Building up of a DC shunt generator

Objectives: At the end of this lesson you shall be able to
- **explain the conditions and method of building up of voltage in a DC shunt generator**
- **explain the method of creating residual magnetism in the poles of a DC generator**
- **determine the magnetization characteristic of a DC shunt generator**
- **estimate the value of field critical resistance in the DC shunt generator.**

Condition for a self-excited DC generator to build up voltage: For a self-excited DC generator to build up voltage, the following conditions should be fulfilled, assuming the generator is in sound condition.

- There must be residual magnetism in the field cores.
- The field resistance should be below the field critical resistance value.
- The generator should run at the rated speed.
- There must be a proper relation between the direction of rotation and the direction of field current. It could be explained as stated below.

The polarity of the induced voltage must be in such a direction as to produce the field current to assist the residual magnetism.

The polarity of the induced emf depends upon the direction of rotation and the polarity of the field poles depends upon the field current direction.

Even after fulfilling the above conditions, if the self-excited DC shunt generator fails to build up voltage, there may be other reasons as listed in Table 1.

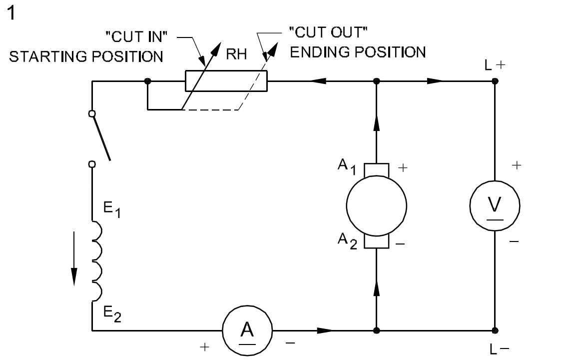
Table 1

Sl.No.	Causes	Reasons	Remedies
1	A break or opening in the field or armature circuit.	Break or loose connection in the field or in the armature winding/circuit.	Locate the open circuit and rectify.
		High resistance in the field circuit beyond the field critical resistance value.	Reduce the resistance of the field regulator.
2	Loose brush connections or contacts.	Improper brush contact/loose brush connections.	Check the brushes for excessive wear, and replace them, if necessary. Check the commutator for pitting. If necessary, turn down the commutator. Always clean the commutator when poor brush contact is discovered. Check the brush tension and readjust it, if necessary Tighten any loose connections.
3	A dirty or severely pitted commutator.	Severe sparking due to overload.	In this case, follow the same procedure as outlined above.
4	A short circuit in the armature or field	Overload or excess heating.	Do a resistance check, ascertain, locate and remove the fault.

Method of building up voltage in a DC shunt generator: Fig 1 shows the circuit diagram for building up voltage in a DC shunt generator. When the generator is made to run at its rated speed initially, the voltmeter reads a small amount of voltage say, 4 to 10 volts. It is due to the residual magnetism. Since the field coils are connected across the armature terminals, this voltage causes a small amount of current to flow through the field coil. If the current flow in the field coils is in the correct direction, it will strengthen the residual magnetism and induce more voltage.

As such, the generated voltage will rise marginally. This rise in voltage, in turn, will further strengthen the increasing field current and induce more voltage. This rise in voltage, in turn, will further strengthen the increasing field current. This cumulative action will build up voltage until saturation is reached. After saturation, any increase in the field current will not increase the induced voltage. However, the whole procedure of building up of voltage takes a few seconds only.

Fig 1



DC SHUNT GENERATOR

Method of creating residual magnetism: Without residual magnetism, a self-excited generator will not build up its voltage. A generator may lose its residual magnetism due to any one of the following reasons.

– The generator is kept idle for a long time.

– Heavy short circuit.

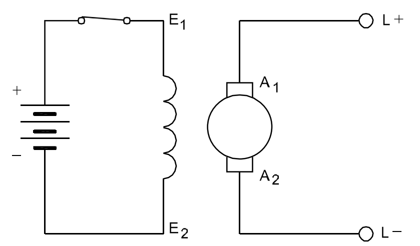
– Heavy overloading.

– The generator is subjected to too much heat.

When the generator loses its residual magnetism, it can be re-created as stated below.

Flashing of field: One of the methods to create residual magnetism is called the flashing of the `field'. This can be done by connecting the shunt field across a battery or any DC source for a few minutes as shown in Fig 2.

Fig 2



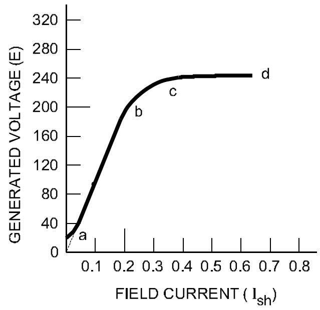
FLASHING OF THE FIELD

While flashing the field, the polarity of the magnetic field, now created, should be the same as that of the residual magnetic field it lost earlier.

In practice, this checking may not be possible. Alternatively note the polarity of the DC supply used for flashing the field and the corresponding field terminals. Run the generator in the specified direction at its rated speed. Measure the residual voltage induced and its polarity. Check whether the polarity of the residual voltage is the same as that of the DC generator. If found reversed, flash the field again by connecting the supply voltage in reverse polarity.

Magnetisation characteristic of a DC shunt generator: The magnetisation characteristic curve shown in Fig 3 gives the relation between the field current and the induced voltage. Referring to the emf equation, the induced emf in a generator is proportional to the flux per pole and the revolutions per minute of the generator. At a constant speed, the generated emf becomes directly proportional to the field flux. In a given machine, the flux depends upon the field current. The graph (Fig 3) illustrates this feature. Because of the residual magnetism, the curved part below point `a' does not start at zero. Between the points `ab', the curve is in almost a straight line indicating that the voltage in the area is proportional to the field current. Between points `b' and `c' a large increase in field current causes only a slight increase in the voltage. It indicates that the field cores are reaching saturation and this part of the curve is called the `knee' of the curve. Between points `c' and `d', the curve is flat indicating that the increased field current is not able to increase the induced voltage. This is due to saturation of the field cores. Because of saturation, the field flux becomes constant, and the induced voltage will not be in a position to increase further. This curve is also called a no-load or open-circuit characteristic curve.

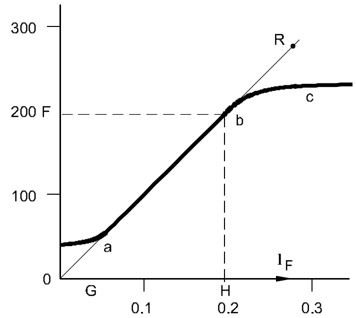
Fig 3



MAGNETISATON CHARACTERISTIC OF A DC SHUNT GENERATOR

Critical resistance: If the shunt field circuit resistance is too large, it does not allow sufficient current to flow into the field to build up its voltage. In other words, it acts like an open field. Therefore, the field circuit resistance should be smaller than a value called critical field resistance. Critical field resistance is the highest value of resistance of the shunt field circuit with which a DC shunt generator can build up voltage. Beyond this value of resistance, the generator fails to build up voltage. The value of the critical resistance can be determined by drawing a tangential line to the open circuit characteristic curve as shown in Fig 4.

Fig 4



FIELD CRITICAL RESISTANCE

For example, by drawing the tangent on the open-circuit characteristic curve as shown by line OR of Fig 4, we find the tangent is parting at point `b' from the curve. By drawing ordinates from point `b' to x and y axis, the value of critical resistance (R_c) can be determined as below.

R_c = Field critical resistance

$$= \frac{\text{voltage represented by the tangent}}{\text{current represented by the tangent}}$$

$$= \frac{OF}{OH} = \frac{200\ V}{0.2\ A} = 1000 \text{ ohms.}$$

Field circuit resistance is the sum of the field resistance and field rheostat resistance. This value should be less than, say 1000 ohms (field circuit resistance) to enable the generator to build up voltage, if the generator is intended to self-excite. Normally this happens when the field regulator resistance is set at a high value.

Test a DC machine for continuity and insulation resistance

Objectives: At the end of this lesson you shall be able to
- **state the necessity of measuring the insulation resistance of an electrical machine**
- **state the frequency of tests**
- **state the required conditions for the tests**
- **state the reasons for the low value of insulation resistance in the machines**
- **state the method of improving the insulation resistance of DC machines.**

Necessity of measuring insulation resistance: The most important aspect in the maintenance of DC machines is taking care of the insulation. Electrical insulation of DC machine windings is designed for the satisfactory operation at the specified voltage, temperature and to retain the electrical and mechanical strength and the dimensional stability over many years of operation. The insulation resistance of DC machines in service should be checked periodically, preferably every month. The possibility of reduction in the value of insulation resistance is due to the continuous working of the machine under full load condition, the heat generated in the winding and local atmospheric moisture, dust and dirt. If they are not checked in time, the insulation becomes weak and the winding will loose its dielectric property, and will ultimately lead to failure of the machine. Periodical checks and measurement of insulation resistance and improvement thereof to the required level will ensure prevention of failure of insulation, and thereby, the breakdown of the machine.

A common device for measuring insulation resistance is a direct indicating insulation tester or Megger. The measurements are made at voltages 500/1000 volt DC depending upon the voltage rating of the machine.

Measurement of insulation resistance: Insulation resistance shall be measured between the winding and frame (earth), and between windings.

For low and medium voltage rated machines, the insulation resistance, when the high voltage test is applied, shall not be less than one megohm as per B.I.S. 9320 - 1979. The insulation resistance shall be measured with a DC voltage of about 500 V applied for a sufficient time for the reading of the indicator to become practically steady, such voltage being taken from an independent source or generated in the measuring instrument.

When it is required to dry out windings at site to obtain the minimum value of insulation resistance, it is recommended that the procedure for drying out as specified in IS:900-1965 may be followed.

Frequency of test: Periodical checks or tests are predetermined in preventive maintenance programmes with a forethought. The planning of the preventive maintenance (PM) schedule should be based on the past experience of maintenance personnel, and the recommendations made by the machine manufacturer. Usually the measurement of insulation resistance is a must during the period of overhauls. The duration of overhaul will be once in 6 months, ideal for DC machines where they are working continuously. Overhauling is done once a year, for such of those machines as are not working continuously. The overhauling is done during plant shut-down periods.

However in DC machines where the overhaul interval is too long, or delayed, it is advisable to have constant vigil and check the insulation resistance at least once a month regularly, and maintain a record of the values of the insulation resistance tests as shown in Table 1.

Table 1

Insulation resistance test

Date	Time	Weather condition	Duty cycle	Test between terminals	Insulation resistance	Remarks

Required conditions for test: The high potential dielectric test and the insulation resistance test are the principal methods of evaluating insulation capability and condition of the machine. The insulation resistance test is often used as a measure of the condition of the winding. Insulation resistance is the ratio of the applied voltage to the leakage current which passes in the circuit at some specified time after the voltage is applied. Direct, rather, than alternating voltages are used for measuring insulation resistance.

The principal currents affecting insulation resistance on application of the test potential for sufficient time are (1) leakage current over the winding surface (2) conduction in current through the insulation material and (3) absorption current in the insulation. The first two currents are steady with time, but the last current delays approximately exponentially from an initial high value. Such insulation resistance measurements are affected by surface conditions (dirt or moisture on the windings), moisture within the insulation wall and the insulation temperature. The magnitude of the test potential may also affect the insulation value, especially if the insulation is not in good condition. Therefore, it is desirable to use insulation resistance as a measure to determine the condition of the machine over a period of years, and to make readings under similar conditions each time and record the values in the test card of the machine in a table similar to Table 1. However, before testing the winding for insulation resistance, it is recommended that the continuity test should be conducted in the armature and field windings to ensure soundness of the respective circuits. As sometimes continuity tests will not reveal internal short circuits, resistance measurement test is recommended, and a record should be maintained for comparison at intervals.

Reasons for low value insulation resistance: The low value of insulation resistance in DC machines is due to excess heat developed in the winding due to their routine working with full load condition or overloading at times or frequent starting with loads. In addition to this, high ambient temperatures are also the reason for low insulation resistance. The other possibility is accumulation of unnecessary local dust and dirt, carbonisation due to brush, local atmospheric moisture, acids and alkalies present in the surroundings of the machine etc. All these are collectively or individually responsible for the weakening of insulation resistance of the winding. Because of these conditions the dielectric property of the insulating material gets reduced, which, in turn, results in low or poor insulation resistance, responsible for the breakdown of the winding due to insulation failure.

Method of improving insulation resistance: On identifying the weak insulation resistance, during the course of preventive maintenance observation in a DC machine, it is necessary to improve the insulation resistance to restore it to a safe value.

Improvement of insulation resistance could be done by any one of the following methods after cleaning the dust and dirt from the machinery.

- By blowing hot air through the machines.
- By heating the machine with carbon filament or incandescent lamps.
- By dismantling and varnishing the winding of the machine.

The following steps are to be adopted for dismantling and varnishing.

- Measure the insulation resistance value between the windings and the frame of the machine and record the value.
- Mark and dismantle the machine.
- Remove dirt and dust in the field winding by blowing dry air with the help of an electric blower.
- Clean and remove dirt, dust and carbon on the armature with special attention to the commutators.
- Clean the brushes, brush-holders and rocker arms.
- Measure the insulation resistance of the winding with an insulation tester; note the values.
- Heat and dry the field coils and armature by external measures.
- Apply insulating varnish of air-drying type to field coils and armature conductors.
- Dry the varnish coating on field coils and armature by external means.
- Measure the insulation resistance and note the improved value of insulation resistance.
- Assemble the machine.
- Measure the insulation value between the windings and the frame of the machine; record the values. Compare these results with those of the first step and make sure the present value shows improvement.
- Connect the machine to the system and run it to check its normal working condition.