled down a set of contact points closes and the circuit is completed. When the magnetic field is broken (like when the generator slows down or stops) a spring pulls the armature up, breaking the contact points.



An obvious failure mode is the contact points. As they open and close, a slight spark is generated, eventually eroding the material on the points until they either "weld" themselves together or become so high in resistance that they won't conduct current when closed. In the first case the battery would discharge through the generator overnight and in the second there would be no charging to the system.

## Voltage Regulator

Another iron core-operated set of contact points is utilized to regulate maximum and minimum voltage at all times. This circuit also has a shunt circuit (a shunt re-directs electrical flow) going to ground through a resistor and placed just ahead (electrically) of the points. When the points are closed the field circuit takes the "easy" route to ground but when the points are open the field circuit must pass through the resistor to get to ground.

The field coil on the generator is connected to one of the voltage regulator contact points. The other point leads directly to ground.

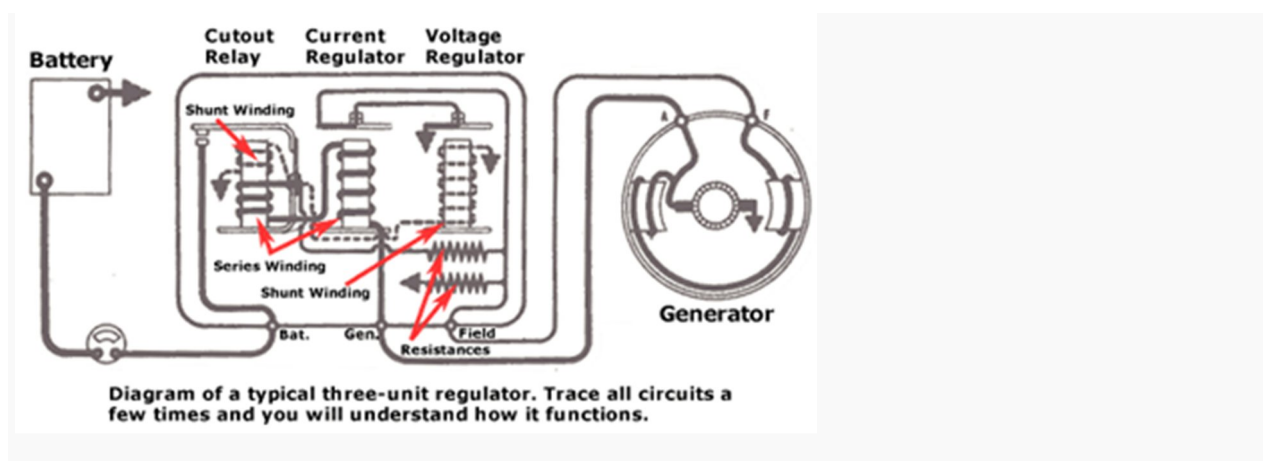
When the generator is operating (battery low or a number of devices running) its voltage may stay below that for which the control is set. Since the flow of current will be too weak to pull the armature down the generator field will go to ground through the points. However, if the system is fully charged the generator voltage will increase until it reaches the maximum limit and current flow through the shunt coil will be high enough to pull the armature down and separate the points.

This cycle is repeated over and over in real time. The points open and close about 50 to 200 times per second, maintaining a constant voltage in the system.

### Current Regulator

Even though the generator's voltage is controlled it is possible for its current to run too high. This would overheat the generator, so a current regulator is incorporated to prevent premature failure.

Similar in appearance to the voltage regulator's iron core, the current regulator's core is wound with a few turns of heavy wire and connected in series with the generator's armature.



In operation, current flow increases to the predetermined setting of the unit. At this time, current flow through the heavy wire windings will cause the core to draw the armature down, opening

the current regulator points. In order to complete the circuit the field circuit must pass through a resistor. This lowers current output, points close, output increases, points open, output down, points close, and so on. The points, therefore, vibrate open and closed much as the voltage regulator's points do, many times every second.

**Ref:** <http://www.secondchancegarage.com/public/83.cfm>

#### **11. Cut-out.**

#### **12. Voltage & current regulators.**

#### **13. Compensated voltage regulator**

#### **14. Alternators principle & constructional aspects**

#### **15. Bridge benefits.**

#### References:

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