TVET CERTIFICATE IV in HYDROPOWER ENERGY

ELECTRICAL GENERATOR OPERATION

HDPEG401

Operate Electrical generators

Competence

REQF Level: 4

Credits: 8

Learning hours: 80

Sector: Energy

Sub-sector: Hydropower

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Purpose statement

This core module describes the skills, knowledge and attitude required to operate an electrical generator. The learner will be able to select and arrange different materials, equipment and tools used when operating an electrical generator. Moreover, he/she will be able to identify different types of DC and AC generators, run them and perform their routine maintenance

Elements of competence and performance criteria		Page No
Learning Unit	Performance Criteria	3
1. Prepare preliminary activity	1.1 Proper interpretation of electrical drawing	
	1.2 Appropriate identification of tools and measurement instruments	
	1.3 Proper arrangement of materials and tools in the working area	
	1.4 Proper identification of PPE(Personal Protective Equipment)	
2.Identify DC generators	2.1 Proper identification of DC generators types	15
	2.2 Proper identification of DC generators accessories	
	2.3 Adequate application of different electrical characteristics	
3. Identify AC generators	3.1 Proper identification of single phase generators	44
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	3.4 Adequate application of different electrical and mechanical characteristic	
4. Run Electrical generators	4.1Proper use of Safety equipment	59
	4.2 Proper use of different switching devices	
	4.3 Adequate running procedures of electrical generators	
	4.4 Convenient monitoring of electrical generators	
5.Perform the routine maintenance	5.1 Proper interpretation of the nameplate/ manufacturer's information 5.2 Proper identification of status indicators/alarming signals 5.3 Appropriate cleaning, replacing/lubrication 5.4 Adjusting/repairing 5.5 Proper testing of electrical generator 5.6 proper cleaning of the workplace	70

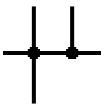
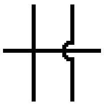
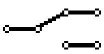
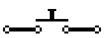
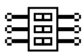
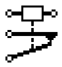
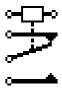
Learning unit 1: Prepare preliminary activities

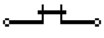
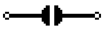
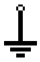
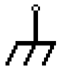
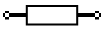
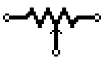
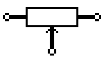
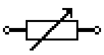
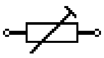
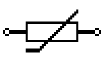
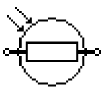
LO1.1: Interpret electrical drawings

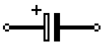
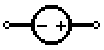
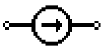
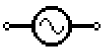
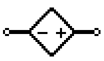
Content/Topic1Electrical symbols

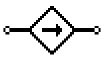
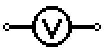
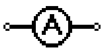
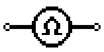
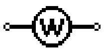
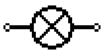
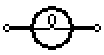
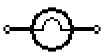
Standard Circuit Symbols for Circuit Schematic Diagrams

Circuit symbols are used in circuit schematic diagrams which show how a circuit is connected together electrically. The standard circuit symbols are important for circuit schematic diagrams.

Symbol	Component name	Meaning
Wire Symbols		
	Electrical Wire	Conductor of electrical current
	Connected Wires	Connected crossing
	Not Connected Wires	Wires are not connected
Switch Symbols and Relay Symbols		
	SPST Toggle Switch	Disconnects current when open
	SPDT Toggle Switch	Selects between two connections
	Pushbutton Switch (N.O)	Momentary switch - normally open
	Pushbutton Switch (N.C)	Momentary switch - normally closed
	DIP Switch	DIP switch is used for onboard configuration
	SPST Relay	Relay open / close connection by an electromagnet
	SPDT Relay	

	Jumper	Close connection by jumper insertion on pins.
	Solder Bridge	Solder to close connection
Ground Symbols		
	Earth Ground	Used for zero potential reference and electrical shock protection.
	Chassis Ground	Connected to the chassis of the circuit
	Digital / Common Ground	
Resistor Symbols		
	Resistor (IEEE)	Resistor reduces the current flow.
	Resistor (IEC)	
	Potentiometer (IEEE)	Adjustable resistor - has 3 terminals.
	Potentiometer (IEC)	
	Variable Resistor / Rheostat (IEEE)	Adjustable resistor - has 2 terminals.
	Variable Resistor / Rheostat (IEC)	
	Trimmer Resistor	Preset resistor
	Thermistor	Thermal resistor - change resistance when temperature changes
	Photoresistor / Light dependent resistor (LDR)	Photo-resistor - change resistance with light intensity change
Capacitor Symbols		

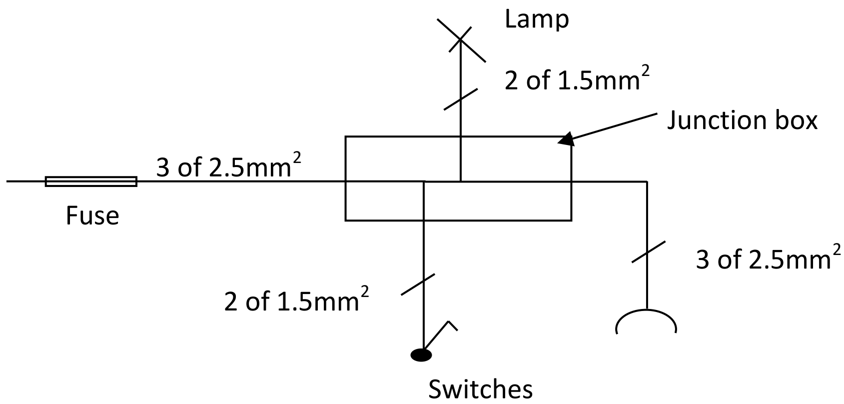
	Capacitor	Capacitor is used to store electric charge. It acts as short circuit with AC and open circuit with DC.
	Capacitor	
	Polarized Capacitor	Electrolytic capacitor
	Polarized Capacitor	Electrolytic capacitor
	Variable Capacitor	Adjustable capacitance
Inductor / Coil Symbols		
	Inductor	Coil / solenoid that generates magnetic field
	Iron Core Inductor	Includes iron
	Variable Inductor	
Power Supply Symbols		
	Voltage Source	Generates constant voltage
	Current Source	Generates constant current.
	AC Voltage Source	AC voltage source
	Generator	Electrical voltage is generated by mechanical rotation of the generator
	Battery Cell	Generates constant voltage
	Battery	Generates constant voltage
	Controlled Voltage Source	Generates voltage as a function of voltage or current of other circuit element.

	Controlled Current Source	Generates current as a function of voltage or current of other circuit element.
Meter Symbols		
	Voltmeter	Measures voltage. Has very high resistance. Connected in parallel.
	Ammeter	Measures electric current. Has near zero resistance. Connected serially.
	Ohmmeter	Measures resistance
	Wattmeter	Measures electric power
Lamp / Light Bulb Symbols		
	Lamp / light bulb	
	Lamp / light bulb	Generates light when current flows through
	Lamp / light bulb	

Content/topic2 Types of electrical drawings

1. Schematic Diagrams

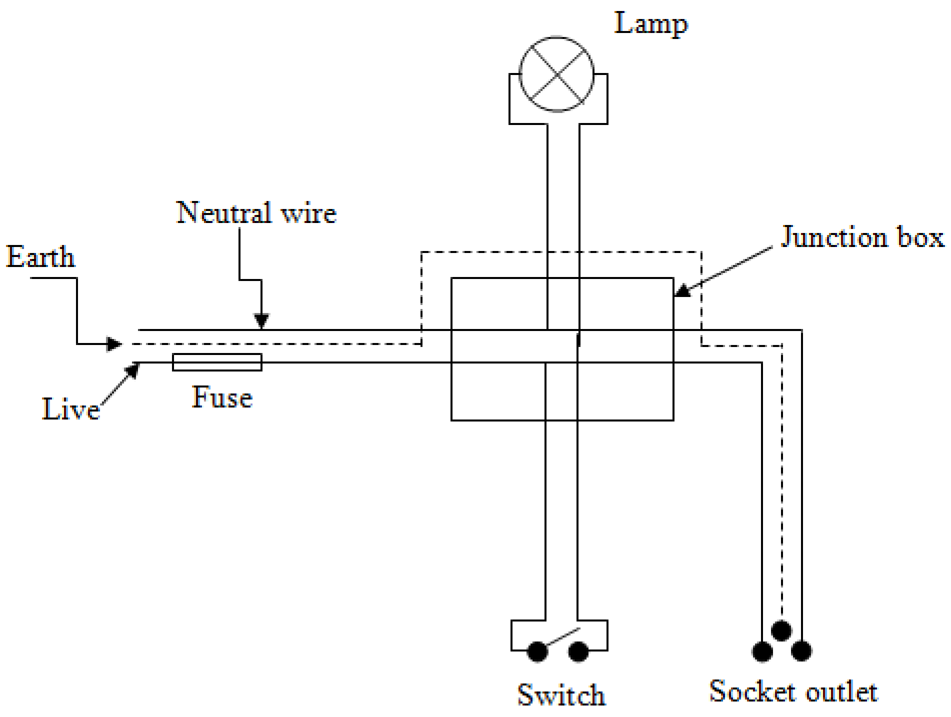
The schematic diagram of an electrical circuit shows the complete electrical connections between components using their symbols and lines. Unlike wiring diagram, it does not specify the real location of the components, the line between the components does not represent real distance between them.



2. **Wiring Diagram**

The wiring diagram is used for the representation of electrical components in their approximate physical location using their specific symbols and their interconnections using lines. Vertical and horizontal lines are used to represent wires and each line represents a single wire that connects between electrical components.

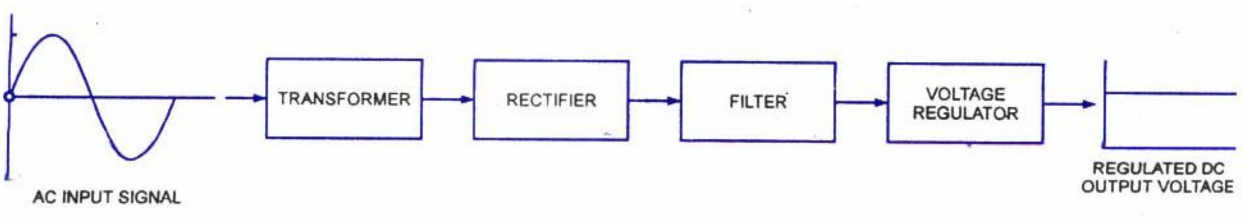
Wiring diagram shows a pictorial view of the components such that it resembles its electrical connection, arrangement and position in real circuit. It really helps in showing the interconnections in different equipment such as electrical panel and distribution boxes etc. they are mostly used for wiring installation in home and industries.



3. **A Block diagram**

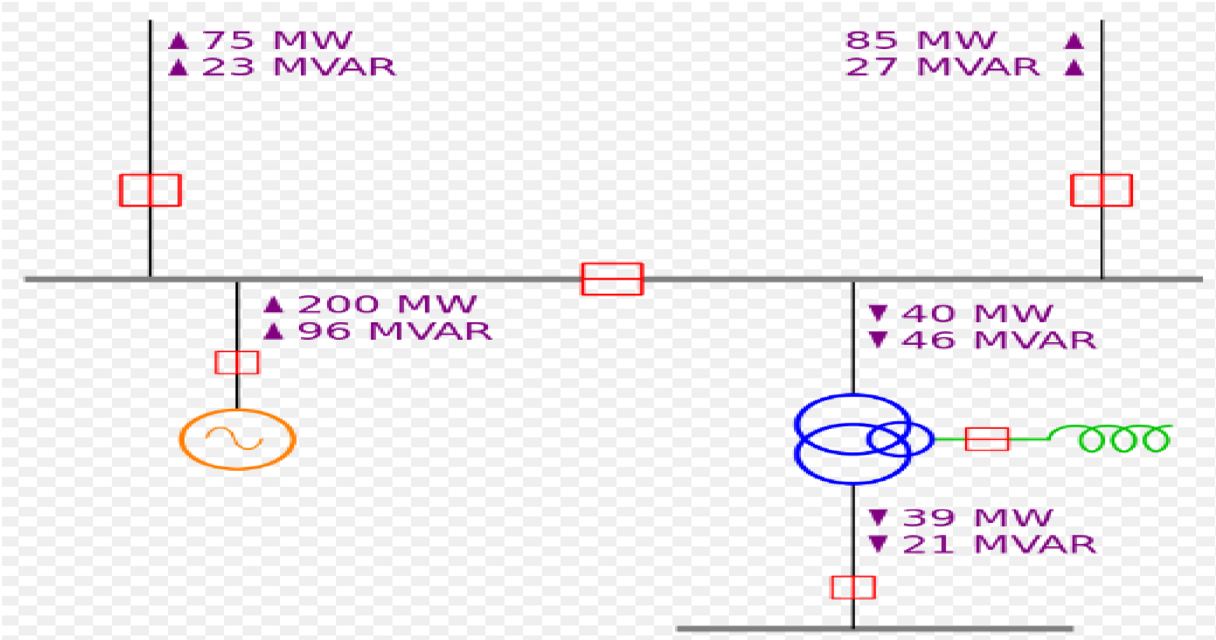
A block diagram is a type of electrical drawing that represents the principle components of a complex system in the form of blocks interconnected by lines that represent their relation. It is the simplest form of electrical drawing as it only highlights the function of each component and provides the flow of process in the system.

Block diagram are easier to design and is the first stage in designing a complex circuit for any project. It lacks the information about the wiring and placement of individual components. It only represents the main components of the system and ignores any small components. This is why; electricians do not rely on block diagram.

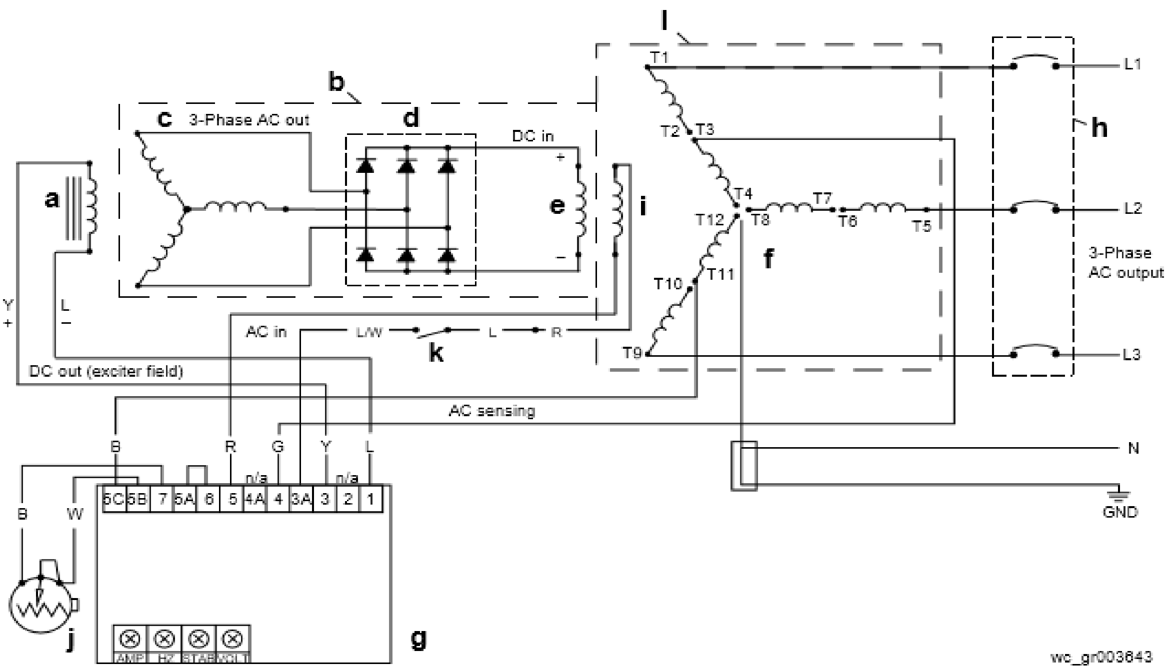


4. Single line diagram

Single Line diagram (SLD) or one-line diagram is the representation of an electrical circuit using a single line. As the name suggests, a single line is used to denote the multiple power lines such as in 3 phase system. Single line diagram does not show the electrical connections of the component but it may show the size and ratings of the components being used. it simplify complex 3 phase power circuits by showing all the electrical components and their interconnection.



Content/Topic3 Interpretation of schematic diagram of a generator



Ref.	Component	Ref.	Component
a	Exciter stator winding	g	Automatic Voltage Regulator (AVR)
b	Rotor assembly	h	Main circuit breaker
c	Exciter rotor winding	i	Auxiliary winding
d	Rotating rectifier (diodes)	j	Voltage adjusting rheostat
e	Main rotor winding	k	Lug door switch
f	Main stator windings	l	Stator assembly

LO.1.2.Identify tools and measurement instrument

Content/Topic 1.Types of measurement instruments

- ✓ **Watt meter**

The wattmeter is an instrument for measuring the electric power (or the supply rate of electrical energy) in watts of any given circuit.

- ✓ **Earth resistance meter**

A ground resistance meter tests the grounding of electrical systems and equipment by measuring the ground resistance value in ohms. Proper grounding is essential to protect people from electric shock;

prevent service interruptions, damage to electrical equipment, and intermittent electrical problems; and safely dissipate lightning strikes, static discharges, and electromagnetic or radio frequency interference.

Digital Earth Resistance Meter ...

- **Voltmeter**

A voltmeter is an instrument used for measuring electrical potential difference between two points in an electric circuit. Analog voltmeters move a pointer across a scale in proportion to the voltage of the circuit; digital voltmeters give a numerical display of voltage by use of an analog to digital converter. A voltmeter in a circuit diagram is represented by the letter V in a circle.

- **Ammeter**

An ammeter (from Ampere Meter) is a measuring instrument used to measure the current in a circuit. Electric currents are measured in amperes (A).

- **Tachometer**

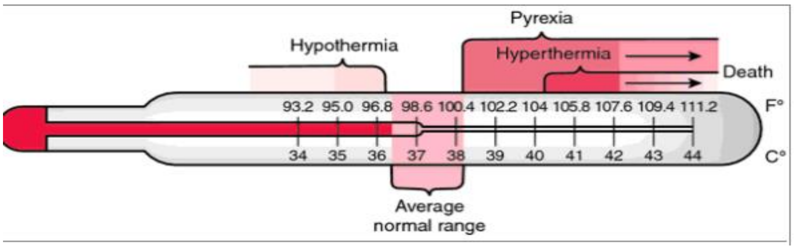
A tachometer (revolution-counter, tach, rev-counter, RPM gauge) is an instrument measuring the rotation speed of a shaft or disk, as in a motor or other machine.

✓ **Multi-meter**

A multi-meter or a multi-tester, also known as a VOM (volt-ohm-milliammeter), is an electronic measuring instrument that combines several measurement functions in one unit. A typical multi-meter can measure voltage, current, and resistance. Analog multi-meters use a micro ammeter with a moving pointer to display readings. Digital multi-meters (DMM, DVOM) have a numeric display, and may also show a graphical bar representing the measured value. Digital multi-meters are now far more common due to their cost and precision, but analog multi-meters are still preferable in some cases, for example when monitoring a rapidly varying value.

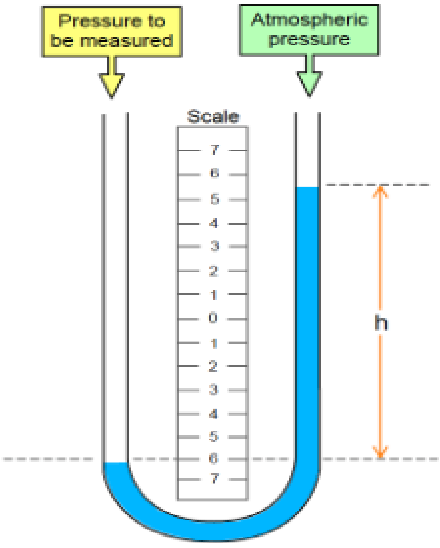
✓ **Thermometer**

Thermometer is instrument for measuring the temperature of a system. Temperature measurement is important to a wide range of activities, including manufacturing, scientific research, and medical practice.



✓ **Manometer**

A Manometer is a device to measure pressures. A common simple manometer consists of a U shaped tube of glass filled with some liquid. Typically the liquid is mercury because of its high density.



- ✓ **Frequency meter**

A frequency meter is an instrument that displays the frequency of a periodic electrical signal. Various types of frequency meters are used. Many are instruments of the deflection type, ordinarily used for measuring low frequencies but capable of being used for frequencies as high as 900 Hz.

- ✓ **Hydrometer**

A hydrometer or aerometer is an instrument that measures the specific gravity (relative density) of liquids: the ratio of the density of the liquid to the density of water.

Content/Topic2.Leads/cords

A power cord, line cord, or mains cable is an electrical cable that temporarily connects an appliance to the mains electricity supply via a wall socket or extension cord.

Content/Topic3.Electromechanical toolkit

Electromechanical toolkit is a set of tools especially keeps in box that are used for electrical and mechanical purpose

LO 1.3. Arrange materials and tools into the working area

Content/Topic 1.Selection of materials and tools for generator operation

Materials

- Brass ball valve (for water supply shut-off)
- Pipe compound
- Copper or brass fittings & nipples (sizes and quantities per instructions)
- In-line water filter (recommended)
- Wire (sizes and quantities per instructions)
- Copper tube or pipe
- Wire cap nuts
- Flex conduit (for units 12kW and above)
- Brass or copper tee connection and plug

Tools Needed:

- Pipe wrench
- Tubing cutter
- Wire cutters or wire strippers
- Adjustable wrench
- Screwdriver (phillips and regular)
- Solder and Flux
- Propane torch

Content/Topic 2 Disposition of materials and tools according to their nature

In order to keep tools in good working condition during storage, there are some basics preparatory steps that should be taken. It is important to follow the cleaning and storage instruction

- ✓ Clean tools after each use
- ✓ Dispose of Any Broken or detective tools
- ✓ Use metal protectant spray on all metal parts

- ✓ Never store tools near the ground
- ✓ Get creative with storage options
- ✓ Make a list of all items that are stored

LO1.4 Identify PPE

Content/Topic 1 Safety equipment used for generator operation

- ✓ **Overcoat and overall**

An overall, also called overalls, bib-and-brace overalls, or dungarees, is a type of garment which is usually used as protective clothing when working. Some people call an overall a "pair of overalls" by analogy with "pair of trousers

- ✓ **Gloves**

If a workplace hazard assessment reveals that employees face potential injury to hands and arms that cannot be eliminated through engineering and work practice controls, employers must ensure that employees wear appropriate protection. Potential hazards include skin absorption of harmful substances, chemical or thermal burns, electrical dangers, bruises, abrasions, cuts, punctures, fractures and amputations. Protective equipment includes gloves, finger guards and arm coverings or elbow-length gloves.

- ✓ **Safety shoes**

Employees who face possible foot or leg injuries from falling or rolling objects or from crushing or penetrating materials should wear protective foot wear.

Also, employees whose work involves exposure to hot substances or corrosive or poisonous materials must have protective gear to cover exposed body parts, including legs and feet. If an employee's feet may be exposed to electrical hazards, non-conductive footwear should be worn. On the other hand, workplace exposure to static electricity may necessitate the use of conductive footwear. Protective equipment used for protecting your feet is called Safety shoes.

- ✓ **Helmet**

A head injury can impair an employee for life or it can be fatal. Wearing a safety helmet or hard hat is one of the easiest ways to protect an employee's head from injury. Hard hats can protect employees from impact and penetration hazards as well as from electrical shock and burn hazards.

- ✓ **Earmuff**

Earmuffs are objects designed to cover a person's ears for hearing protection or for warmth. They consist of a thermoplastic or metal head-band, that fits over the top or back of the head, and a cushion or cup at each end, to cover the external ears.

- ✓ **Goggles**

Many occupational eye injuries occur because employees are not wearing any eye protection while others result from wearing improper or poorly fitting eye protection.

- ✓ **Nose protection mask**

A dust mask is a flexible pad held over the nose and mouth by elastic or rubber straps to protect against dusts encountered during construction or cleaning activities,

Learning unit 2 Identify DC Generators

L.O 2.1 Identify the types of DC generators

Content/Topic 1 Basic principle of DC generators

Generator principle

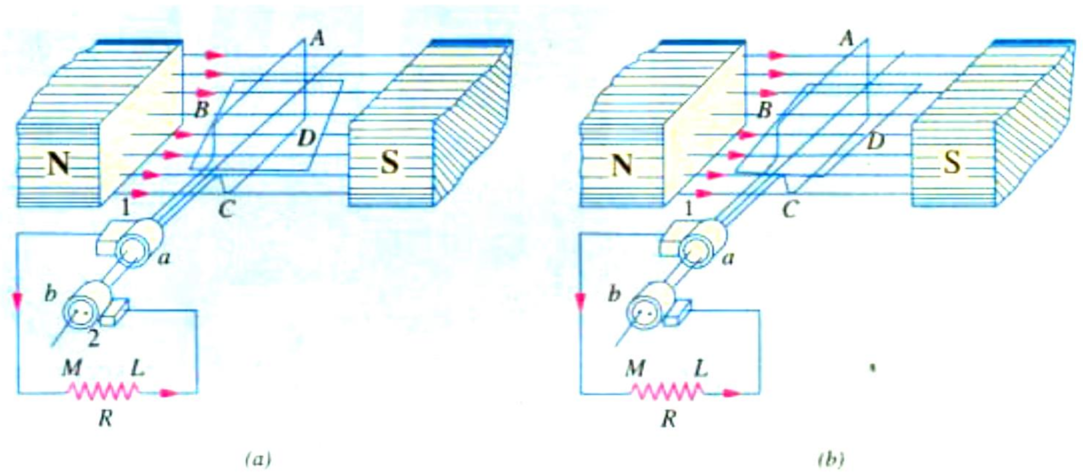
An electrical generator is a machine which converts mechanical energy (or power). The energy conversion is based on the principle of the production of dynamically (or motional) induced e.m.f. whenever a conductor cuts magnetic flux, dynamically induced e.m.f. is produced in it according to Faraday's Laws of Electromagnetic Induction. This e.m.f. causes a current to flow if the conductor circuit is closed. Hence the three necessary conditions due to which an e.m.f. can be produced are:

- A magnetic field
- A conductor or conductors which can so move as to cut the flux.
- Relative motion between the magnetic field and the conductor

Simple loop Generator

Construction

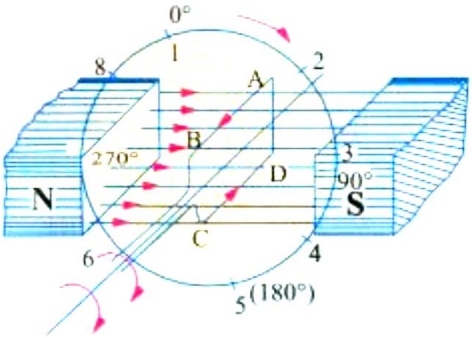
In the Figure below is shown a single-turn rectangular copper coil ABCD rotating about its own axis in a magnetic field provided by either permanent magnet or electromagnets. The two ends of the coil are joined to two slip-rings 'a' and 'b' which are insulated from each other and from the central shaft. Two collecting brushes (of carbon or copper) press against the slip-rings. Their function is to collect the current induced in the coil and to convey it to the external load resistance R. the rotating coil may be called 'armature' and the magnets as 'field magnets'.

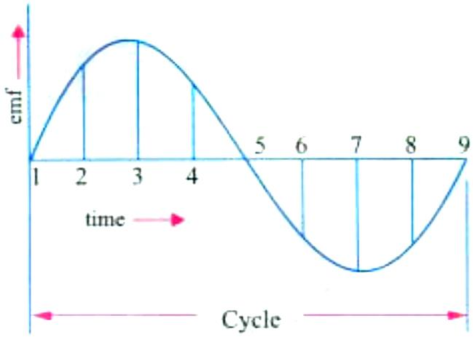


Working

Imagine the coil to be rotating in clock-wise direction. As the coil assumes successive positions in the field, the flux linked with it changes. Hence an e.m.f.is induced in it which is proportional to the rate of change of flux linkages ($e=Nd\varphi/dt$). Where the plane of the coil is at right angles to lines of flux i.e, when it is in position, 1, then flux linked with the coil is maximum but rate of change of flux linkage is minimum.

It is so because in this position, the coil sides AB and CD do not cut or shear the flux, rather they slide along them i.e, or they move parallel to them. Hence, there is no induced e.m.f. in the coil. Let us take this no e.m.f or vertical position of the coil as the starting position. The angle of rotation or time will be measured from this position.





As the coil continues rotating further, the rate of change of flux linkages (and hence induced e.m.f. in it) increases, till position 3 is reached where θ= 90^0. Here, the coil plane is horizontal i.e, parallel to the lines of flux. As seen, the flux linked with the coil is minimum but rate of change of flux linkages is maximum. Hence, maximum e,m.f is induced in the coil when in this position of the above figure.

In the next quarter revolution i.e, from 90^0 to 1800, the flux linked with the coil gradually increases but the rate of change of flux linkages decreases. Hence, the induced e.m.f. decreases gradually till in position 5 of the coil, it is reduced to zero value.

So we find that in the next half revolution of the coil, no (or minimum) e.m.f.is induced in it when in position 1, maximum when in position 3 and no e.m.f when in position 5. The direction of this induced e.m.f. can be found by applying Fleming's Right-hand rule which gives its direction from A to B and C to D.

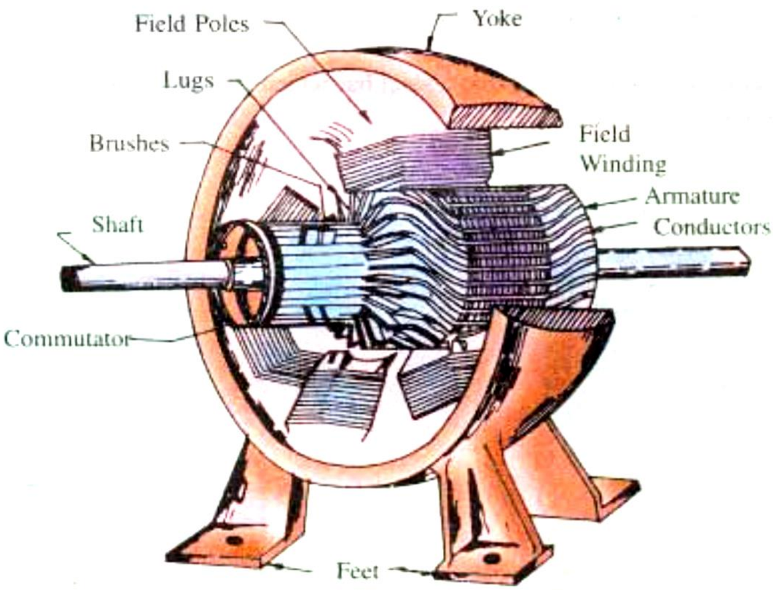
Fleming's Right-hand rule. If the thumb, fore-finger and middle finger of the right hand are stretched perpendicular to each other, and the thumb points the direction of the motion of the conductor, fore-finger points the direction of the flux then the middle finger will point the direction of e.m.f. induced in the conductor.

Practical Generator

The simple loop generator has been considered in detail merely to bring out the basic principle Underlying construction and working of an actial generator which consist of the following essential parts:

1. Magnetic frame or Yoke
2. Pore-Cores and Pole- Shoes
3. Pore Coils or Field Coils
4. Armature Core
5. Armature Winding or Conductors
6. Commutator
7. Brushes and Bearings

Of these, the yoke, the pole cores, the armature core and air gaps, between the poles and the armature core form a magnetic circuit whereas the rest form the electrical circuit.



Yoke (Body)

The outer frame or yoke serves double purpose:

i) It provides mechanical support for the poles and acts as a protecting cover for the whole machine

ii) It carries the magnetic flux produced by the poles.

The feet and the terminal box etc. are welded to the frame afterwards. Such yokes possess sufficient mechanical strength and have high permeability.

The body constitutes the outer shell within which all the other parts are housed. This will be closed at both the ends by two end covers which also support the bearings required to facilitate the rotation of the rotor and the shaft.

Pole Cores and Pole Shoes

The field magnets consist of pole cores and pole shoes. The pole shoes serve two purposes:

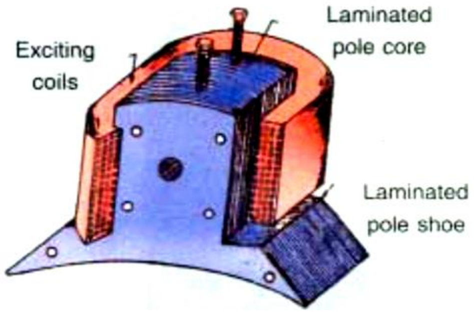
i) They spread out the flux in the air gap and also, being of larger cross-section, reduce the reluctance of the magnetic path

ii) They support the exciting coils (or field coils)

Pole Coil

The field coils or pole coils, which consist of copper wire or strip, are former-wound for the correct dimension.

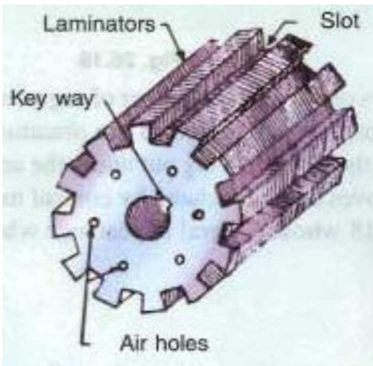
Then, the former is removed and wound coil is put into place over the core.



When current is passed through these coils, they electromagnetise the poles which produce the necessary flux that is cut by revolving armature conductors.

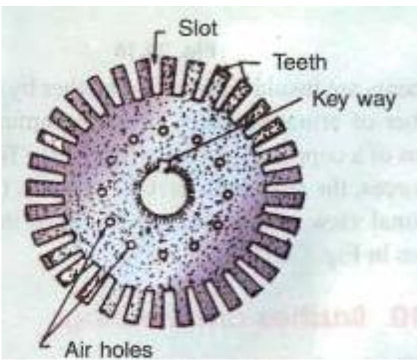
Armature core

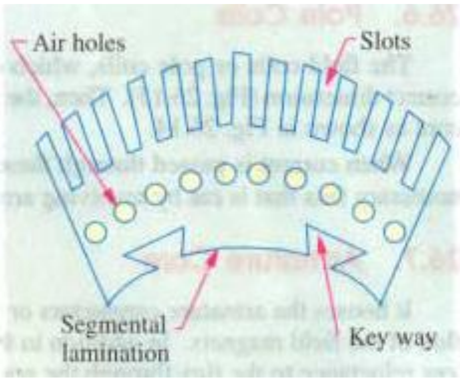
It houses the armature conductors or coils and causes them to rotate and hence cut the magnetic flux of the fied magnets. In addition to this, its most important function is to provide a path of very low reluctance to the flux through the armature from a N-pole to a S- pole. It is cylindrical or drum shaped and is build up of usually circular sheet discs or laminations approximately 0.5 mm thick.



It keyed to the shaft. The slots are either die-cut or punched on the outer periphery of the disc and the keyway is located on the inner diameter as shown.

Usually, these laminations are perforated for air ducts which permits axial flow of air through the armature for cooling purposes. Such ventilating channels are clealy visible in the laminations





The purpose of using laminations is to reduce the loss due to eddy currents. Thinner the laminations, greater is the resistance offered to the induced e.m.f. smaller the current and hence lesser the I^2R loss in the core.

Armature windings

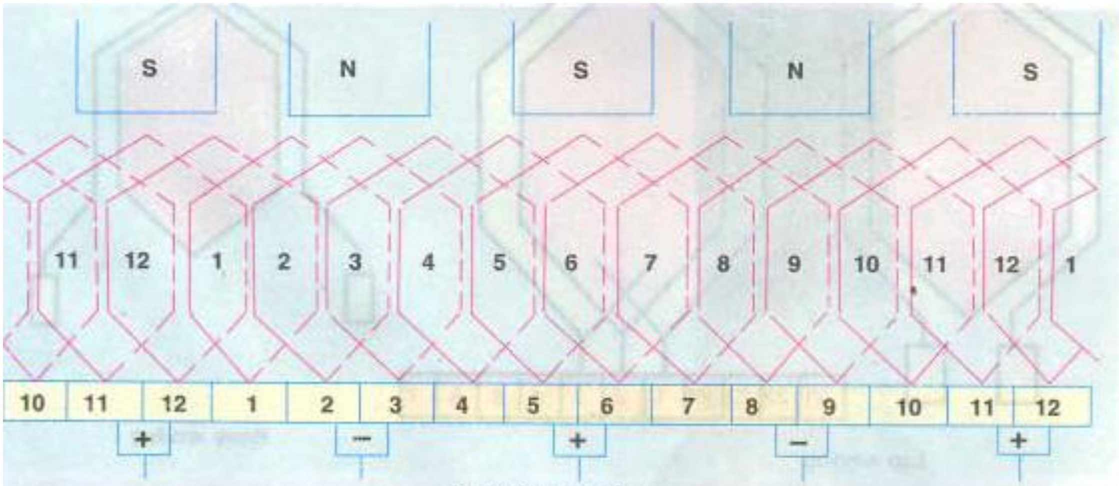
The armature windings are usually former-wound. These are first wound in the form of flat rectangular coils and are then pulled into their proper shape in a coil puller. Various conductors of the coils are insulated from each other. The conductors are placed in the armature slots which are lined with tough insulating material. The armature windings conduct the induced current.

Types of armature winding

Two types of windings mostly employed for drum-type armatures are known as Lap winding and Wave winding.

- **Lap winding**

In ths type winding there are many paths through the armature as there are poles on the machine. Therefore, to obtain full use of this type winding, there must be as many brushes as there are poles, alternate brushes being positive and negative.

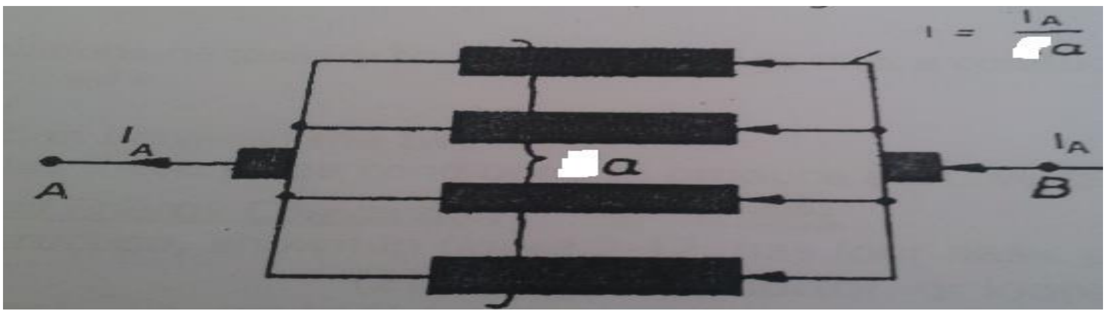


Simplex lap winding

- **Wave winding**

In a wave winding there are only two paths regardless of the number of poles.

Number of parallel paths



I_A= total armature current, I: current/ path, a: number of paths

In this case the total generator current, (I_A= armature current) is the sum of ALL the currents in these paths. This means that for larger machines with higher current values it is preferable to use a large number of parallel paths in order to reduce the current per path which represents the conductor current.

For simplex Lap winding: number of paths (a) = number of poles (P)

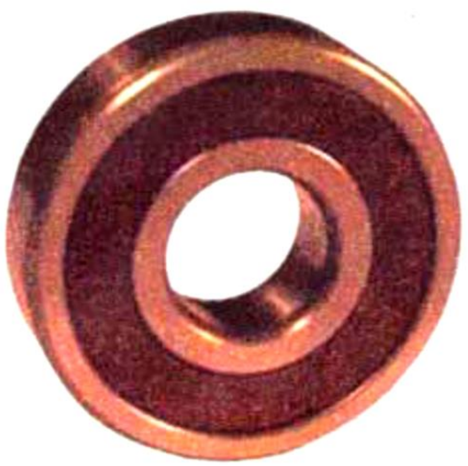
For simplex wave winding: number of paths (a) = 2

Commutator

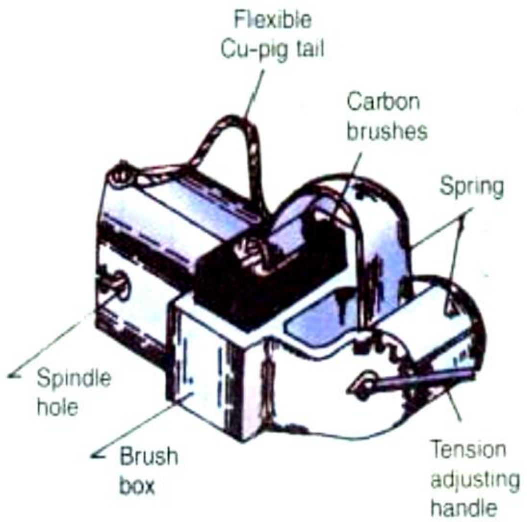
The function of the commutator is to facilitate collection of current from the armature conductors. It converts the alternating current induced in the armature conductors into unidirectional current in the external load circuit. It is of cylindrical structure and is built up of wedge-shaped segments of high-conductivity hard-drawn or drop forged copper. These segments are insulated from each other by thin layers of mica. The number of segments is equal to the number of armature coils.

Brushes and Bearings

The brushes function is to collect current from commutator, is usually made of carbon or graphite and are in the shape of rectangular block. These brushes are housed in brush-holders usually of the box-type variety. The bearings facilitate the rotation of the armature.



Bearing



Interpoles (commutating poles)

Interpoles are similar to the main field poles and located on the yoke between the main field poles. They have windings in series with the armature winding. Interpoles have the function of reducing the armature reaction effect in the commutating zone. They eliminate the need to shift the brush assembly.

Equation of the generated e.m.f:

The generated voltage in a single conductor is:

E= N $\frac{d\varphi}{dt}$ = N B $\frac{dx}{dt}$L= NBVL

This equation can be developed to the following equation for DC machines:

E=$\frac{\phi\, Zn}{60}$ x $\frac{numberofpoles}{numberofparallelpaths}$

Let ϕ = flux/ pole in Weber

Z = total number of armature conductor

= No. of slots X No. of conductors/slot

P = No. of generator poles

A = No. of parallel paths in armature

N = armature rotation in revolution per minute (r.p.m.)

E = e.m.f. induced in any parallel path in armature

Example

The armature winding of a dc generator has the following particulars:

Number of poles = 4, number of slots = 36, number of conductors/ slots = 6

Magnetic flux = 12mwb, rotating speed = 600 rpm.

Calculate the open circuit voltage (no-load terminal voltage), when the armature coils are wound as: 1) simplex Lap, 2) simplex wave

Solution

Total number of conductors Z = number of conductors/ slots x number of slots

Z = 6 x 36 = 216 conductors

E = $\frac{\phi\, Zn}{60} \times \frac{number of poles}{number of parallel paths} = \frac{(12\ X10^{-3})(216)(600)}{60} \times \frac{P}{A}$

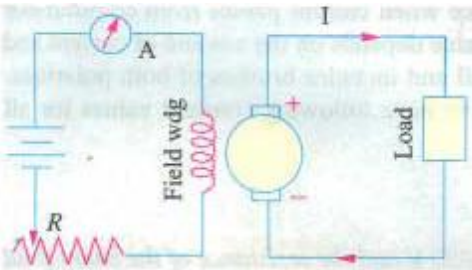
E = 25.92 volts (simplex Lap A = P = 4)

E = 51.84 volts (simplex wave A = 2)

Content/Topic 2Types of DC Generators

The generators are usually classified according to the way in which their fields are excited. Generators may be divided into (a**) separately-excited generators and (b)self-excited generators.**

(a) separately-excited generators are those whose field magnets are energised from an independent external source of d.c current. The rotor is driven by a prime mover.

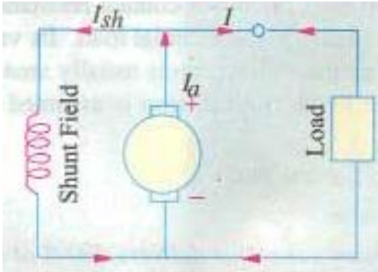


(b) self-excited generators are those whose field magnets are energised by the current produced by the generators themselves. Due to residual magnetism, there is always presence of some flux in the poles. When the armature is rotated, some e.m.f and hence induced current is produced which is partly fully passed through the field coils thereby strengthening the residual pole flux.

There are thee types of self- excited generetors named according to the manner in which their field coils (or windings) are connected to the armature:-

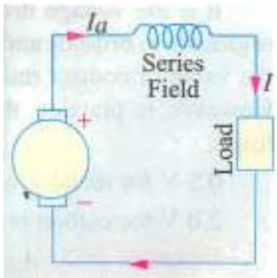
i) Shunt wound

The field windings are connected across or in parallel with the armature conductors and have the full voltage of the generator applied across them.



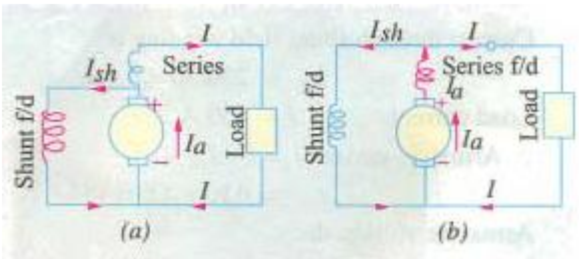
ii) Series wound

In this case, the field windings are joined in series with the armature conductors. As they carry full load current, they consist of relatively few turns of thick wire or strips. Such generators are rarely used axcept for special purposes i.e. as boosters etc.



iii) Compound wound

It is a combination of a few series and a few shunt windings and can be either short-shunt or long-shunt as shown below in the figure (a) and (b) respectively.

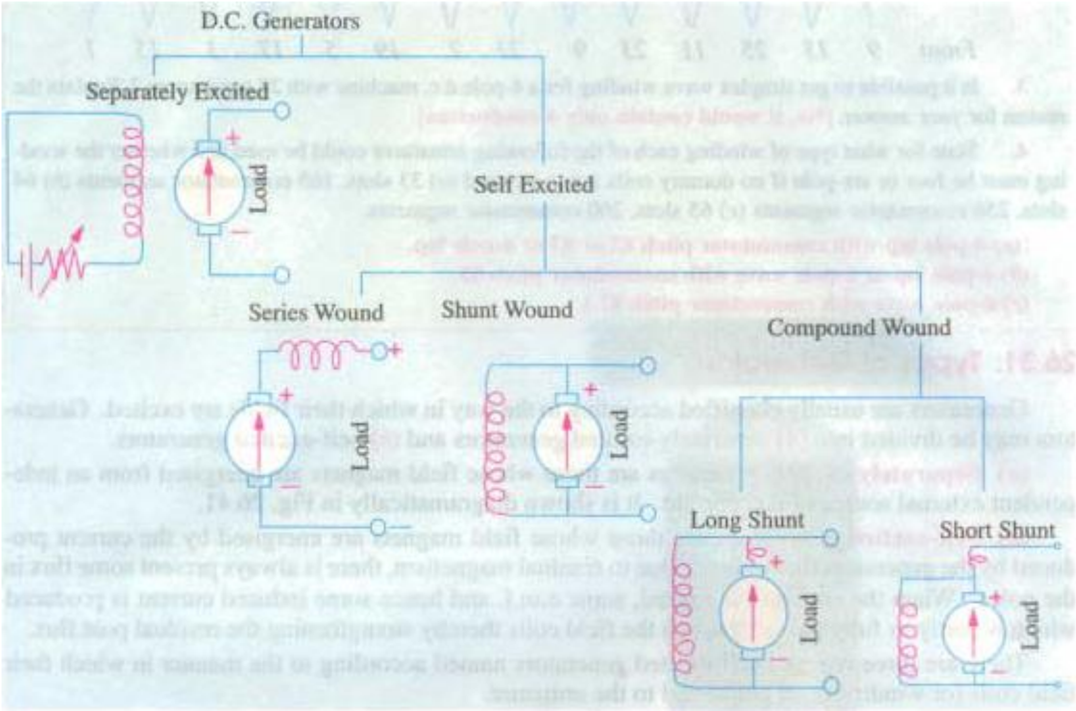


For Short shunt: shunt field winding is in parallel with the armature winding

Long shunt: shunt field winding is in parallel with both series field and armature winding

In a compound generator, the shunt field is stronger than the series field. When series field aids the shunt field, generator is said to be commulatively-compounded. On the other hand if the series opposes the shunt field, the generator is said to be differentially compounded.

Various types of d.c generators have been shown separately in figure below.



Brush contact Drop

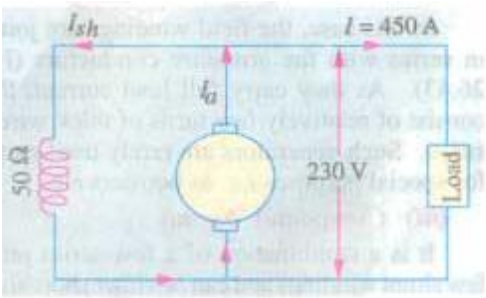
It is the voltage drop over the brush contact resistance when current passes from commutator segments to brushes and finally to the external load. The brush contact drop is assumed to have contact values for all loads. 0.5V for metal-graphite brushes, 2.0V for carbon brushes.

Example

A shunt generator delivers 450A at 230V and the resistance of the shunt field and armature are 50Ω and0.03Ω respectively. Calculate the generated e.m.f.

Solution

This is the Geneartor circcuit



Current through shunt field winding is:

I_{sh} = 230/50 = 4.6A

Load urrent I = 450A

Therefore armature current $I_a = I_{sh} + I$

= 450 + 4.6 = 454.6 A

Armature voltage drop

$I_a R_a$ = 454.6 x0.03 = 13.6 V

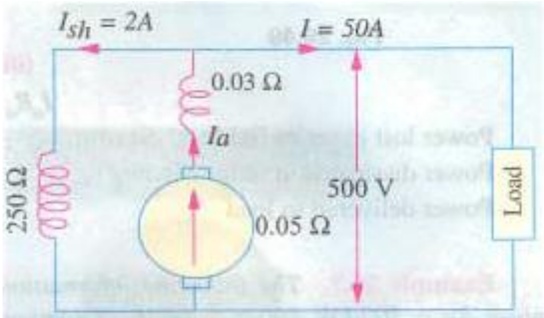
Now E_g = terminal voltage + armature drop

= 230+ 13.6 = 243.6 V

Example2: A long-shunt compound generator delivers a load current of 50 A at 500 V and has armature, series field and shunt resistances of 0.05Ω, 0.03Ω and 250Ω respectively. Caluculate the generated voltage and the armature current. Allow 1 V per brush for contact drop.

Solution:

This is the generator circuit



Ish = 500/250 = 2A

Current through armature and series winding is

=50 + 2 = 52 A

Voltage drop on series field winding

= 52 x 0.03 = 1.56 V

Armature voltage drop

IaRa = 52 x 0.05 = 2.6 V

Drop at brushes = 2 x 1 = 2 V

Now, Eg = V + IaRa + series drop + brash drop

= 500 + 2.6 + 1.56 + 2 = 506.16 V

Content/Topic 3 Application of DC Generators

1. Applications of Shunt Wound DC Generators

The application of shunt generators is very much restricted for its dropping voltage characteristic. They are used to supply power to the apparatus situated very close to its position. These types of DC generators generally give constant terminal voltage for small distance operation with the help of field regulators from no load to full load.

1. They are used for general lighting.
2. They are used to charge battery because they can be made to give constant output voltage.
3. They are used for giving the excitation to the alternators.
4. They are also used for small power supply.

2. Applications of Series Wound DC Generators

These types of generators are restricted for the use of power supply because of their increasing terminal voltage characteristic with the increase in load current from no load to full load.

We can clearly see this characteristic from the characteristic curve of series wound generator. They give constant current in the dropping portion of the characteristic curve. For this property they can be used as constant current source and employed for various applications.

1. They are used for supplying field excitation current in DC locomotives for regenerative breaking.

2. These types of generators are used as boosters to compensate the voltage drop in the feeder in various types of distribution systems such as railway service.
3. In series arc lightening this type of generators are mainly used.

3 Applications of Compound Wound DC Generators

Among various types of DC generators, the compound wound DC generators are most widely used because of its compensating property. Depending upon number of series field turns, the cumulatively compounded generators may be over compounded, flat compounded and under compounded. We can get desired terminal voltage by compensating the drop due to armature reaction and ohmic drop in the line. Such generators have various applications.

1. Cumulative compound wound generators are generally used for lighting, power supply purpose and for heavy power services because of their constant voltage property. They are mainly made over compounded.
2. Cumulative compound wound generators are also used for driving a motor.
3. For small distance operation, such as power supply for hotels, offices, homes and lodges, the flat compounded generators are generally used.
4. The differential compound wound generators, because of their large demagnetization armature reaction, are used for arc welding where huge voltage drop and constant current is required.

At present time the applications of DC generators become very limited because of technical and economic reasons. Now a day the electric power is mainly generated in the form of alternating current with the help of various power electronics devices.

5. Applications of Separately Excited DC Generators

This type of DC generators are generally more expensive than self-excited DC generators because of their requirement of separate excitation source. Because of that their applications are restricted. They are generally used where the use of self-excited generators are unsatisfactory.

1. Because of their ability of giving wide range of voltage output, they are generally used for testing purpose in the laboratories.
2. Separately excited generators operate in a stable condition with any variation in field excitation. Because of this property they are used as supply source of DC motors, whose speeds are to be controlled for various applications. Example- Ward Leonard Systems of speed control.

LO 2.2 Identify DC Generators accessories

Content/Topic 1Control and monitoring accessories

- ✓ **Control panel**

A control panel is a flat, often vertical, area where control or monitoring instruments are displayed or it is an enclosed unit that is the part of a system that users can access, as the control panel of a security system (also called control unit).

They are found in factories to monitor and control machines or production lines and in places such as nuclear power plants, ships, aircraft, and mainframe computers. Older control panels are most often equipped with push buttons and analog instruments, whereas nowadays in many **cases touch screens are used for monitoring and control purposes.**

- ✓ **Power Cord**

A power cord, line cord, or mains cable is an electrical cable that temporarily connects an appliance to the mains electricity supply via a wall socket or extension cord.

- ✓ **Battery Charger**

A battery charger, or recharger, is a device used to put energy into a secondary cell or rechargeable battery by forcing an electric current through it

- ✓ **Installation Kits (cables, Plugs & Connectors)**

An electrical cable is an assembly of one or more wires running side by side or bundled, which is used to carry electric current.

An electrical connector, is an electro-mechanical device used to join electrical terminations and create an electrical circuit. Electrical connectors consist of plugs (male-ended) and jacks (female-ended).

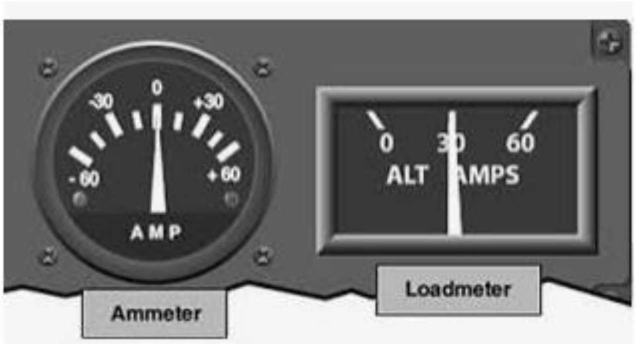
Industrial connectors

- ✓ **Power Inlet Boxes**

The power inlet for generator will be used to connect the generator output to the external circuit.

✓ **Load Meters**

A load meter is a device that is commonly found within the electrical meters that are installed by utility companies. The primary function of this gauge is to indicate the peak usage of electricity since the last time that the monitor was read, normally to determine if any sudden power surges had occurred within the last month that would cause the other readings to be invalid.



✓ **Monitoring Equipment**

Monitoring equipment are the equipment used to know the state of generator(used to reduce the effects of power outages and operate your remote sites more efficiently) such as
High/low fuel sensors, intrusion sensors, Battery sensors, Generator sensors

Content/Topic 2 Mounting and coupling Accessories

✓ **Shaft coupling/transmission belt**

A coupling is a device used to connect two shafts together at their ends for the purpose of transmitting power. Couplings do not normally allow disconnection of shafts during operation, however there are torque limiting couplings which can slip or disconnect when some torque limit is exceeded.

- ✓ **Pivot mount**

Mounting and coupling to driven equipment are essential to the success of any machine installation.

- ✓ **L mount**

An engine-generator or portable generator is the combination of an electrical generator and an engine (prime mover) mounted together to form a single piece of equipment. This combination (marking L form) is also called an engine-generator set or a gen-set. In many contexts, the engine is taken for granted and the combined unit is simply called a generator.

- ✓ **Universal tracking mount**

Track mount is a method of coupling where generators are attached anywhere on a continuous track device in order to perform any mechanical transmission.

Content/Topic 3 Miscellaneous

- ✓ **Maintenance Kit**

Scheduled maintenance is a necessity for all standby generators. The Air Cooled Scheduled Maintenance kits offer all the components necessary to perform a complete maintenance on Honeywell air-cooled generators. Oil will need to be purchased separately based upon the recommendations listed. Maintenance is recommended at every 200 hours or 2 years. If running in a dusty environment, more frequent maintenance may be required. Maintenance intervals may differ per model. Refer to the generator owner's manual for more information.

- ✓ **Wheel Kit**

Make your generator portable. Smooth-rolling never-flat tires make it easy to transport your generator to the jobsite.

- ✓ **Cover**

The cover is defined as the housing of the generator parts, and it plays the role of protecting the machine.

Content/Topic 4 Prime mover/engine

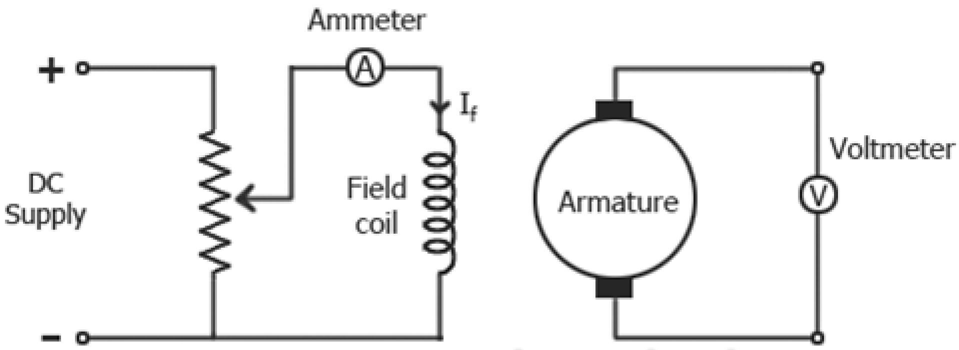
In engineering, a prime mover is an engine that converts fuel to useful work. In locomotives, the prime mover is thus the source of power for its propulsion. In an engine-generator set, the engine is the prime mover, as distinct from the generator.

L.O 2.3.Apply electrical characteristics of DC generators

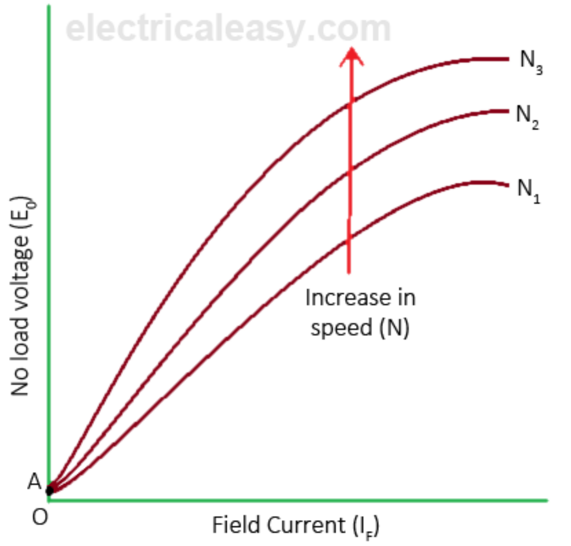
Content/Topic 1 : No-load saturation characteristics (open-circuit characteristic)

Open Circuit Characteristic (O.C.C.) (E_0/I_f)

Open circuit characteristic is also known as **magnetic characteristic** or **no-load saturation characteristic**. This characteristic shows the relation between generated e.m.f at no load (E_0) and the field current (I_f) at a given fixed speed. The O.C.C. curve is just the magnetization curve and it is practically similar for all type of generators. The data for O.C.C. curve is obtained by operating the generator at no load and keeping a constant speed. Field current is gradually increased and the corresponding terminal voltage is recorded. The connection arrangement to obtain O.C.C. curve is as shown in the figure below. For shunt or series excited generators, the field winding is disconnected from the machine and connected across an external supply.



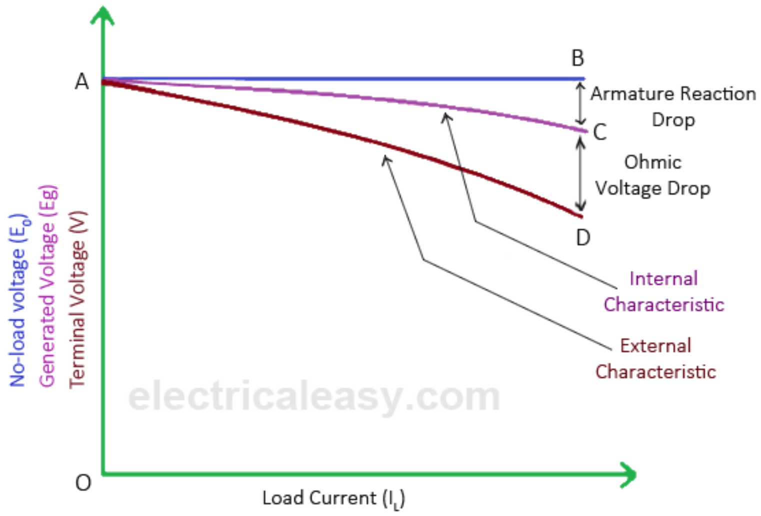
Now, from the emf equation of dc generator, we know that Eg = kɸ. Hence, the generated emf should be directly proportional to field flux (and hence, also directly proportional to the field current). However, even when the field current is zero, some amount of emf is generated (represented by OA in the figure below). This initially induced emf is due to the fact that there exists some residual magnetism in the field poles. Due to the residual magnetism, a small initial emf is induced in the armature. This initially induced emf aids the existing residual flux, and hence, increasing the overall field flux. This consequently increases the induced emf. Thus, O.C.C. follows a straight line. However, as the flux density increases, the poles get saturated and the ϕ becomes practically constant. Thus, even we increase the I_f further, ϕ remains constant and hence, Eg also remains constant. Hence, the O.C.C. curve looks like the B-H characteristic.



Open Circuit Characteristic (O.C.C.)

The above figure shows a typical no-load saturation curve or open circuit characteristics for all types of DC generators.

- **Separately excited DC generator**



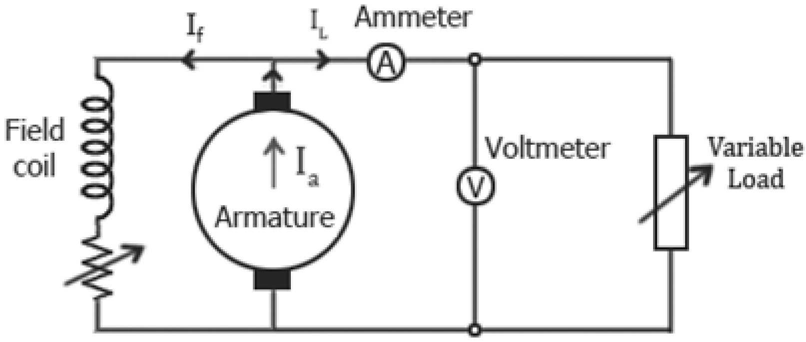
Characteristics of separately excited DC generator

If there is no armature reaction and armature voltage drop, the voltage will remain constant for any load current. Thus, the straight line AB in above figure represents the no-load voltage vs. load current I_L. Due to the demagnetizing effect of armature reaction, the on-load generated emf is less than the no-load voltage. The curve AC represents the on-load generated emf Eg vs. load current I_L i.e. internal characteristic (as $I_a = I_L$ for a separately excited dc generator). Also, the terminal voltage is lesser due to ohmic drop occurring in the armature and brushes. The curve AD represents the terminal voltage vs. load current i.e. external characteristic.

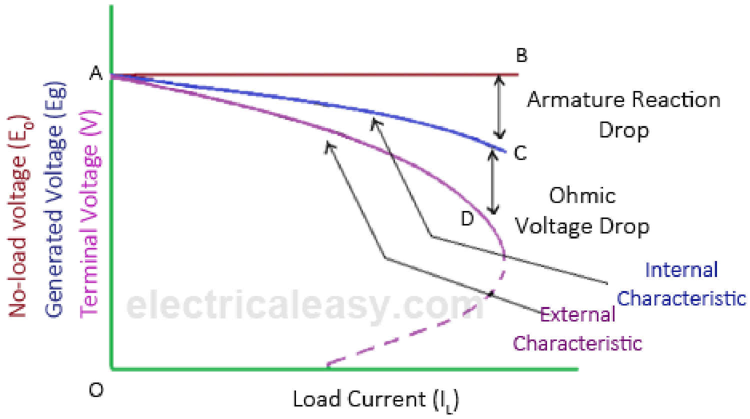
- **Self excited DC Generator**

✓ **Characteristics Of DC Shunt Generator**

To determine the internal and external load characteristics of a DC shunt generator the machine is allowed to build up its voltage before applying any external load. To build up voltage of a shunt generator, the generator is driven at the rated speed by a prime mover. Initial voltage is induced due to residual magnetism in the field poles. The generator builds up its voltage as explained by the O.C.C. curve. When the generator has built up the voltage, it is gradually loaded with resistive load and readings are taken at suitable intervals. Connection arrangement is as shown in the figure below.



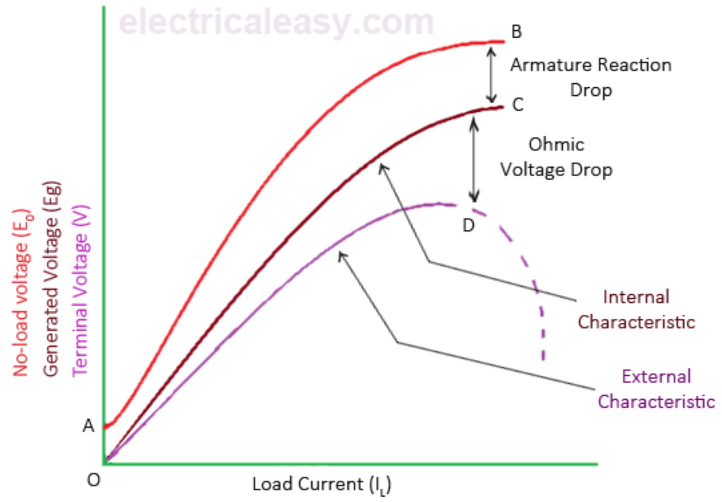
Unlike, separately excited DC generator, here, $I_L \neq I_a$. For a shunt generator, $I_a = I_L + I_f$. Hence, the internal characteristic can be easily transmitted to Eg vs. I_L by subtracting the correct value of I_f from I_a.



Characteristics of DC shunt generator

During a normal running condition, when load resistance is decreased, the load current increases. But, as we go on decreasing the load resistance, terminal voltage also falls. So, load resistance can be decreased up to a certain limit, after which the terminal voltage drastically decreases due to excessive armature reaction at very high armature current and increased I^2R losses. Hence, beyond this limit any further in load resistance results in decreasing load current. Consequently, the external characteristic curve turns back as shown by dotted line in the above figure.

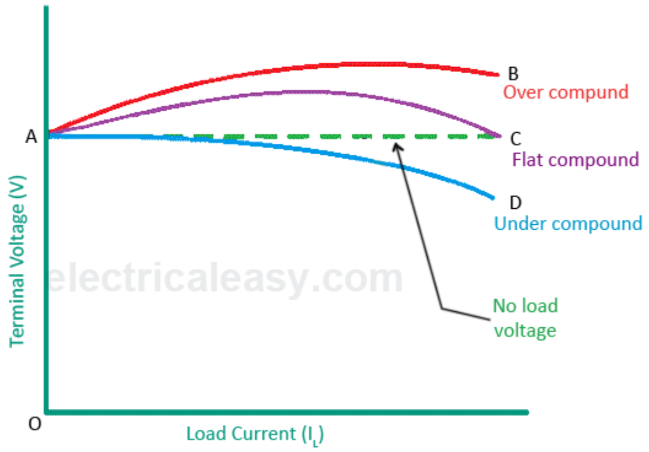
- ✓ **Characteristics Of DC Series Generator**



Characteristics of DC series generator

The curve AB in above figure identical to open circuit characteristic (O.C.C.) curve. This is because in DC series generators field winding is connected in series with armature and load. Hence, here load current is similar to field current (i.e. I_L=I_f). The curve OC and OD represent internal and external characteristic respectively. In a DC series generator, terminal voltage increases with the load current. This is because, as the load current increases, field current also increases. However, beyond a certain limit, terminal voltage starts decreasing with increase in load. This is due to excessive demagnetizing effects of the armature reaction.

- ✓ **Characteristics Of DC Compound Generator**



External characteristic of DC compound generator

The above figure shows the external characteristics of DC compound generators. If series winding amp-turns are adjusted so that, increase in load current causes increase in terminal voltage then the generator is called to be over compounded. The external characteristic for over compounded generator is shown by the curve AB in above figure.

If series winding amp-turns are adjusted so that, the terminal voltage remains constant even the load current is increased, then the generator is called to be flat compounded. The external characteristic for a flat compounded generator is shown by the curve AC.

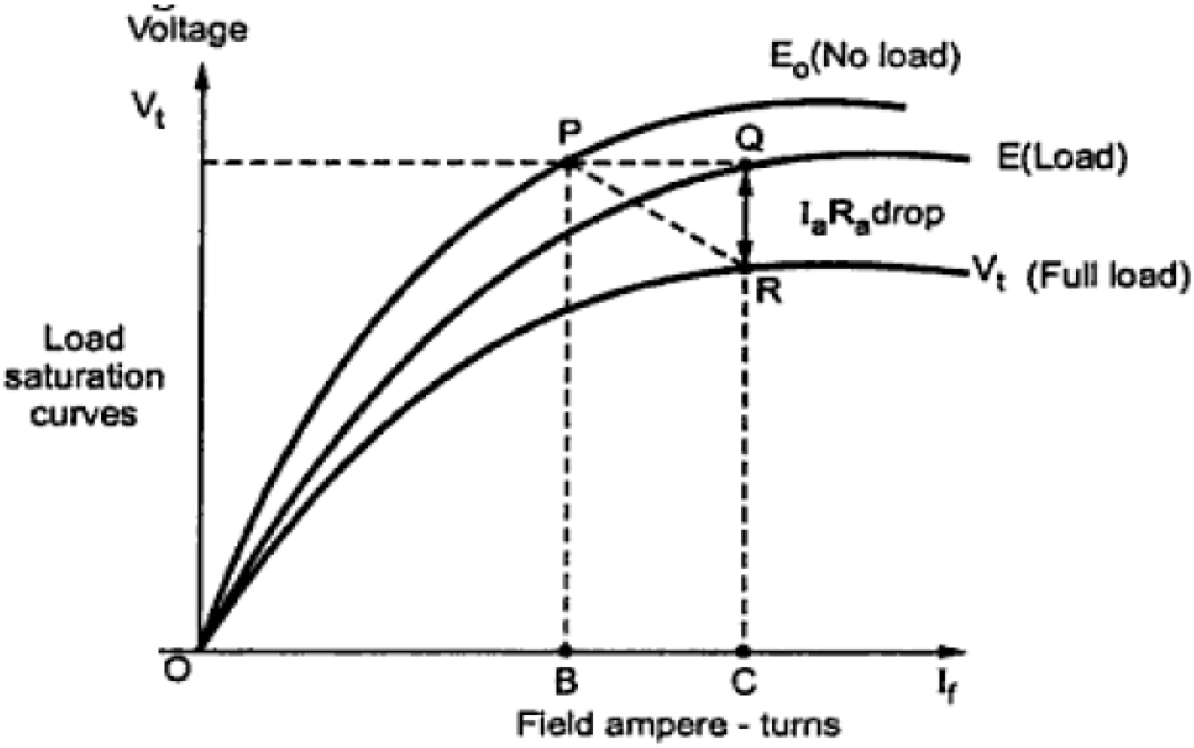
If the series winding has lesser number of turns than that would be required to be flat compounded, then the generator is called to be under compounded. The external characteristics for an under compounded generator are shown by the curve AD.

Content/Topic2 load characteristics

These are further divided into two categories, **external characteristics and internal characteristics**
External characteristics is the graph of the terminal voltage V_t against load current I_L
Internal characteristics is the graph of the generated induced e.m.f against the armature current.In most of the cases, the shunt field current is very small as compared with load current I_L. Hence in practice the internal characteristics shows the graph of induced e.m.f E against load current IL instead of I_a neglecting I_{sh}.

- ✓ **Characteristics of separately excited d.c generators**

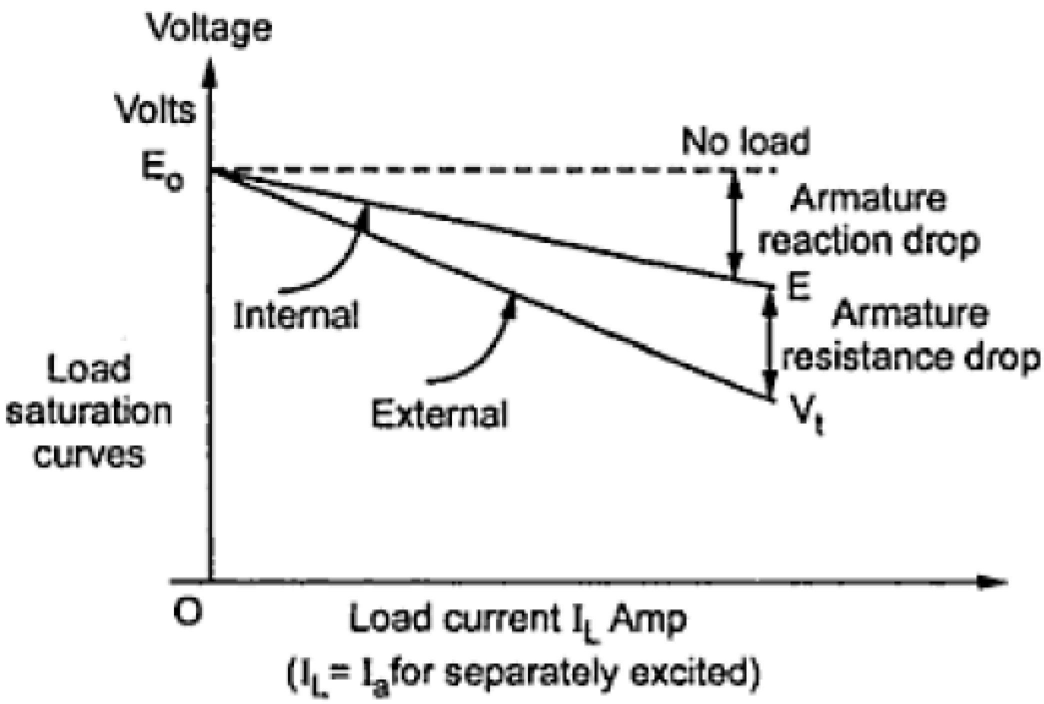
Load saturation Curve
This is the graph of terminal voltage V_t against field current I_f. When generator is loaded, armature current I_a flows and armature reaction exists. Due to this, terminal voltage V_t is less than the no load rated voltage. On no load, current I_a is zero and armature reaction is absent. Hence less number of ampere turns are required to produce rated voltage E_0
These ampere-turns are equal to OB as shown in the figure below on load, to produce same voltage more field ampere-turns are required due to demagnetising effect of armature reaction. These are equal to BC as shown in the figure. Similary there is drop IaRa across armature resistance. Hence terminal voltage V=E-I_aR_a. This graph OR is also shown in the figure The triangle PQR is called drop reaction triangle. Thus OP is no load saturation curve, OQ is the graph of generated voltage on load and OR is the graph of terminal voltage on load.



Internal and external characteristics

Let E_0 be the no load rated voltage which drops to E due to armature reaction on load and further drop to Vt due to armature resistance drop Ia Ra on load.

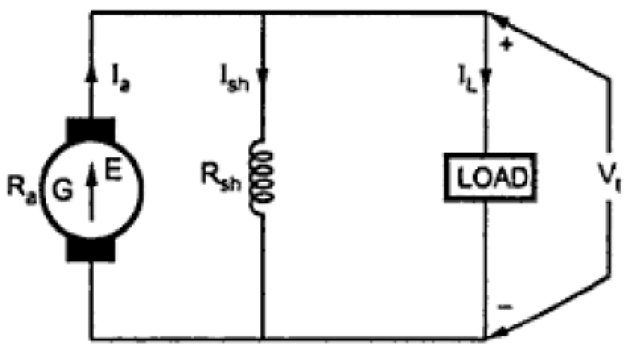
The graph of Vt against load current IL is called external characteristics these are shown in the figure below for separately excited d.c generator. The graphs are to be plotted for constant field current. In case of separately excited d.c generator induced e.m.f is totally dependent on flux and field current Hence to have control over the field current in case of separately excited d.c generator field regulator is necessary.



✓ **Load characteristics of DC Shunt Generator**

Consider the d.c shunt generator shown in the figure below the internal characteristics is EVsI_L while the external characteristics is Vt against I_L .

Let us see the nature of these two characteristics.

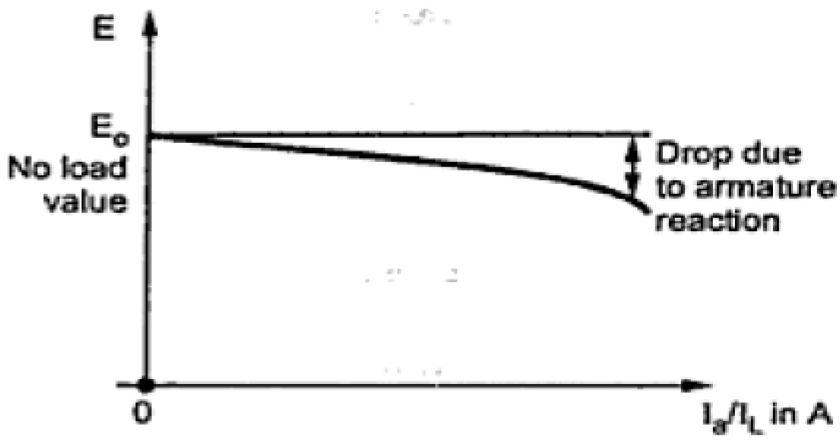


Internal Characteristics

Ideally the induced e.m.f is not dependent on the load current IL or armature current Ia. But as load current increases, the armature current Ia increases to supply load demand. As Ia increases, armature flux increases.

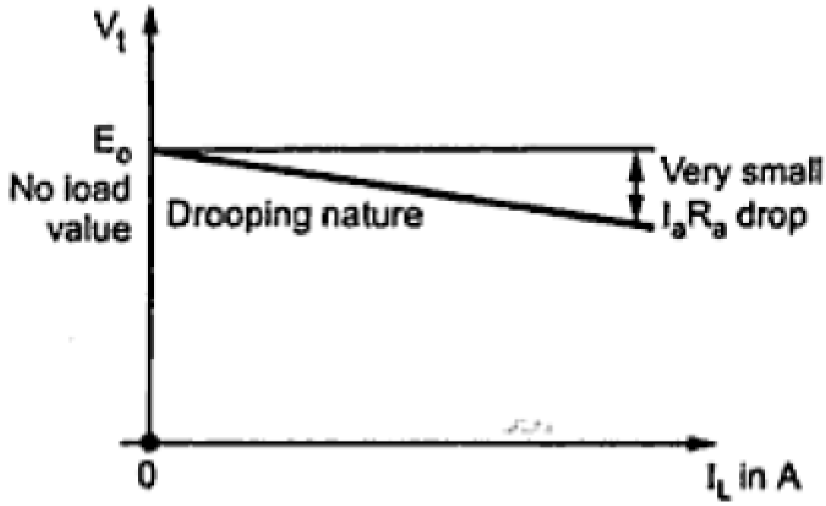
The effect of flux produced by armature on the main flux produced by the field winding is called an armature reaction

Due to the armature reaction, main flux pattern gets distorted Hence lesser flux gets linked with the armature conductors. This reduces the induced e.m.f



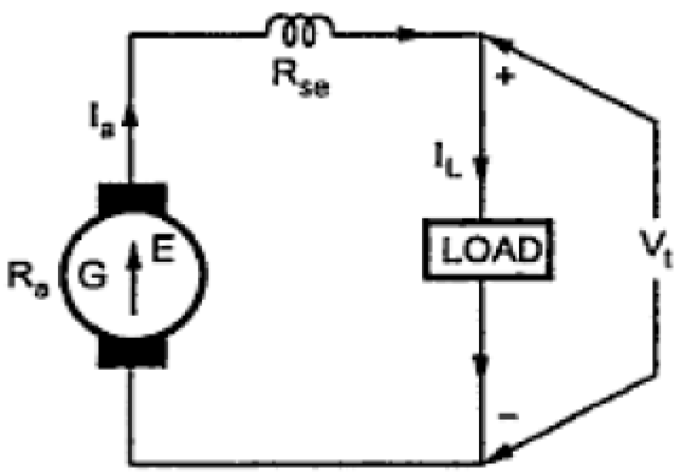
External Characteristics

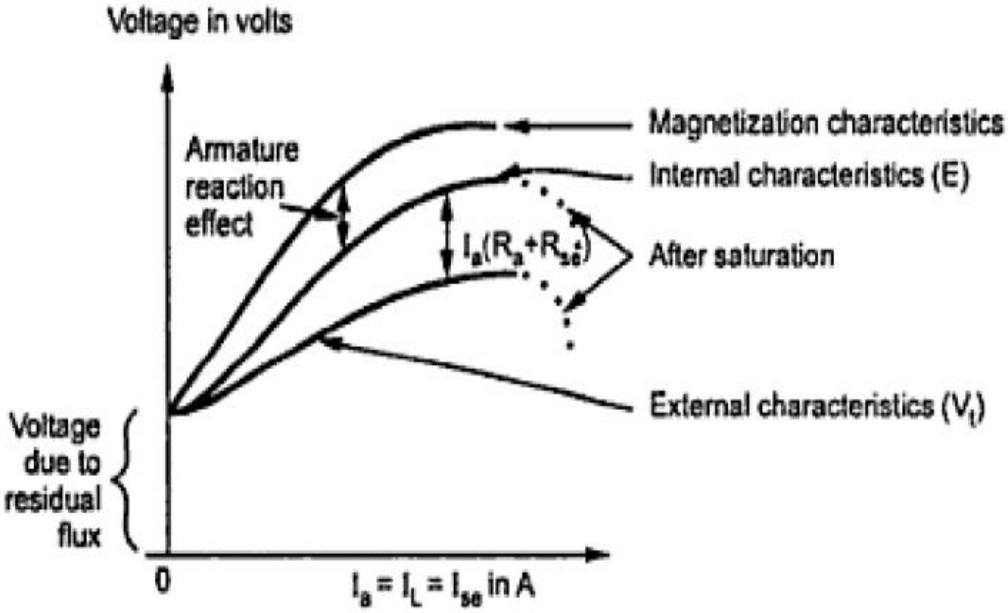
For d.c shunt generator we know that $E=V_t+I_aR_a$ neglecting other drops. So as load current IL increases, Ia increases. Thus the drop Ia Ra increases and terminal voltage Vt=E-IaRa decreases. But the value of armature resistance is very small, the drop in terminal voltage as IL changes from no load to full load is very small. Hence d.c shunt generator is called constant voltage generator



- ✓ **Load characteristics of DC seriesgenerator**

Consider a series generator $Ia=Isc=I_L$ As load current increases, Ise increases.The flux is directly proportional to Ise. So flux also increases. The induced e.m.f. E is proportional to flux hence induced e.m.f also increases.Thus the characteristics of E against internal characteristics is of increasing nature.





As Ia increases,armature reaction increases but its effect is negligible compared to increase in E But for high load current saturation occurs and flux remains constant. In such case, due to the armature reaction E starts decreasing as shown by the dotted line in the above figure. Now as IL=IA increases,thus the drop Ia(Ra+Rse)increases.

Thus the external characteristics is also of rising nature as E increases but it will be below internal characteristics due to drop Ia(Ra+Rse).

In self-excited series generator, open circuit characteristics cannot be obtained. In open circuit,Ia=IL=0 hence induced e.m.f is zero. Thus open circuit characteristics are possible only by separately exciting the winding.

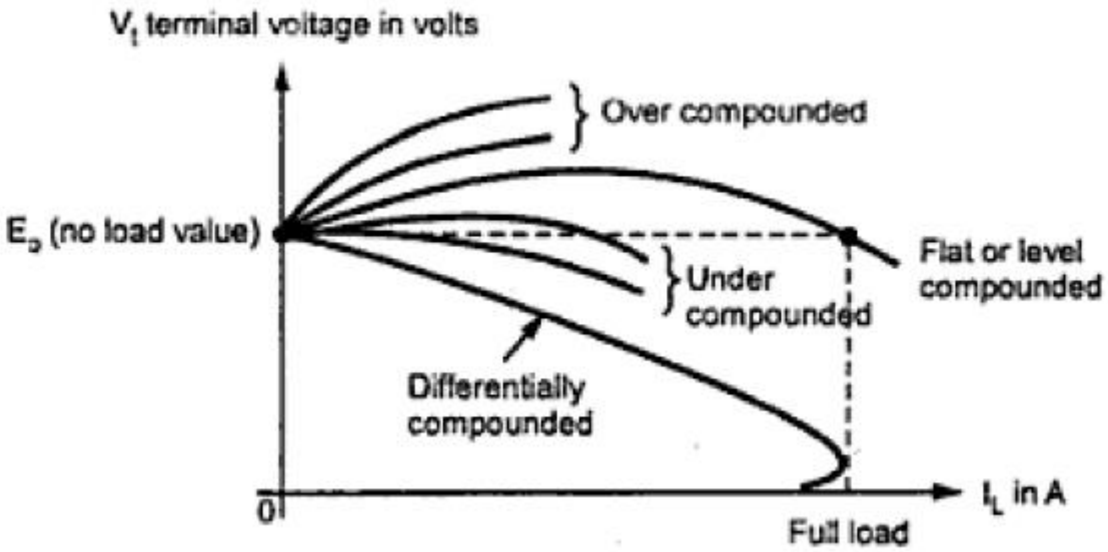
In practice when there is no load IL=0, then there exists certain induced e.m.f due to residual flux retained by the field winding.

- ✓ **Load Characteristics of D.C Compound Generator**

The characteristics depends on whether generator is cumulatively compound or differentially compound generator. In cumulatively compound $\phi_T=\phi_{sh}+\phi_{se}$.

As load current increases, I_a increases hence I_{se} also increases producing more flux. Thus induced e.m.f increase and terminal voltage also increases. But as I_a increase, the various voltage drops and armature reaction drop also increases. Hence there is drop in the terminal voltage.

If the drop in V_t due to increasing I_L is more dominating than increase in Vt due to increase in flux then generator is called under compounded and its characteristics is droppin in nature.



If drop in Vt due to armature reaction and other drops is much less than increase in Vt due to increase in flux then generator is called over compounded and its characteristics is rising in nature as shown on the above figure.

Effect of the two are such that on full load current Vt is same as no load induced e.m.f. the effect are neutralising each other on full load then generator is called flat compounded or level compounded. Its characteristics are shown in the above figure.

In differentially compound $\phi_T=\phi_{sh}-\phi_{se}$ .The net flux is difference between the two. A s IL increases, ϕ_{sh} is almost constant but ϕ_{se} increase rapidly. Hence the resultant flux ϕ_T reduces. Hence the induced e.m.f E and hence the terminal voltage also decreases drastically. There is drop due to armature resistance, series field resistance, armature reaction due to which terminal voltage drops further .Thus we get the characteristics of such differentially compound generator

Content/Topic 4 Calculation of critical resistance

Consider the field magnetization characteristics of a d.c. shunt generator shown in the Fig. 1.

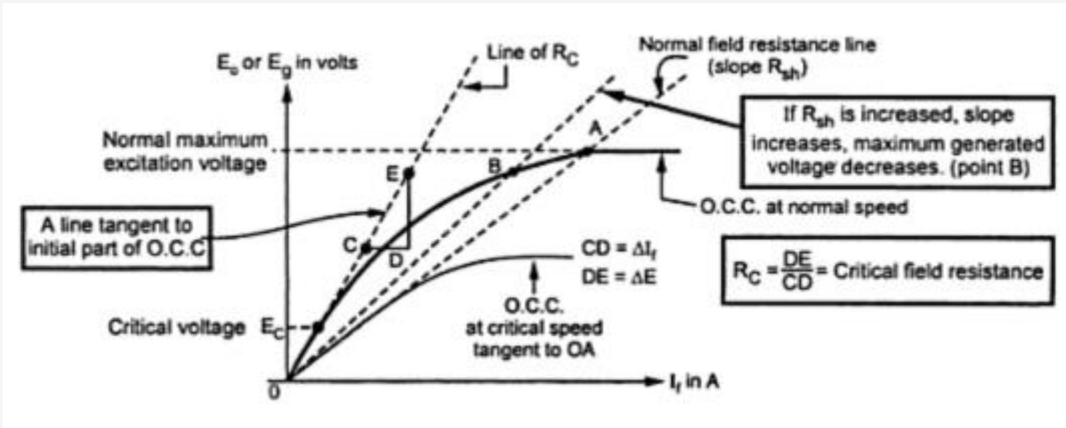


Fig. 1 Concept of critical resistance

The Fig. 1 shows that generator voltage builds in step till point A. This point is intersection of field resistance line with the open circuit characteristics (O.C.C.). The voltage corresponding to point A is the maximum voltage it can generate. If the slope of field resistance line is reduced by decreasing the field resistance, the maximum voltage generator can build will be higher than that corresponding to point A. Similarly if the slope of field resistance line is increased by increasing the field resistance, the maximum voltage generator can build will be less that that corresponding to point A i.e. corresponding to point B.

If now the slope of the field resistance line is increased in such a way that it becomes tangential to the lower part of the open circuit characteristics. The voltage corresponding to this point is E_C. This voltage is just sufficient to drive the current through field resistance so that cumulative process of building the voltage starts. This value of field resistance is called critical resistance denoted as R_C, of the shunt field circuit at given speed.

Note: If field circuit resistance is more than R_C at start then induced e.m.f. fail to drive current through field circuit and generator fails to excite at given speed.

Thus we can define **critical resistance** as that resistance of the field circuit at a given speed at which generator just excites and starts voltage building while beyond this value generator fails to excite

The critical resistance is the slope of the critical resistance line.

$$\therefore \qquad \boxed{R_C = \frac{\Delta E}{\Delta I_f} = \frac{DE}{CD} = \tan\theta}$$

Similar to the critical resistance there is a concept of critical speed. We know that E α N. As speed decreases the induced e.m.f. decreases and we get O.C.C. below the O.C.C. at normal speed. If we go on reducing the speed, at a particular speed we will get O.C.C. just tangential to normal field resistance line.

Note: This speed at which the machine just excites for the given field circuit resistance is called the critical speed of a shunt generator denoted as N_C.

Practical Determination of R_C

Generally data for plotting the open circuit characteristics is given. Plot the characteristics on the graph paper to the scale.

Draw the tangent, to the initial part of this O.C.C. then the slope of this line is the critical resistance for the speed at which the data is given.

Note: If speed changes, then the O.C.C. changes hence the value of R_C changes.
Now if R_C is asked at speed N_2, while data for O.C.C. is given at N_1. It is known that,

$$E_o \propto N$$

$$\therefore \qquad \frac{E_{o1}}{E_{o2}} = \frac{N_1}{N_2}$$

$$\therefore \qquad \boxed{E_{o2} = \frac{N_2}{N_1} E_{o1}}$$

Note: Generate the data for O.C.C. at new speed and repeat the procedure to obtain R_C.

Content/Topic 5Calculation of critical speed

It is known that as speed changes, the open circuit characteristics also changes, similarly for different shunt field resistances, the corresponding lines are also different.

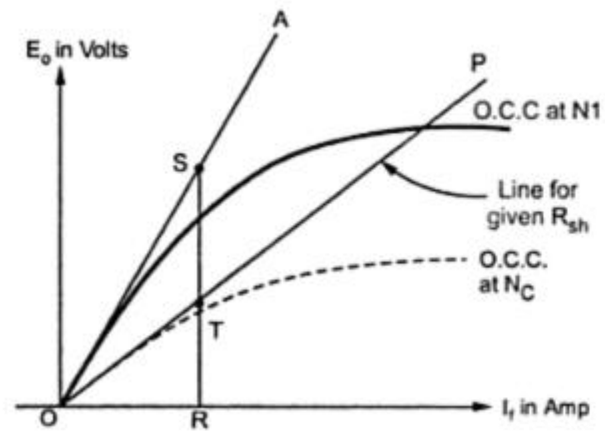
Note: The speed for which the given field resistance acts as critical resistance is called the critical speed, denoted as N_C.

Thus if the line is drawn representing given R_{sh} then O.C.C. drawn for such a speed to which this line is tangential to the initial portion, is nothing but the critical speed N_C.

Graphically critical speed can be obtained for given R_{sh}.

The steps are,
1. Drawn O.C.C. for given speed N_1.
2. Draw a line tangential to this O.C.C. say OA.
3. Draw a line representing the given R_{sh} say OP.
4. Select any field current say point R.
5. Draw vertical line from R to intersect OA at S and OP at T.
6. Then the critical speed N_C is,

While $\frac{RT}{RS} = \frac{N_C}{N_1}$ i.e $\boxed{N_C = N_1 \frac{RT}{RS}}$



$$\boxed{N_C = N_1 \times \frac{RT}{RS}}$$

Fig. 2 Determine critical speed

(Bakshi, 2009)

Content/Topic 6 Conditions for Voltage build-up of shunt generator

A self-excited dc generator supplies its own field excitation. A self-excite generator shown in figure is known as a shunt generator because its field winding is connected in parallel with the armature. Thus, the armature voltage supplies the field current.

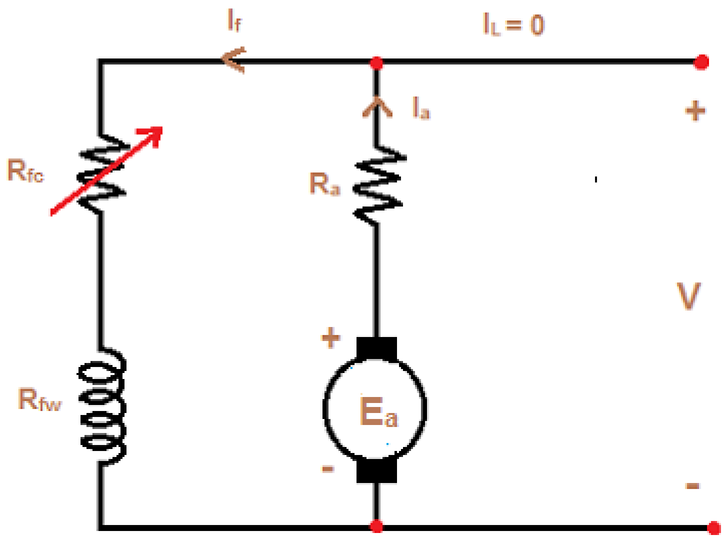


Figure - Equivalent circuit of a shunt dc generator

This generator will build up a desired terminal voltage. Assume that the generator in figure has no load connected to it and armature is driven at a certain speed by a prime mover. We shall study the condition under which the voltage buildup takes place.

The voltage build up in a dc generator.

Due to this residual flux, a small voltage E_{ar} will be generated.

It is given by

$$E_{ar} = K \phi_{res} \omega$$

This voltage is of the order of 1V or 2V. It causes a current If to flow in the field winding in the generator. The field current is given by

$$I_f = \frac{V}{R_f}$$

This field current produces a magneto-motive force in the field winding, which increases the flux. This increase in flux increases the generated voltage Ea. The increased armature voltage Ea increases the terminal voltage V. with the increase in V, the field current If increases further. This in turn increases Φ and consequently Ea increases further. The process of the voltage Build-up continues.

Figure shows the voltage buildup of a dc shunt generator.

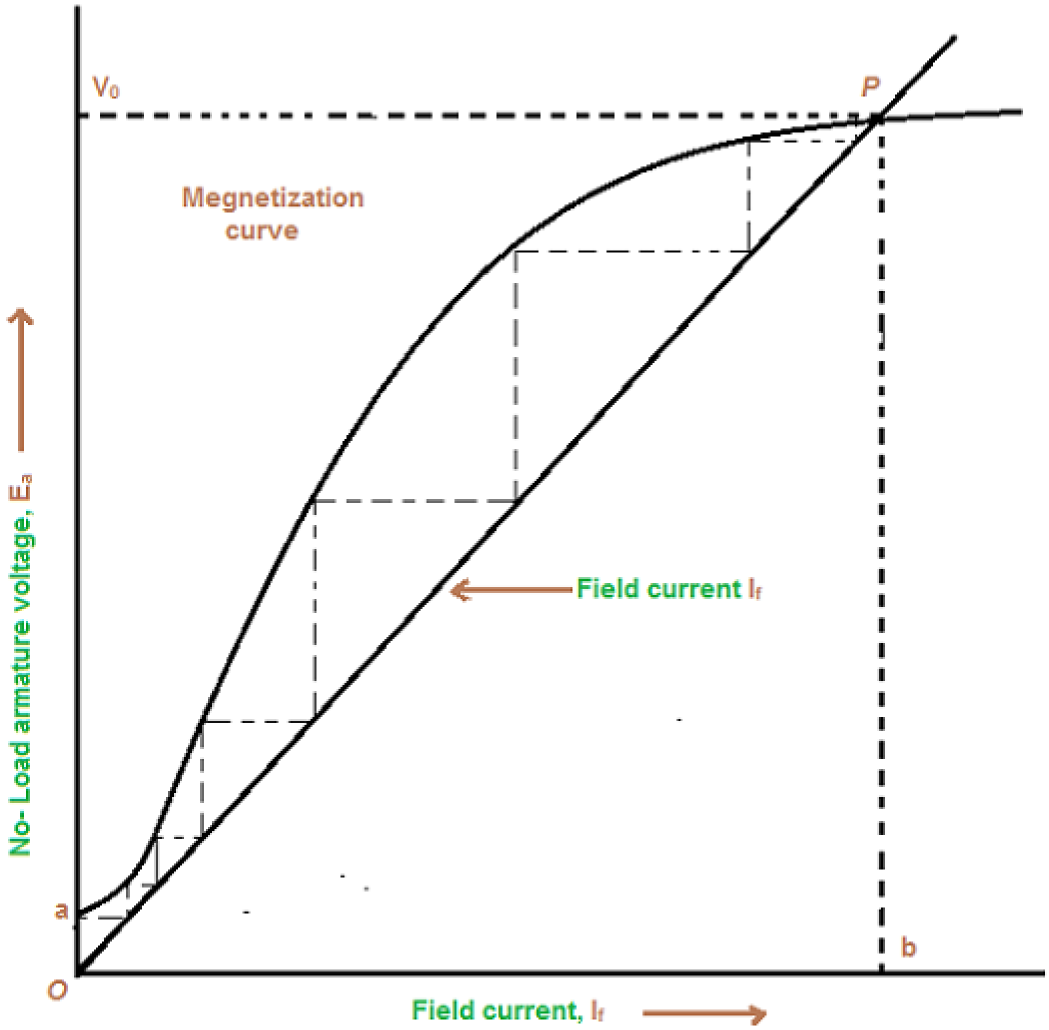


Figure - Voltage buildup of a dc shunt generator.

The effect of magnetic saturation in the pole faces limits the terminal voltage of the generator to a steady state value.We have assumed that the generator is no load during the buildup process. The following equations describe the steady state operation.

$I_a = I_f$

$V = E_a - I_a R_a = E_a - I_f R_a$

Since the field current If in a shunt generator is very small, the voltage drop If Ra can be neglected, and $V = E_a$

The E_a versus If curve is the magnetization curve shown in figure

For the field circuit V = If Rf

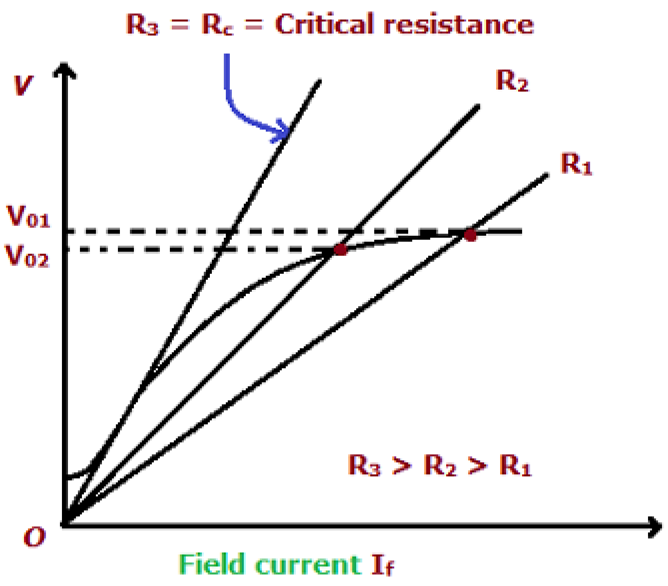
The straight line given by V = If Rf is called the field-resistance line.

The field resistance line is a plot of the voltage If Rf across the field circuit versus the field If. The slop this line is equal to the resistance of the field circuit. The no-load terminal voltage V_0 of the generator. Thus, the intersection point P of the magnetization curve and the field resistance line gives the no-load terminal voltage V0 (bP) and the corresponding field current (Ob). Normally, in the shunt generator the voltage buildup to the value given by the point P. at this point Ea =If Rf = V0.

If the field current corresponding to point P is increase further, there is no further increase in the terminal voltage.
The no-load voltage is adjusted by adding resistance in series with shunt field.
This increase slope of this line causing the operating point to shift at lower voltage.
The operating points are graphical solution of two simultaneous equations namely, the magnetization curve and field resistance line. A graphical solution is preferred due to non-linear nature of magnetization curve.

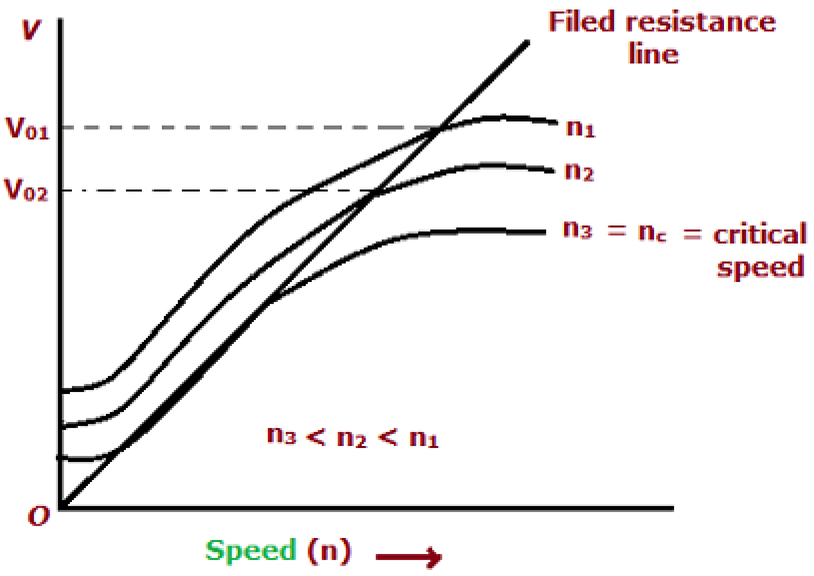
Self-excited generator are designed to obtain no-load voltage from 50% to 125% of the rated value while varying the added resistance in field circuit from maximum to zero value.

Show figures the voltage buildup in the dc shunt generator for various field circuits.



A decrease in the resistance of the field circuit reduces the slope of the field resistance line result in higher voltage. If the speed remains constant, an increase in the resistance of field circuit increases the slop of field resistance line, resulting in a lower voltage. If the field circuit resistance is increased to Rc which is terminal as the critical resistance of the field, the field resistance line becomes a tangent to the initial part of the magnetization curve. When the field resistance is higher than this value, the generator fails to excite.

Figure shows the variation of no-load voltage with fixed Rf and variable speed of the armature.



The magnetization curve varies with the speed and its ordinate for any field current is proportional to the speed of the generator. All the points on the magnetization curve are lowered, and the point of intersection of the magnetization curve and the field resistance line moves downwards. At a particular speed, called the critical speed, the field resistance line becomes tangential to the magnetization curve. Below the critical speed the voltage will not build up.

In Brief, the following condition must be satisfied for voltage buildup in a self-excited generator.

1. There must be sufficient residual flux in the field poles.
2. The field terminal should be connected such a way that the field current increases flux in the direction of residual flux.
3. The field circuit resistance should be less than the critical field circuit resistance.

If there is a no residual flux in the field poles, Disconnected the field from the armature circuit and apply a dc voltage to the field winding. This process is called flashing the field. It will induce some residual flux in the field poles.

Content/Topic 7 Voltage regulation

The regulation of a generator refers to the voltage change that takes place when the load changes. It is usually expressed as the change in voltage from a no-load condition to a full-load condition, and is expressed as a percentage of full-load. It is expressed in the following formula:

$$\text{Percent of regulation} = \frac{(E_{nL} - E_{fL})}{E_{fL}} \times 100$$

Where E_{nL} is the no-load terminal voltage and E_{fL} is the full-load terminal voltage of the generator.

Learning Unit 3: Identify AC generators

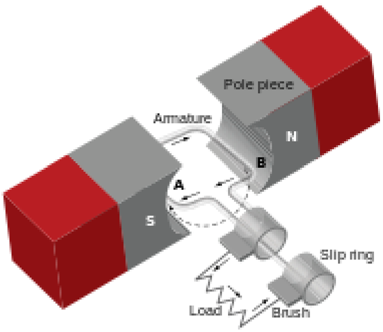
L.O.3.1 Identify single phase generators

Content/Topic 1 Review on Faraday's law

The energy conversion is based on the principle of the production of dynamically (or motional) induced e.m.f. whenever a conductor cuts magnetic flux, dynamically induced e.m.f. is produced in it according to Faraday's Laws of Electromagnetic Induction.

Content/Topic 2 Principle of single-phase AC generation

Single-phase generator (also known as single-phase alternator) is an alternating current electrical generator that produces a single, continuously alternating voltage. Single-phase generators can be used to generate power in single-phase electric power systems.



Elementary generator is an example of single-phase generators with two poles

(wikipedia, Single-phase generator, 2019)

- ✓ **Rotating armature method**

The design of revolving armature generators is to have the armature part on a rotor and the magnetic field part on stator. A basic design, called elementary generator, is to have a rectangular loop armature to cut the lines of force between the north and south poles. By cutting lines of force through rotation, it produces electric current. The current is sent out of the generator unit through two sets of slip rings and brushes, one of which is used for each end of the armature. In this two-pole design, as the armature rotates one revolution, it generates one cycle of single phase alternating current (AC). To generate an AC output, the armature is rotated at a constant speed having the number of rotations per second to match the desired frequency (in hertz) of the AC output.

- ✓ **Rotating field method**

A rotating magnetic field is a magnetic field that has moving polarities in which its opposite poles rotate about a central point or axis. Ideally the rotation changes direction at a constant angular rate. This is a key principle in the operation of the alternating-current motor.

Content/Topic 3 Types/ classifications of single-phase generators

Portable RV/Recreational Generators: The inverter technology makes them super quiet for recreational use and also provides the cleanest power for sensitive electronics like computers. These generators run on gasoline.

Portable Residential Generators: A good choice to power essential items in your home when the power goes out (refrigerators, freezers, pumps, sump pumps, furnaces, lights, etc.) and for use around your yard (electrical tools, etc.). Most residential portable generators run on gasoline, but some models run on L.P., Natural Gas, or all three.

Portable Construction and Industrial Generators: These generators are the perfect choice for the job site and various industrial applications. Single phase gasoline or diesel models and three phase diesel models are available. High cycle generators offer 60 Hz power for standard tools and 180Hz power for high-cycle vibrators.

Mobile Towable Generators: These diesel generators provide a lot of transportable power for many industrial and construction applications. Switchable voltage models allow use with several different voltage applications. Single voltage models are for more defined single voltage applications.

Standby Generators: These stationary generators are designed to run most or all of your home or business when the power goes out. These generators are often used with an automatic transfer switch and starting system. Standby generators are also used for industrial and agricultural applications.

PTO Generators: Pair these generators with your tractor for portable power around your yard or farm.

Two Bearing Generators: These generators are powered by a variety of independent power sources using a pulley system – often used on service trucks.

Vehicle Mounted Generators: These generators are mounted on vehicles for emergency, spray foam, construction, oil field, and mining applications.

Welder Generators: Combines a generator with welding capabilities in one unit.

Alternators or synchronous generators can be classified in many ways depending upon their application and design. According to application these machines are classified as-

1. Automotive type - used in modern automobile.
2. Diesel electric locomotive type - used in diesel electric multiple units.
3. Marine type - used in marine.
4. Brush less type - used in electrical power generation plant as main source of power.
5. Radio alternators - used for low brand radio frequency transmission.

Content/Topic 4 Applications of single-phase generators

Certain applications, usually restricted to less than 10 kVA are better served by a single-phase synchronous generator. Examples are emergency, domestic/office supply, portable power for construction tools etc. Because of simplicity of distribution wiring, these loads are better served by a single-phase arrangement.

L.O.2.Identify asynchronous generators

Content/Topic 1 Construction and principle

An induction generator or asynchronous generator is a type of alternating current (AC) electrical generator that uses the principles of induction motors to produce power. Induction generators operate by mechanically turning their rotors faster than synchronous speed.

Construction

Induction machine is a rotating machine. Hence it has a stationary part and a rotary part. The stationary part is called as stator and the rotary part is called as rotor.

Stator

The stator of the induction machine is similar to that of the synchronous machine. It consists of winding housed in the slots cut in the stator.

Rotor

The two types of rotor constructions are employed for the rotor are:

1. Wound rotor.
2. Squirrel cage rotor

The rotor core is made up if laminated steel to reduce eddy current loses. It contains semi enclosed slots suitably punched over it to accommodate the rotor winding in case of wound rotor and rotor bars in case of squirrel cage rotor. The semi enclosed rotor slots increases the permeance per pole and reduces the magnetizing current.

Wound rotor.

The winding of a wound rotor are similar to the winding of the stator except that the number of slots and turns are lesser and the conductor is thicker than the stator winding. In three leads of the three phase winding are taken out through the slip rings and are connected in star. The slip rings are tapped using carbon brushes. External variable resistance can be included in the winding to reduce the starting current and improve the starting torque and to control the speed.

Squirrel cage rotor

The squirrel cage rotor has solid bars of conducting material placed in the rotor slots. These bars are permanently short circuited at the both end using end rings. In large machines alloyed copper bars with copper end rings and in small machines die cast aluminum rods and end bars are used. The squirrel cage induction motors have low starting torque. The starting torque of the motor can be increased by using double cage rotor or deep bar rotor.

The number of rotor slots is kept less than the number of stator slots to prevent magnetic locking of the rotor. The rotor teeth are skewed slightly.

Principal of operation

An induction generator produces electrical power when its rotor is turned faster than the synchronous speed. For a typical four-pole motor (two pairs of poles on stator) operating on a 60 Hz electrical grid, the synchronous speed is 1800 rotations per minute (rpm). The same four-pole motor operating on a 50 Hz grid will have a synchronous speed of 1500 RPM. The motor normally turns slightly slower than the synchronous speed; the difference between synchronous and operating speed is called "slip" and is usually expressed as per cent of the synchronous speed. For example, a motor operating at 1450 RPM that has a synchronous speed of 1500 RPM is running at a slip of +3.3%.

In normal motor operation, the stator flux rotation is faster than the rotor rotation. This causes the stator flux to induce rotor currents, which create a rotor flux with magnetic polarity opposite to stator. In this way, the rotor is dragged along behind stator flux, with the currents in the rotor induced at the slip frequency.

In generator operation, a prime mover (turbine or engine) drives the rotor above the synchronous speed (negative slip). The stator flux still induces currents in the rotor, but since the opposing rotor flux is now cutting the stator coils, an active current is produced in stator coils and the motor now operates as a generator, sending power back to the electrical grid.

Induction machine is sometimes used as a generator. It is also called Asynchronous Generator. What are the conditions when the poly phase (here three phase) induction machine will behave as an induction generator? The following are conditions when the induction machine will behave as an induction generator are written below:
(a) Slip becomes negative due to this the rotor current and rotor emf attains negative value.

(b) The prime mover torque becomes opposite to electric torque. Now let us discuss how we can achieve these conditions. Suppose that an induction machine is coupled with the prime mover whose speed can be controlled. If the speed of the prime mover is increased such that the slip becomes negative (i.e. speed of the prime mover becomes greater than the synchronous speed).

Content/Topic 2 Excitation

An induction machine requires an externally-supplied armature current. Because the rotor field always lags behind the stator field, the induction machine always "consumes" reactive power, regardless of whether it is operating as a generator or a motor.

A source of excitation current for magnetizing flux (reactive power) for the stator is still required, to induce rotor current. This can be supplied from the electrical grid or, once it starts producing power, from the generator itself.

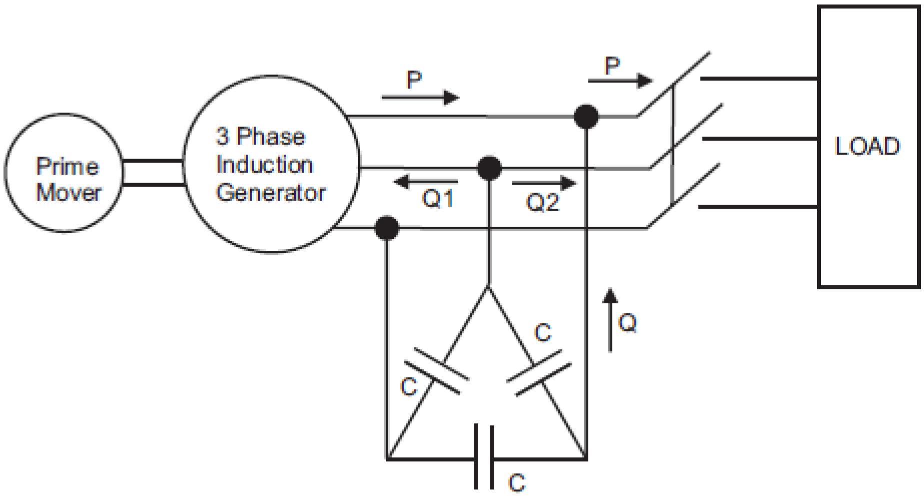
An induction machine can be started by charging the capacitors, with a DC source, while the generator is turning typically at or above generating speeds. Once the DC source is removed the capacitors will provide the magnetization current required to begin producing voltage.

An induction machine that has recently been operating may also spontaneously produce voltage and current due to residual magnetism left in the core.
Due to this, all the conditions that we have mentioned above will become fulfilled and machine will behave like an induction generator. Now if the speed of the prime mover is further increased such that it exceeds

the negative maximum value of the torque produced then the generating effect of the generator vanishes. Clearly the speed of the induction generator during the whole operation is not synchronous; therefore the induction generation is also called a synchronous generator. Induction generator is not a self-excited machine therefore in order to develop the rotating magnetic field, it requires magnetizing current and reactive power. The induction generator obtains its magnetizing current and reactive power from the various sources like the supply mains or it may be another synchronous generator. The induction generator can't work in isolation because it continuously requires reactive power from the supply system. However we can have a self-excited or isolated induction generation in one case if we will use capacitor bank for reactive power supply instead of AC supply system. (wikipedia, Induction generator, 2020)

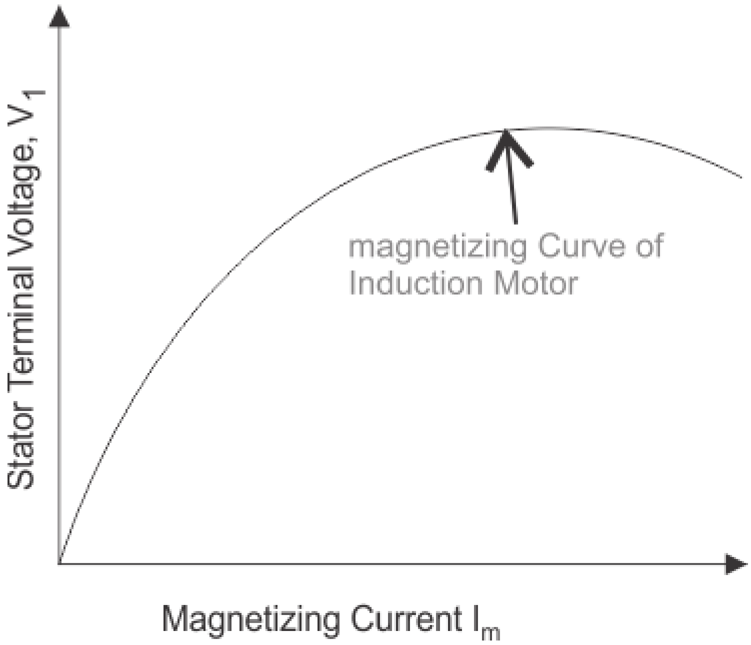
Isolated Induction Generator

This type of generator is also known as self-excited generator. Now why it is called self-excited? It is because it uses capacitor bank which is connected across its stator terminals as shown in the diagram given below.

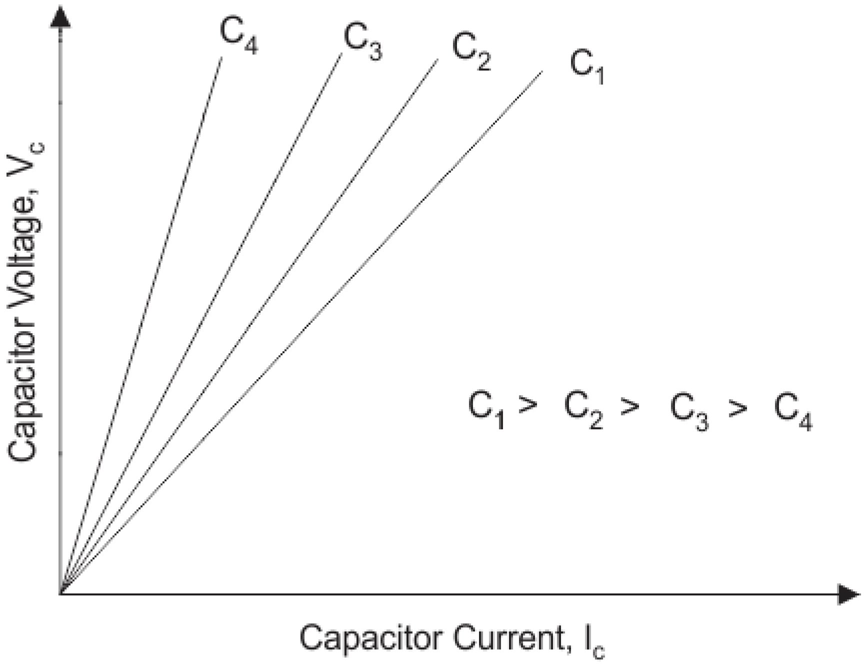


The function of the capacitor bank is to provide the lagging reactive power to the induction generator as well as load. So mathematically we can write total reactive power provided by the capacitor bank is equals to the summation of the reactive power consumed by the induction generator as well as the load. There is generation of small terminal voltage oa (as in figure given below) across the stator terminal due the residual magnetism when the rotor of the induction machine runs at the required speed. Due to this voltage oa the capacitor current ob is produced. The current bc sends current od which generates the voltage de.

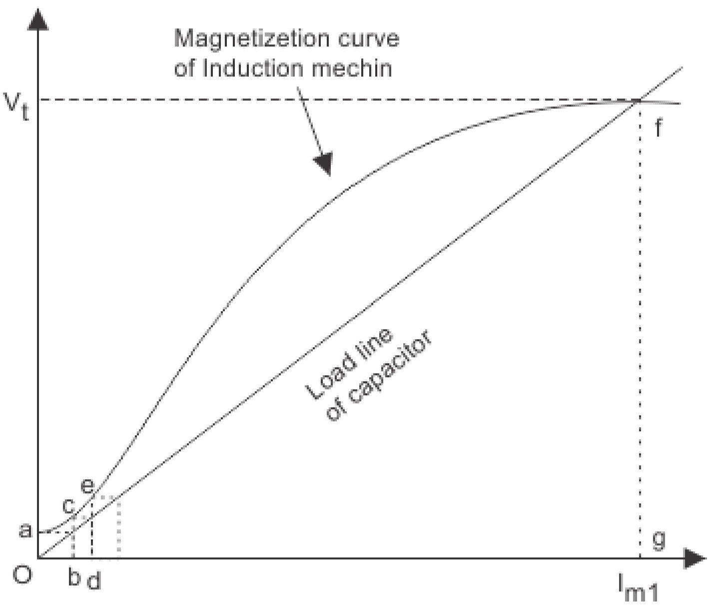
The cumulative process of voltage generation continues till the saturation curve of the induction generator cuts the capacitor load line at some point. This point is marked as f in the given curve.



Stator Terminal Voltage, V_1
magnetizing Curve of
Induction Motor
Magnetizing Current I_m



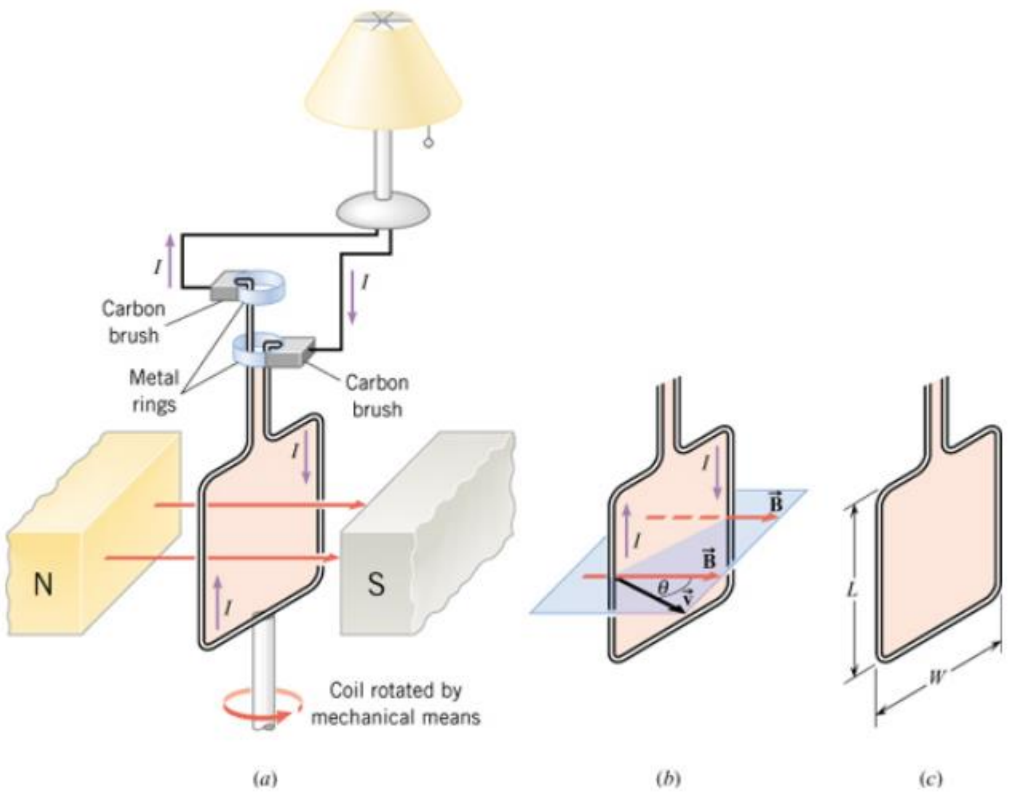
C_4
C_3
C_2
C_1
Capacitor Voltage, V_c
$C_1 > C_2 > C_3 > C_4$
Capacitor Current, I_c



Magnetizetion curve
of Induction mechin
V_t
f
Load line
of capacitor
e
c
a
g
O
b
d
I_{m1}

Content/Topic 3 E.m.f. and voltage regulation

How an electric generator produces an emf An electric generator has essentially the same configuration as an electric motor, it is just used differently, i.e



Derivation of the emf induced in a rotating planar coil

Use our motional emf equation for a straight wire Ɛ =VBL where V,B and L are all perpendicular to each other.

If the left vertical side of the spinning coil moves at velocity v the component of v perpendicular to B is v sin Ɵ so its contribution to the emf BLvsin Ɵ. Since the right vertical side contributes the same emf Ɛ=2 BLv sin Ɵ

Voltage regulation

The voltage regulation of an induction generator is defined as the change in terminal voltage from no-load to full-load (the speed and the field excitation being constant) divided by full-load voltage.

Vph<Vph

% Regulation=(Eph-Vph/Vph)x100

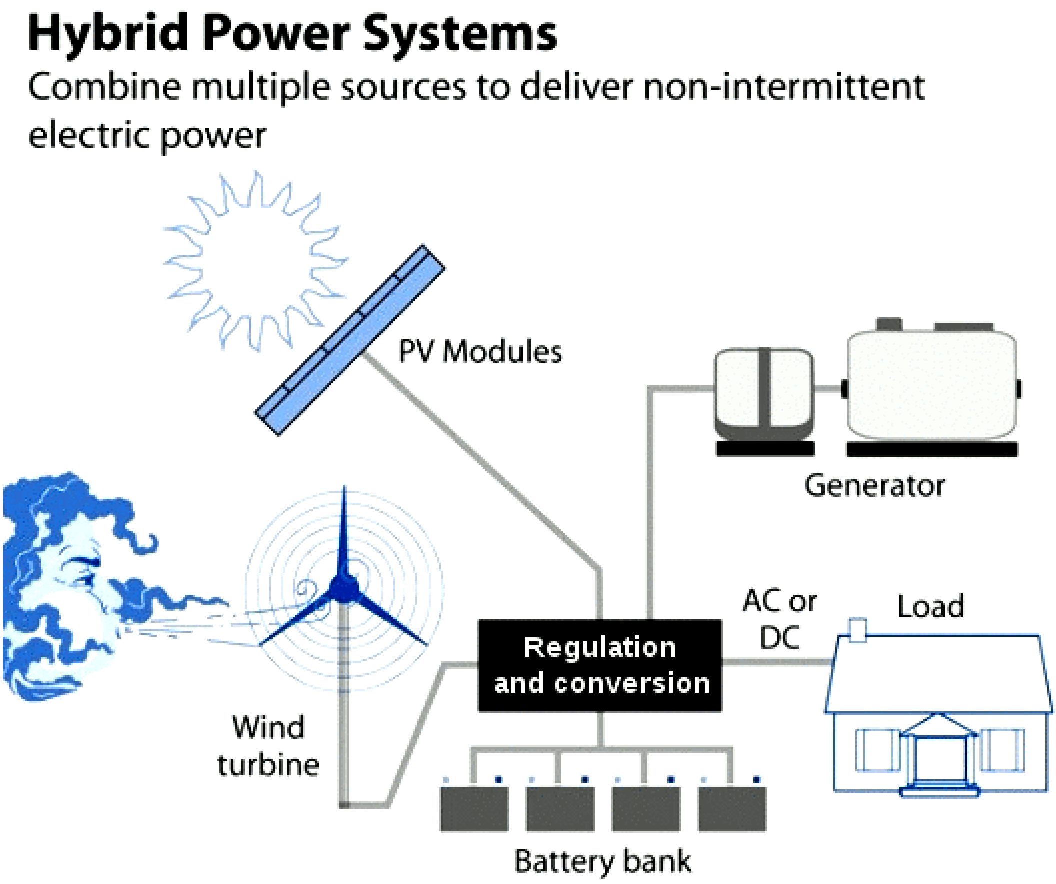
Content/Topic 4 Grid and Standalone connection

- ✓ **Standalone connection**

A stand-alone power system (SAPS or SPS), also known as remote area power supply (RAPS), is an off-the-grid ectricity system for locations that are not fitted with an electricity distribution system. Typical SAPS include one or more methods of electricity generation, energy storage, and regulation.
A diesel generator is the combination of a diesel engine with an electric generator (often an alternator) to generate electrical energy. This is a specific case of engine-generator.

- ✓ **A grid connection**

A grid-connected system allows you to power your home or small business with renewable energy during those periods (daily as well as seasonally) when the sun is shining, the water is running, or the wind is blowing. Any excess electricity you produce is fed back into the grid. When renewable resources are unavailable, electricity from the grid supplies your needs, eliminating the expense of electricity storage devices like batteries.



Content/Topic 5 Application in wind Energy

Induction generators are often used in wind turbines and some micro hydro installations due to their ability to produce useful power at varying rotor speeds. Induction generators are mechanically and electrically simpler than other generator types. They are also more rugged, requiring no brushes or commutators.

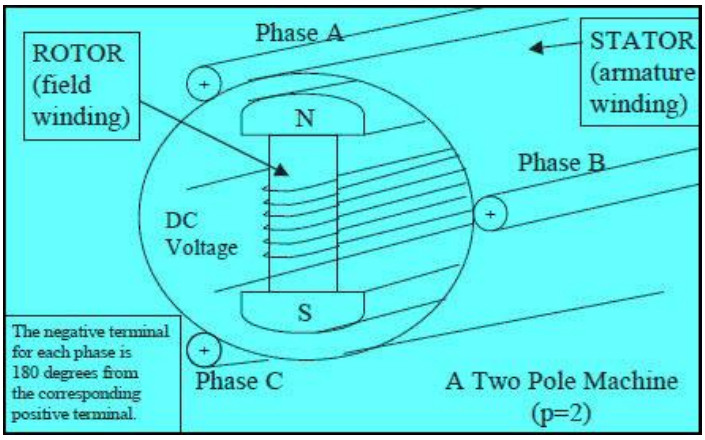
L.O.1.3.Identify Synchronous generators (alternators)

Content/Topic 1 Principle of synchronous generators

The synchronous generator or alternator is an electrical machine that converts the mechanical power from a prime mover into an AC electrical power at a particular voltage and frequency. The synchronous generator works on the principle of Faraday laws of electromagnetic induction. The electromagnetic induction states that electromotive force induced in the armature coil if it is rotating in the uniform magnetic field. The EMF will also be generated if the field rotates and the conductor becomes stationary. Thus, the relative motion between the conductor and the field induces the EMF in the conductor. The wave shape of the induces voltage always a sinusoidal curve.

Content/Topic 2 Details of Construction of alternators

In general, synchronous generator consists of two parts rotor and stator. The rotor part consists of field poles and stator part consists of armature conductors. The rotation of field poles in the presence of armature conductors induces an alternating voltage which results in electrical power generation.



Construction of Synchronous Generator

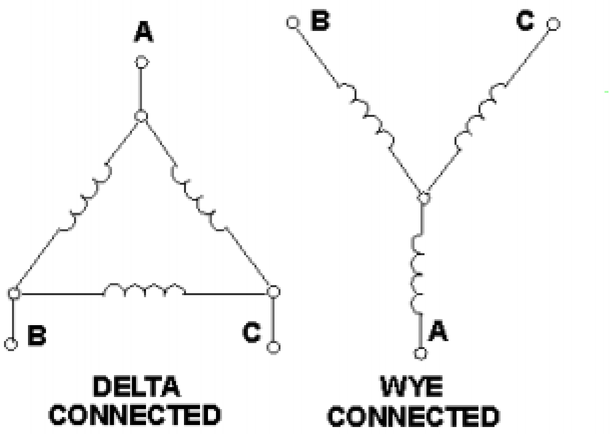
The speed of field poles is synchronous speed and is given by

$$N_s = \frac{120f}{P}$$

Where, ‘f’ indicates alternating current frequency and ‘P’ indicates number of poles.(Electronics/Project/Focus, 2020)

Content/Topic 3 Connection of stator windings

The stator coils of three-phase alternators may be joined together in either Wye or Delta connections, as shown in figure below. With these connections only three wires come out of the alternator. This allows convenient connection to three-phase motors or power distribution transformers. It is necessary to use three-phase transformers or their electrical equivalent with this type of system.



Content/Topic 4 E.m.f. equation

We know that Synchronous Generator or Alternator will generate an EMF. The following is the derivation of emf equation of Synchronous Generator or Alternator.

Let Φ = Flux per pole, in Wb

P = Number of poles

N = Synchronous speed in r.p.m

f = Frequency of induced emf in Hz

Z = Total number of conductors

Z_{ph} = Conductors per phase connected in series

$Z_{ph} = Z/3$ as number of phases = 3

Consider a single conductor placed in a slot.

The average value of emf induced in a conductor = $d\Phi/dt$

For one revolution of a conductor,

Eavg per conductor = (Flux cut in one revolution/Time taken for one revolution)

Total flux cut in one revolution is Φxp

Time taken for one revolution is 60/Ns seconds.

$$\therefore \quad e_{avg} \text{ per conductor} = \frac{\phi P}{\left(\frac{60}{N_s}\right)} = \phi \frac{PN_s}{60}$$

$$\text{But} \qquad f = \frac{PN_s}{120}$$

$$\therefore \qquad \frac{PN_s}{60} = 2f$$

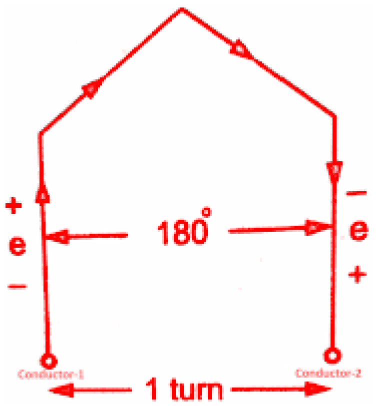
Substituting in above equation

Eavg per conductor = 2 f Φ volts

Assume full pitch winding for simplicity i.e. this conductor is connected to a conductor which is 180° electrical apart. So these two emf's will try to set up a current in the same direction i.e. the two emf are helping each other and hence resultant emf per turn will be twice the emf induced in a conductor.

emf per turn = 2 x (emf per conductor) = 2 x (2 f Φ)

= 4 f Φ volts.



Turn of full pitch coil

Let Tph be the total number of turns per phase connected in series. Assuming concentrated winding, we can say that a are placed in single slot per pole per phase (So induced emf's in all turns will be in phase as placed in a single slot. Hence net emf per phase will be algebraic sum of the emf's per turn.

Average Eph = Tph x (Average emf per turn)

Average Eph = Tph x 4 f Φ

But in ac circuits, RMS value of an alternating quantity is used for the analysis. The form factor is 1.11 of sinusoidal emf.

Content/Topic 5 Voltage regulation

The voltage regulation of an induction generator is defined as the change in terminal voltage from no-load to full-load (the speed and the field excitation being constant) divided by full-load voltage.

Vph<Eph

% Regulation=(Eph-Vph/Vph)x100

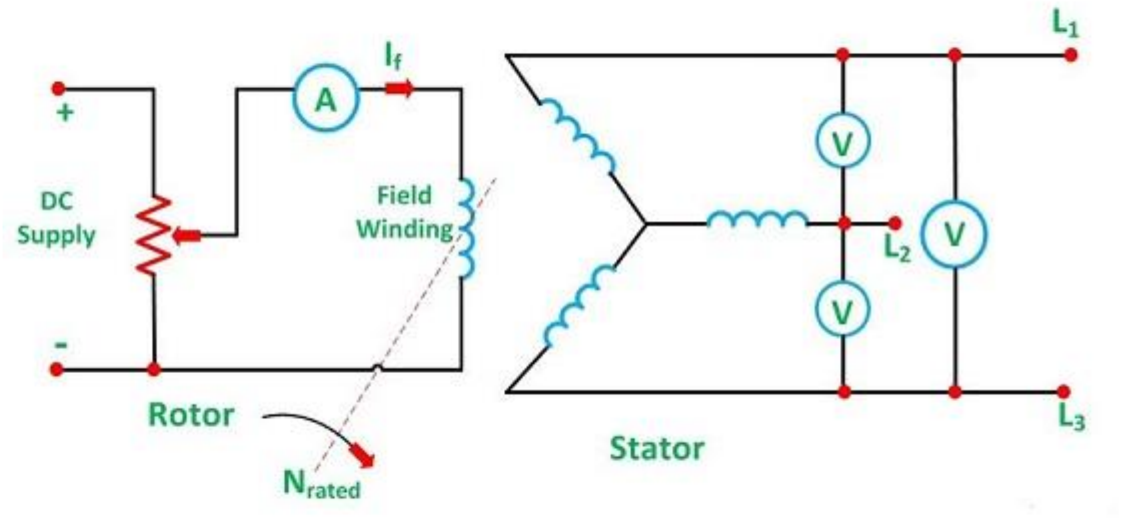
Content/Topic 6 Armature reaction of alternators

The effect of Armature (stator) flux on the flux produced by the rotor field poles is called Armature Reaction. When the current flows through the armature winding of an alternator, a flux is produced by the resulting MMF. This armature flux reacts with the main pole flux, causing the resultant flux to become either less than or more than the original main field flux.(globe, 2020)

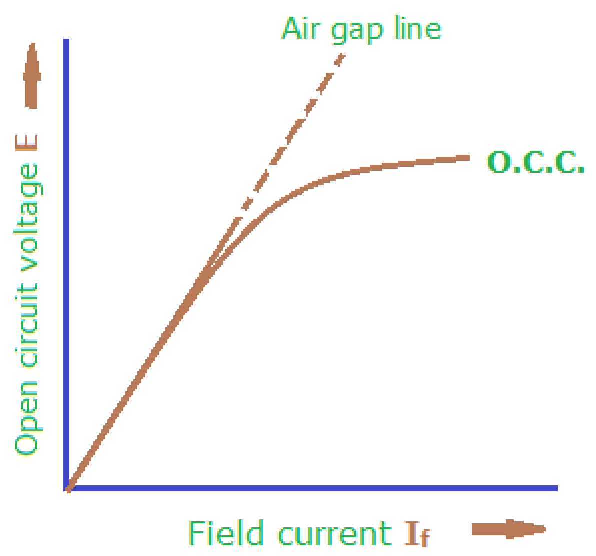
L.O.3.4 Apply electrical and mechanical characteristics

Content/Topic 1 Open-circuit Characteristics

The alternator is run at rated synchronous speed and the load terminals are kept open. That is, all the loads are disconnected. The field current is set to zero; this condition is called open circuit test condition.



The field current is gradually increase in steps, and the terminal voltage Et is measure at each step, The excitation current may be increased to get 25% more than rated voltage of the alternator. A graph is plotted between the open circuit test voltage Ep and field excitation current If.

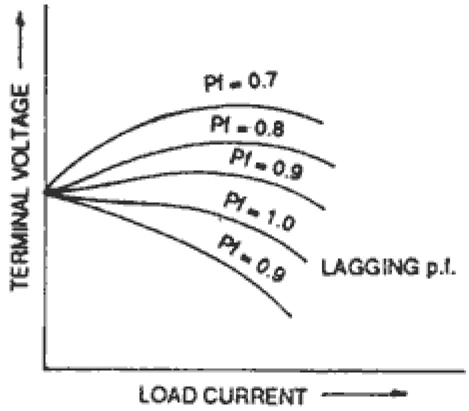


The characteristic curve so obtain is called open circuit characteristic (O.C.C.). It takes the shape of a normal magnetization curve. The extension of linear portion of an O.C.C. is called the air gap line are show in figure above. (notes, 2017)

Content/Topic 2 On-Load Characteristics

While the exciting current and the speed remain constant, the terminal voltage changes with the load current in the armature and the relationship between the terminal voltage and load current of an alternator is known as its load characteristics.
When the armature current increases, the terminal voltage drops. This is mainly due to

- Resistance and reactance of armature winding, and
- Armature reaction.



Content/Topic 3 Power flow chart and efficiency

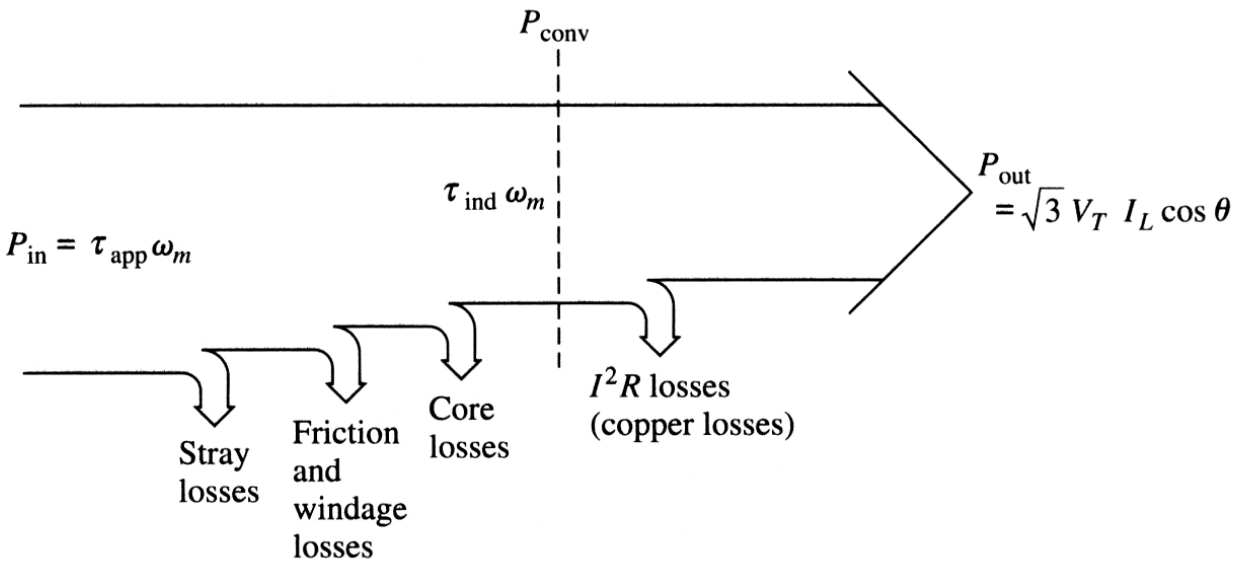
A synchronous generator needs to be connected to a prime mover whose speed is reasonably constant (to ensure constant frequency of the generated voltage) for various loads.
The applied mechanical power

$$P_{in} = \tau_{app}\omega_m$$

is partially converted to electricity

$$P_{conv} = \tau_{ind}\omega_m = 3E_A I_A \cos\gamma$$

Where γ is the angle between EA and IA.
The power-flow diagram of a synchronous generator.



Then the real output power of the synchronous generator can be approximated as

$$P_{out} \approx \frac{3V_{\phi}E_A \sin\delta}{X_S}$$

We observe that electrical losses are assumed to be zero since the resistance is neglected. Therefore:

$$P_{conv} \approx P_{out}$$

Here δ is the power angle of the machine – the angle between V_{ϕ} and E_A. This is Different from the power factor angle/

The maximum power can be supplied by the generator when $\delta = 90^0$:

$$P_{\max} = \frac{3V_{\phi}E_A}{X_S}$$

Generator P-f Curve

•All generators are driven by a prime mover, such as a steam, gas, water, wind turbines, diesel engines, etc.

•Regardless the power source, most of prime movers tend to slow down with increasing the load.

•The speed drop (SD) of a prime mover is defined as:

$$SD = \frac{n_{nl} - n_{fl}}{n_{fl}} \cdot 100\%$$

•Most prime movers have a speed drop from 2% to 4%. Most governors have a mechanism to adjust the turbine's no-load speed (set-point adjustment).

Types of Losses in Synchronous Machines

The losses in the synchronous machine are similar to those of the transformer and other types of rotating machines. Like all electrical machines, synchronous machines have copper, steel, rotational, and stray losses. Whether the machine operates as a motor or as a generator, the losses can be summed as

$P_{loss}=P_{scl}+P_{rl}+P_{fw}+P_{core}+P_{stray}$ (2)

Where

P_{scl} = the copper loss in the stator (armature) windings

P_{ri} = losses in the rotor, which includes the copper losses of the field windings, the losses in the excitation system, and copper losses in the damper windings

P_{fw} = friction and windage losses

P_{core} = hysteresis and eddy current losses, primarily in the stator iron

P_{stray} = stray losses not otherwise accounted for in the calculation of the other losses

Copper Losses

Copper losses are found in all the windings in the machine. By convention, they are computed using the DC resistance of the winding at 75°C. The actual resistance depends on the operating frequency and flux conditions. Any difference between the actual and computed copper loss is accounted for under the stray loss category. Brush losses for machines with slip rings are normally neglected and accounted for under the stray loss category.

Mechanical Losses

The mechanical or friction and windage losses are due to the friction in the bearings and the energy that is dissipated in turning the rotor through the air inside the machine.

The rotational losses can be determined by driving the machine at rated speed with no load or excitation. Rotational losses are frequently lumped with core loss and determined at the same time.

Open-Circuit or No-Load Core Losses

The core loss due to hysteresis and eddy currents is measured at no load, and when combined with the mechanical losses, they constitute the no-load rotational loss. The difference between the measured and actual core loss is put in the stray loss category.

Stray Loss

Stray losses include the difference between the actual losses and their calculated values, as well as losses that are not specifically calculated, such as the brush conta

Learning unit 4 Run electrical generators

L.O.4.1 Use of safety equipment

Content/Topic 1 Review on PPE

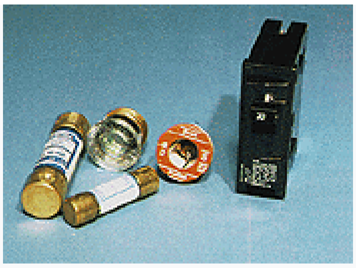
Overcoat and overall
Gloves
Safety shoes
Helmet
Earmuff
Goggles
Nose protection mask (respirators)
Cleaning cloth / brush

Content/Topic 2 Generators protection equipment

- ✓ **Overload protection equipment**

Every electric circuit in a wiring system must be protected against overloads. A circuit overload occurs when the amount of current flowing through the circuit exceeds the rating of the protective devices.

The amount of current flowing in a circuit is determined by the load -- or the "demand" -- for current. For example, if a circuit is rated for 15 amps maximum, then a fuse or circuit breaker of that rating will be in that circuit. If the current exceeds 15 amps, the circuit breaker will open up, cutting off any more current flow. Without overload protection wires can get hot, or even melt the insulation and start a fire.There are two kinds of protection for electrical units that need to be considered. The first is concerned with the protection of the actual electrical wires supplying the circuits against an overload above their carrying capacity. The second type is concerned with protecting the individual appliances and electrical equipment connected to a supply circuit from an overload. Both types of protection involve either fuses or breakers, but are based on different ideas and objectives.



- ✓ **Short-circuit current protection equipment**

A common example of short-circuit is when positive and negative terminal of a battery are connected together with a low-resistance conductor, like a wire. In this condition, battery can set to fire and can even explode. That’s what happens with mobile batteries in mobiles at many times.
To avoid this short circuit condition, Short-circuit Protection Circuit is used. Short-circuit Protection Circuit will divert the flow of current or break the contact between the circuit and the power source.

Sometimes we experience power failure with a sudden spark while using some faulty home appliances like oven, iron, etc, then. The reason behind this is that, somewhere there is some excess current flows through some circuit inside that faulty appliance. This may lead to shock or could fire up the house if not protected. So a fuse or circuit breaker is used in order to avoid such damage. In such condition circuit breaker or fuse disconnects the main supply to the house. A fuse breaker circuit is also a form of short-circuit protection circuit, in which a low resistance wire is used which melts and disconnects the main power supply to house whenever there is excess current pass through it.

- ✓ **Grounding system**

The grounding system is a backup pathway that has an alternate route for an electrical current to flow to ground due to any risk in the electrical system before it gets a fire or shock.
Simply, "grounding" means a low-resistance path has been made for electricity to flow into the ground. A "grounded" connection includes a connection between the electrical equipment and a ground through a wire. Once wired properly, this provides your devices and appliances a secure place to discharge excess electrical current. This will potentially prevent electrical equipment from several risks. The ground wire in an electric outlet is basically a safety valve.

Emergency Stop Switches (E-Stops)

An emergency stop switch, also known as E-stop switch, E stop switch, emergency switch, kill switch, or emergency button, emergency stop push button switch, it is a fail-safe control switch that provides safety for the machinery and for the person using the machinery.

L.O.4.2 Use of switching devices

Content/Topic 1 Different switching Devises

1. **Transfer switch (changer over)**

A transfer switch is an electrical switch that switches a load between two sources. Some transfer switches are manual, in that an operator effects the transfer by throwing a switch, while others are automatic and trigger when they sense one of the sources has lost or gained power.
An Automatic Transfer Switch (ATS) is often installed where a backup generator is located, so that the generator may provide temporary electrical power if the utility source fails.

As well as transferring the load to the backup generator, an ATS may also command the backup generator to start, based on the voltage monitored on the primary supply. The transfer switch isolates the backup generator from the electric utility when the generator is on and providing temporary power.

For example, in a home equipped with a backup generator and an ATS, when an electric utility outage occurs, the ATS will tell the backup generator to start. Once the ATS sees that the generator is ready to provide electric power, the ATS breaks the home's connection to the electric utility and connects the generator to the home's main electrical panel. The generator supplies power to the home's electric load, but is not connected to the electric utility lines. It is necessary to isolate the generator from the distribution system to protect the generator from overload in powering loads in the house and for safety, as utility workers expect the lines to be dead.

Interlock devices

An interlock is a feature that makes the state of two mechanisms or functions mutually dependent. It may be used to prevent undesired states in a finite-state machine, and may consist of any electrical, electronic, or mechanical devices or systems. In most applications, an interlock is used to help prevent a machine from harming its operator or damaging itself by preventing one element from changing state due to the state of another element, and vice versa. Elevators are equipped with an interlock that prevents the moving elevator from opening its doors, and prevents the stationary elevator (with open doors) from moving

Contactor

A contactor is an electrically-controlled switch used for switching an electrical power circuit.A contactor is typically controlled by a circuit which has a much lower power level than the switched circuit, such as a 24-volt coil electromagnet controlling a 230-volt motor switch.

Contactors come in many forms with varying capacities and features. Unlike a circuit breaker, a contactor is not intended to interrupt a short circuit current. Contactors range from those having a breaking current of several amperes to thousands of amperes and 24 V DC to many kilovolts.

A contactor has three components. The contacts are the current carrying part of the contactor. This includes power contacts, auxiliary contacts, and contact springs. The electromagnet (or "coil") provides the driving force to close the contacts. The enclosure is a frame housing the contacts and the electromagnet.(wikipedia, Contactor, 2020)

Push button

A push-button (also spelled pushbutton) or simply button is a simple switch mechanism for controlling some aspect of a machine or a process. Buttons are typically made out of hard material, usually plastic or metal.[1] The surface is usually flat or shaped to accommodate the human finger or hand, so as to be easily depressed or pushed.

A Push Button is a type of switch work on a simple mechanism called “Push-to-make”. Initially, it remains in off state or normally open state but when it is pressed, it allows the current to pass through it or we can say it makes the circuit when pressed. Normally their body is made up of plastic or metal in some types.

Push Button structure has four legs, two on one side and other two on another side. So, we can operate two lines of the circuit by single Push Button. Two legs on both the sides are internally connected.

Circuit breaker

A circuit breaker is an automatically operated electrical switch designed to protect an electrical circuit from damage caused by excess current from an overload or short circuit. Its basic function is to interrupt current flow after a fault is detected. Unlike a fuse, which operates once and then must be replaced, a circuit breaker can be reset (either manually or automatically) to resume normal operation.

Circuit breakers are made in varying sizes, from small devices that protect low-current circuits or individual household appliance, up to large switchgear designed to protect high voltage circuits feeding an entire city. The generic function of a circuit breaker, RCD or a fuse, as an automatic means of removing power from a faulty system is often abbreviated as OCPD (Over Current Protection Device).(wikipedia, Circuit breaker, 2020)

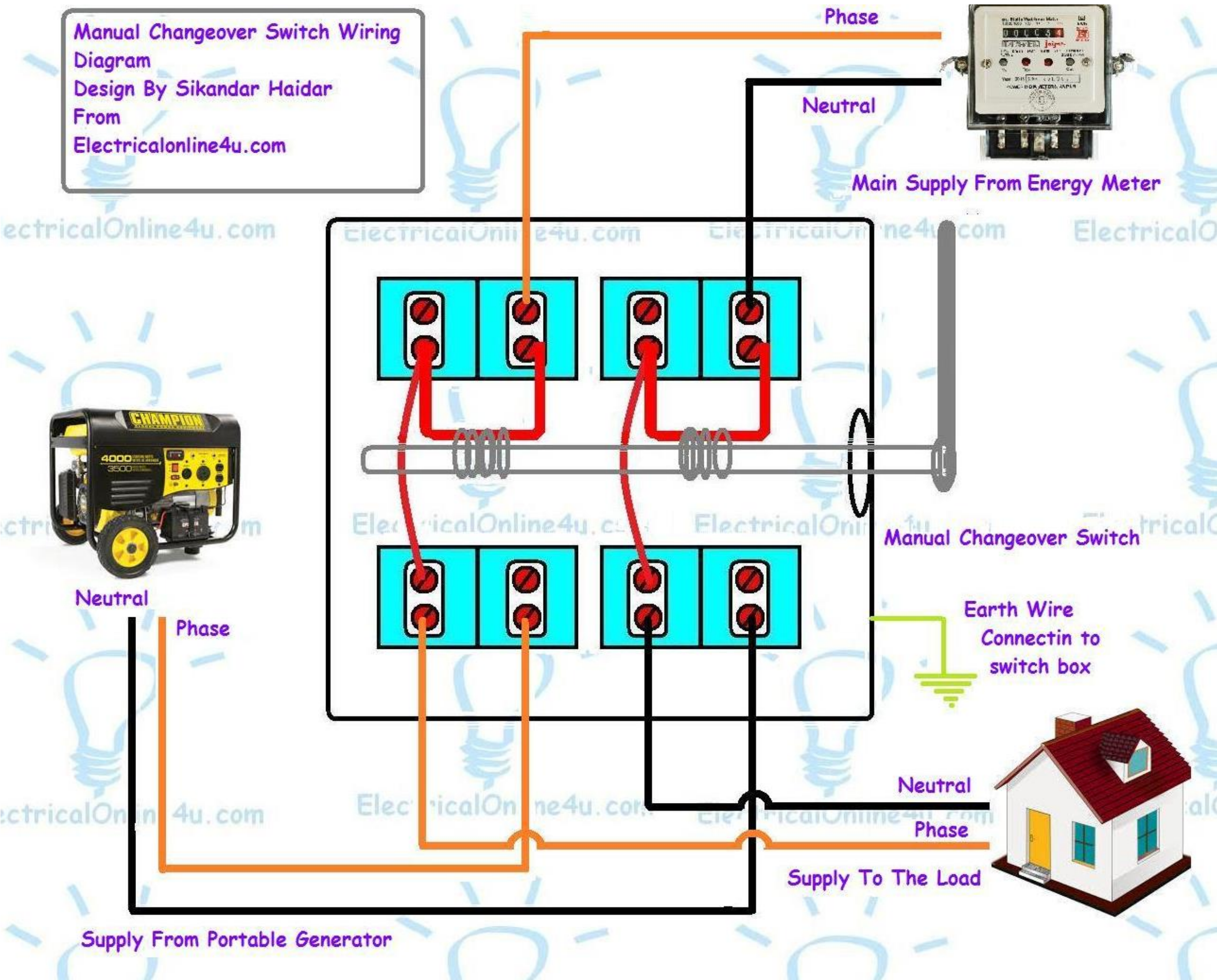
Content/Topic 2Function and connection of switching devices

Function of Transfer switch

-A changeover or transfer switch is designed to transfer a house (or business) electricity from the commercial power grid to a local generator when an outage occurs. Also known as “transfer switches,”

-they connect directly to the generator, commercial power supply or line, and the house. When the homeowner or business owner experiences a power outage, he or she can switch over to the generator via a changeover switch.

-It is mostly used in domestic and industrial level, to auto switch power supply from Generator to Mains and vice-versa.

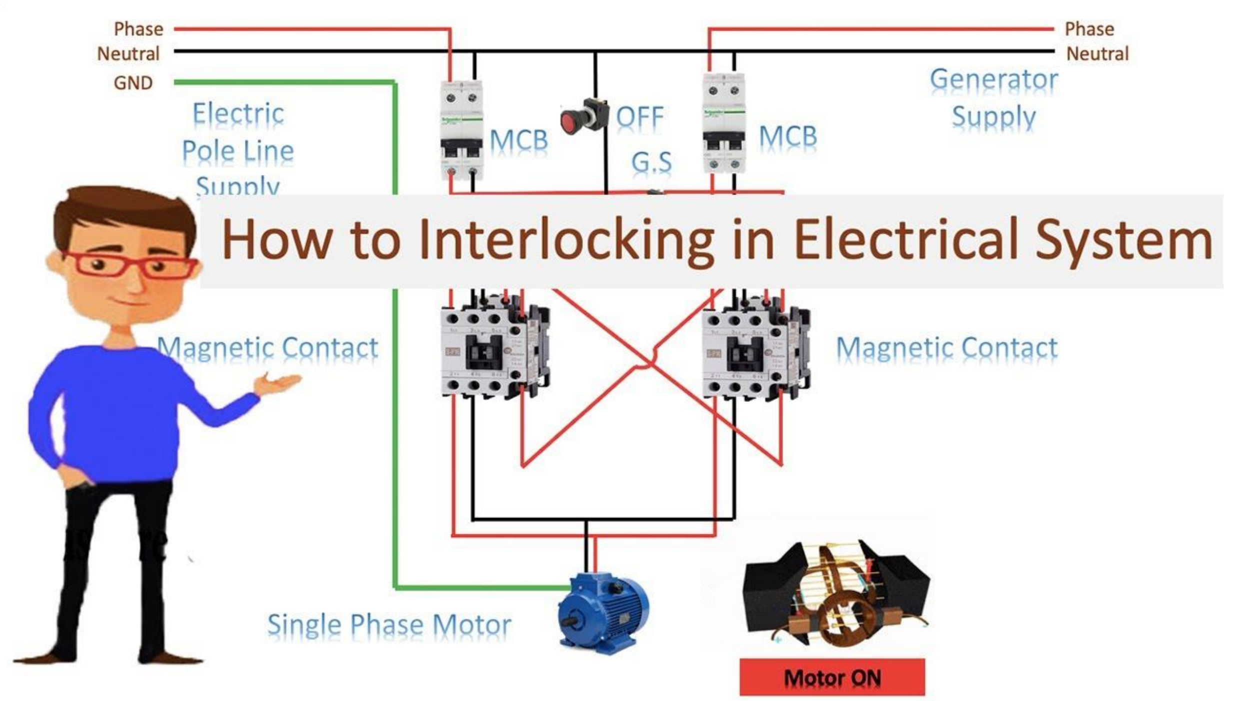


(pinterest, 2020)

Function of Interlock

An interlock device is designed to allow a generator to provide backup power in such a way that it (a) prevents main and generator power to be connected at the same time,

(b)allows circuit breakers to operate normally without interference in the event of any overload condition. Most interlock devices for electrical systems employ a mechanical device to manage movement of circuit breakers. Some also allow for the use of padlocks to prevent someone from accidentally activating the main power system without authorization.

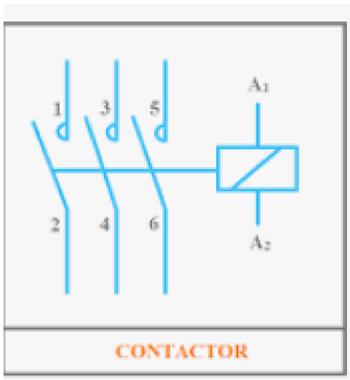


(Bondhon, 2019)

Function of contactor

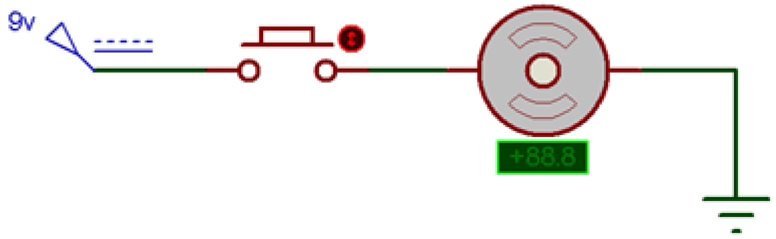
When electric current pass through the contactor, it causes the electromagnet to create a strong magnetic field. This magnetic field pulls the armature into the coil, and this creates an electrical arc. Electric currents flow in through one contact and into the device in which the contactor is embedded. Therefore, the function of the contactor is to switch an electrical circuit on or off. Overloading of the circuit can be prevented by adding an thermal overload relay.

To deactivate, the contactor can be pulled out of the parent device in which it's embedded and operating. In the absence of electric current flowing through, the spring pushes the armature, thus breaking the connection.



Push button

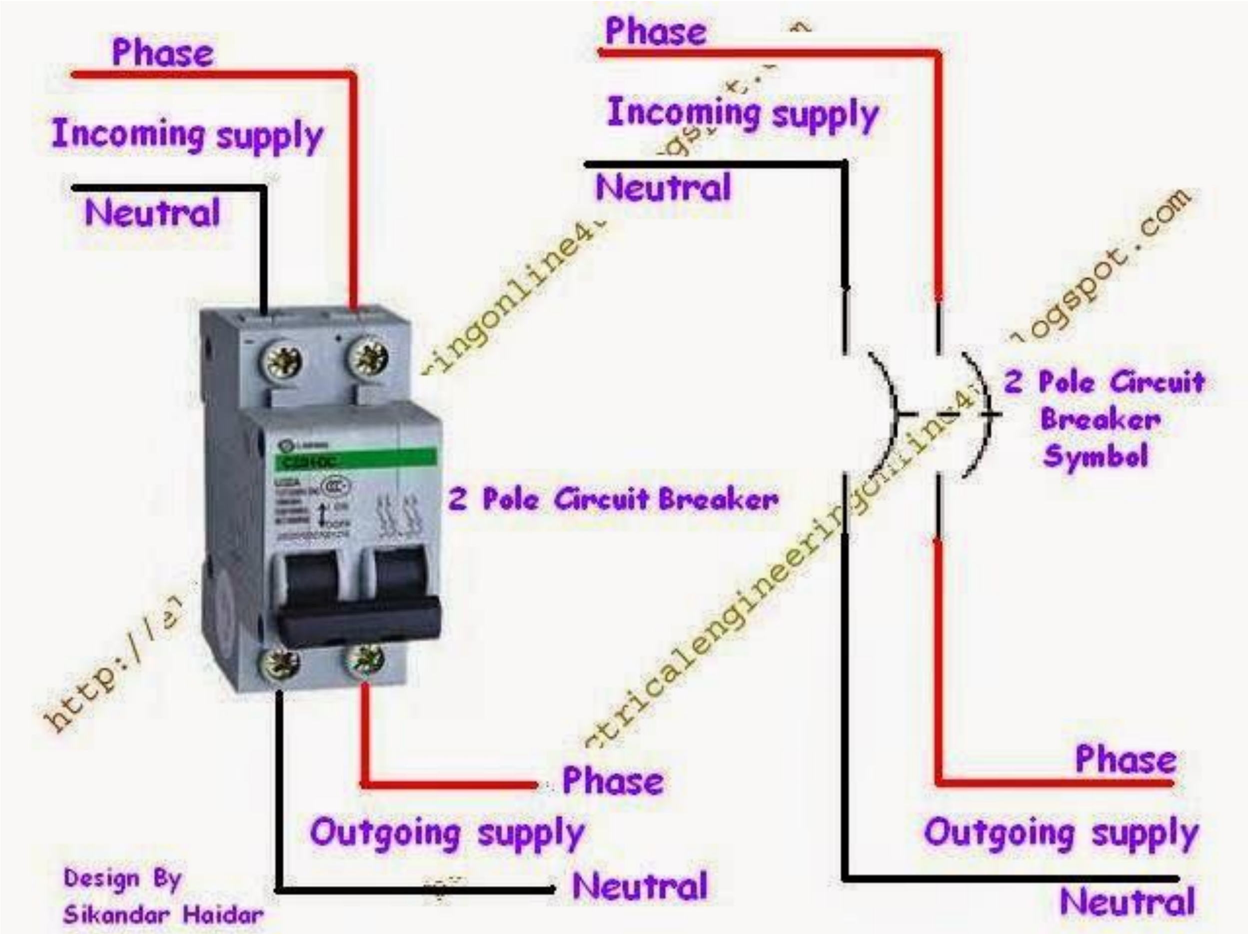
Push-Buttons are normally-open tactile switches. Push buttons allow us to power the circuit or make any particular connection only when we press the button. Simply, it makes the circuit connected when pressed and breaks when released. A push button is also used for triggering of the SCR by gate terminal. These are the most common buttons which we see in our daily life electronic equipments



(components101, 2020)

Circuit breaker

1. It breaks down the total power available in your house into smaller amounts for specific loads in your house.
2. It protects each circuit from power overload.
3. It allows shutting off power it controls so you don't have to shut off power to your whole house while making repairs or working on something connected to that circuit.
4. They are better than fuses because they are resettable.
5. They can save your life and the life of your loved ones.



L.O 4.3: Apply running procedures in electrical generators

<u>Content/Topic 1 : Installation procedures of a generator</u>

- ✓ **Preparation of the installation Area**

DO NOT locate the generator set near patios, decks, play areas, or animal shelters. Keep items such as lawn furniture, toys, sports equipment, and all combustible materials away from the generator set exhaust outlet. Remind family members, children, and visitors to use caution near the generator set. Generator sets connected to automatic transfer switches start automatically during exercise periods and power outages. Some generator set components become hot when the generator set is running and remain hot for a time after the generator set shuts down.

- ✓ **Load estimation (Diversity factor, utilization factor)**
- **Diversity factor**. Diversity factor is the ratio of the sum of the individual maximum demands of the various subdivisions of a system (or part of a system) to the maximum demand of the whole system (or part of the system) under consideration. Diversity is usually more than one.
- **The utilization factor** or use factor is the ratio of the time that a piece of equipment is in use to the total time that it could be in use. It is often averaged over time in the definition such that the ratio becomes the amount of energy used divided by the maximum possible to be used.

The ratio of the maximum demand on a generator or generating station to the capacity of the generators

- ✓ **Wiring of generator**

Steps for Wiring & Installation of a Generator By using Manual Transfer or Changeover Switch

To connect a portable generator to the home electric supply system by manual changeover switch, follow the steps below:

1. Install a Changeover switch (about 63-100A depends on the load) near main distribution board in the home.
2. Connect the main power supply (Line and Neutral) as incoming to the first upper slots of Changeover Switch as shown in fig.
3. Connect a 6 AWG (7/064" or 16mm^2)" cable wire to the lower two slots of Changeover switch.
4. Now connect a 3-pin power socket to the 6AVG wire and install onto the wall (near to the generator) and put the generator 3-pin power plug into the power socket which you have installed before.
5. You have done and ready to supply emergency electric power to the home appliances in case of emergency power blackout.(technology, 2013)

Content/Topic 2: Starting and shutting-down procedures

Pre-requisite conditions(check oil level, fuel level, coolant, wiring,battery,load)

When the generator is ready for start-up and load manufacturer's recommendations must be followed for the unit. Remove all tags and locks from equipment installed during connection. Permanent units are shipped without fluids, while mobile units can be shipped with all fluids.

Basic rule of thumb checks for start-up operations for mobile units are:

1. Verify all electrical connections are correctly connected and tight.
2. Check fuel, oil and coolant levels. Verify air filter indicator is in green and operable.
3. Start engine and check for fuel, oil, exhaust leaks and louver operation.
4. Make sure no engine or generator alarms exist.
5. Load generator set and make sure all operating parameters are correct.

Automatic Start procedure

1. This method is only possible if sufficient amount of starting air is available. The air valves and interlocks are operated like in the turning gear operation.
2. In this method the operator has nothing to do, for the generator starts itself depending on the load requirement.
3. However during the Maneuvering process and in restricted areas, the operator has to start by going into the computer based Power Management System (pms). Once inside the system, the operator needs to go to the generator page and click start.
4. In PMS system, the automation follows sequence of starting, matching voltage and frequency of the incoming generator and the generator comes on load automatically.
5. In case of a blackout condition or a dead ship condition, the operator might have to start the generator manually.

Manual start procedure

The manual process is totally different from the automatic start system. The following steps need to be followed:

1. Check that all the necessary valves and lines are open and no interlock is active on the generator before operating.
2. Generally before starting the generator the indicator cocks are opened and small air kick is given with the help of the starting lever. After this, the lever is brought back to the zero position, which ensures there is no water leakage in the generator. The leakage can be from cylinder head, liner or from the turbocharger.
3. The step is performed by putting the control to local position and then the generator is started locally.
4. In case any water leakage is found, it is to be reported to a senior officer or chief engineer and further actions are to be taken.
5. It is to note that this manual starting procedure is not followed generally on Ums ships, but it is a common procedure on manned engine room.
6. In engine rooms, which have water mist firefighting system installed, this procedure is not followed because when the engine is given a manual kick with open indicator cocks, small amount of smoke comes out of the heads which can lead to false fire alarm, resulting in release of water mist in the specified area.
7. After checking the leakage, in case of any, the indicator cocks are closed and generator is started again from the local panel.
8. The generator is then allowed to run on zero or no load condition for some time for about 5 minutes.
9. After this the generator control is put to the remote mode.
10. If the automation of the ship is in working after putting in remote mode the generator will come on load automatically after checking voltage and frequency parameters.
11. If this doesn't happen automatically, then one has to go to the generator panel in Engine control room and check the parameters.
12. The parameters checked are voltage and the frequency of the incoming generator.

13. The frequency can be increased or decreased by the frequency controller or governor control on the panel.
14. The incoming generator is checked in synchroscope to see if it's running fast or slow, which means if frequency is high or low.
15. In synchroscope, it is checked that the needle moves in clockwise and anticlockwise direction.
16. Clockwise direction means it is running fast and anti-clockwise means it is running slow.
17. Generally the breaker is pressed when the needle moves in clockwise direction very slowly and when it comes in 11'o clock position.
18. This process is to be done in supervision of experienced officer if someone is doing for the first time, for if this is done incorrectly the blackout can happen which can lead to accidents, if the ship is operating in restricted areas.
19. Once this is done, the generator load will be shared almost equally by the number of generators running.
20. After this the parameters of the generator are checked for any abnormalities.

Automatic stopping Procedure

In this procedure the generator is stopped by going into the PMS system in the computer and pressing the stop button to bring stop the generator.

1. This is to be followed only when two or more generators are running.
2. Even if you trying to stop the only running generator it will not stop due to inbuilt safety. The safety system thus prevents a blackout.
3. When the stop button is pressed the load is gradually reduced by the PMS and after following the procedure the generator is stopped.

Manual stopping procedure

1. In this procedure the generator to be stopped, is put off load from the generator panel in the Engine control room.
2. The load is reduced slowly by the governor control on the panel.
3. The load is reduced until the load comes on the panel below 100 kw.
4. When the load is below 100kw the breaker is pressed and the generator is taken off-load.
5. The generator is allowed to run for 5 minutes in idle condition and the stop button is pressed on the panel.
6. The generator is then stopped.

L.O. 4.4 Monitor electrical generators

Content/Topic1 Generator Control Panel

A generator control panel is a display parameter that presents various details and parameters, such as current, voltage, and frequency. While some control panels have built-in displays so that operators could visually review a generator's function, many other control panels have meters and gauges that will display information.

Whether the control panel has a built-in display, meters, or gauges, they are usually constructed in a metal weatherproof housing and mounted on the generator, along with vibration proof padding to help insulate the control panel from shocks.

Larger commercial generators (industrial grade generators and high voltage commercial generators) generally have control panels that are detached from the generator itself due to their size. Control panels that are fitted for these generators are usually able to be standalone, wall-mounted, or shelf-mounted due to shear weight and size.

Generator control panels also have buttons and switches that help ensure operation of the generator. In addition to having the on/off switch, generator control panels have buttons that allow the generator operator to program specific functions or to monitor specific parameters. Generally, all switches and gauges are clustered together and grouped by functionality. This makes the generator control panel user friendly and safe for operational use, as it can help minimize the chances of a generator operator from accidentally hitting the wrong control in the event of an emergency.(power, 2020)

- ✓ **On/Off buttons Meter panels(Voltmeter,ammeter,frequency-meter)**

MAIN COMPONENTS
1. Analogue voltmeter
2. Analogue ammeter
3. Analogue frequency meter
4. M6 control unit
5. Alert light
6. Running hours counter
7. Voltage level selector
8. Fuses
9. Differential relay
10. Circuit breaker protection
11. Emergency stop

Content/Topic 2Voltage and frequency control

Diesel generator frequency is the Electrical frequency, measured in Hertz (Hz), which describes the number of times that the current alternates, or changes direction, each second. This can be seen in an alternating current sine wave graph on an oscilloscope display, each complete wave being caused by one complete rotation of the magnets. For example, if a complete sine wave is completed 50 times every second, then the frequency is 50 Hz. The higher the frequency, the more cycles are competed per second.

A generator that is continuously running should have a frequency that matches the required frequency of the appliances that it supplies. A standby generator's frequency should equal the mains frequency, which is 50 Hz in Europe, Asia and most other countries, and 60 Hz in the Americas and a few other countries. Power Continuity have a generator power calculator in the Apple App store, free to download and use to work out your power frequencies.

Large AC generators commonly use a combination Exciter-Voltage Regulation system to maintain generator field current under varying electrical loads. The basic voltage regulation system is designed to automatically regulate generator output terminal voltage within close tolerances of a specified value. The generic regulation system is a 'closed loop' feedback system in which generator output voltage is automatically compared to a reference voltage.

Content/Topic 3 Reactive power control for AC Generators

Most electrical systems that undergo changes of voltage or current have either capacitance or inductance. In a DC system, these are only important during a significant change. Because AC power is continually changing (the voltage is sinusoidal), the inductance and/or capacitance become more important. Electrical power is needed in AC machinery (motors, generators, and transformers) to create the magnetic fields and voltage induction that enable these machines to operate. This 'magnetizing' power, which is 'stored' energy in the AC system, is reactive power. The current component of this power acts at 90 degrees from the real power (KW). Reactive power is measured in volt-amperes-reactive or VARs. For high voltage systems, reactive power may be measured in kilo-VARs or mega-VARs

Content/Topic 4 Fuel monitoring

Fuel monitoring solution to prevent fuel losses and minimize your operations cost. Organizations are starting to focus on optimizing their overall operational cost. As we know, since fuel cost is one of the major operational costs, there is always a leakage of cost in this area. It may be due to inefficient diesel generators, thefts and lack of insight/data on how to optimize

Content/Topic 5 Cooling system monitoring

The purpose of the engine cooling system is to dissipate heat generated by the combustion of fuel within the engine and maintain a favorable operating temperature to prevent damage and enhance engine efficiencies.

You wouldn't change your oil without changing the oil filter, so why is it ok to put in a new radiator or add coolant and not replace the radiator cap and thermostat. Radiator caps and thermostats are essential for a properly functioning cooling system. They are two components that monitor the system parameters and adjust to maintain desired conditions.

Learning unit 5 Perform routine maintenance

L.O.5.1: Interpret nameplate's/ manufacturer's information

Content/Topic 1 Generator nameplate elements

The generator's nameplate(sometimes referred to as the data tag)is usually located near the control panel or within sight of the observation window on enclosed units. Older generators have metal nameplates riveted directly to the housing, while more modern generators have the information on laminated decals. the exact location is usually listed in the operator's manual

1. KW ratings
2. KVA ratings
3. Power factor
4. Operating voltage
5. Number of phases
6. Current ratings
7. Number of cycles
8. Exciting voltage and current
9. Operating temperature

Content/Topic2 Interpretation of generators nameplate indication

kW ratings: it is real power generated by generator

kVA ratings:is apparent power produced by generator which is equal to ratio of real power to the power factor

Power factor: Percent power factor is a measure of a particular motors requirements for magnetizing amperage.

Operating voltage: Voltage rating at which the generator is designed to operate most efficiently, generator are designed to generate voltage at plus or minus a 10% tolerance of this value. Generator with a 460V rating could operate (generate) effectively at around 414V.

Number of phases: indicate the value of phases produced by generator example 3 phase AC generator.

Current ratings: To Find the amperage of generator that produce 120 volts. Wattage is equal to volts time amperage (w = v X a). Divide wattage by volts to find the amperage (a = w/v). In this example 3,000 watts divided by 120 volts is equal to 25 amperes.

Number of cycles: Therefore, a 2-pole generator producing an output frequency of 60 Hz has an engine speed of 3,600 rpm. Likewise, a 4-pole generator at an engine speed of 1,800 rpm produces output of 60 cycles per second. The most US generators maintain a frequency of 60 cycles per second. However, European ones maintain a frequency of 50

Excitation voltage and current:a generator produces output voltage proportional to the magnetic field, which is proportional to the excitation current; if there is no excitation current there is no voltage.

Operating temperature: The rating of the motor is the ambient (room) temperature vs. the time it can operate at that temperature, most generator are rated for continuous duty.

L.O 5.2: Identify status indicators/ alarm signals

Content/Topic1 Status indication and warning signs interpretation

- **ON/OFF indication**: this indicate that the power is ON and power is OFF status of the load connected to the AC outlet.

- **Fuel level indication**is an instrument used to indicate the amount of fuel in a fuel tank.

- **Temperature indication** this will indicate the level of temperature during generator working. They are in form of electronics or analog display

- **Frequency indication** A frequency meter is an instrument that displays the frequency of a periodic electrical signal from generator. Various types of frequency meters are used in conjunction with generator.

Status indicator

Content/Topic 2 Warning signs and alarm sequences

The alarm sequences are designed to take appropriate action according to the severity of the event, which caused the alarm.

The alarms of diesel generators are as follows-:

- Fuel Theft Alarm
- Low fuel level alarm
- Cooling water level is low
- Maintenance Alarm
- Generator Low Battery Alarm
- High-Temperature Alarm
- Short Circuit alarm
- Generator Low Battery Alarm
- Voltage Alarm

A warning sign is a type of sign which indicates a potential hazard, obstacle or condition requiring special attention.

L.O 5.3: Clean, replace, lubricate, adjust, repair

Content/Topic 1 Cleaning techniques of the generator

- ✓ By air blower
- ✓ By brush
- ✓ By oil

Content/Topic 2 Types of lubricating oils

Lubricating oil called also lubricant is a class of oils used to reduce the friction, heat and wear between mechanical components that are in contact with each other. There are 3 types of lubricating oils

1. **Animal/Vegetables oils:** rarely used as additives
2. **Mineral/Petroleum Oils**: extracted from petroleum
3. **Synthetic Oils**: synthesized from pure carbon and Hydrogen gases in a controlled process. Their viscosity changes very little with temperature

Content/Topic3 Adjusting defective parts

Common parts of generator

The capacitor

The capacitor has two functions; it induces voltage into the rotor as well as regulates voltage. A bad capacity will result in a low voltage reading from the generator as the power being generated will be from the residual magnetism of the rotor (usually about 2-5V). To test a capacitor, a multi-meter that can test capacitance is required. To test a capacitor, it must first be removed from the generator and discharged. Be careful when removing the wire leads that a short is not created across the capacitors terminals. To discharge, use a screwdriver with an insulated handle to cross the terminals on the capacitor (this will result in a loud pop and a spark). Once discharged, take a reading from the capacitor. The measured capacitance should be +/-5uf of the specified rating printed on the side of the capacitor. If not, the capacitor should be replaced.

Alternator

The alternator uses residual magnetism from the windings to charge the capacitor. If the generator has not been used for an extended period the magnetism can be lost and the capacitor will not be charged. If this occurs the capacitor must be 'field flashed' to restore its charge so the rotor can once again be excited. To charge the capacitor a special charging harness must be constructed consisting of a short length of 12-gauge wire with a standard 120v plug on one end. The opposite end should have a few female blade connectors which will be attached to the terminals on the capacitor. A single pole momentary switch is added to the live or positive side of the wiring harness. Connect the harness to the capacitors terminals and plug in the plug end to a 120v outlet. The momentary switch should be depressed for not more than one second. This will restore the capacitors charge. It can then be reinstalled in the generator. Once the capacitor is charged, care must be taken to ensure that no shorts are created between the terminals while it is reinstalled. Again, if there is any doubt or confusion about this process, take the generator to a professional to have this repair performed.

Stator

There are two types of stators used in generators; brushed and brushless. The stator is typically made up of three windings; two power windings and one winding that is used to either excite the rotor on a brushed stator or charge the capacitor on a brushless stator. The magnetically charged rotor rotates inside of the fixed stator windings, which produces electricity. To test a brushless stator, the wires from the stator to the electrical panel will first need to be removed. You will also need some information from the manufacturer; the function of each of the stator wires, as well as the normal resistance reading for each of the coils within the stator. Once this information is found, you can begin testing. The first test will determine if there is an open circuit within the winding, which would indicate a damaged or broken winding. Using a multi-meter set to test resistance, connect the multi-meter to each end of the wire coil using the leads. The meter should give a resistance measurement that is within the manufacturers specifications. A reading outside of this spec will indicate a bad winding. Perform this test on both power windings. The next test will check for a short between the windings and ground. The manufacturer will specify which stator lead to use for this test. Set the multi-meter to test resistance. One test lead will be connected to the stator lead specified by the manufacturer, and the other lead will be connected to a clean frame ground on the generator. The meter should read "OL" (overload) or Infinity. If a resistance measurement is detected, there is likely a short to ground condition in the stator. The final test for a brushless stator is to test for a short between windings. Again, the manufacturer will need to specify which leads to use for this test. Set your multi-meter to test resistance. The test leads will be connected to two of the stator leads specified by the manufacturer. The two leads will be one lead from each of the power windings. The meter should read "OL" (overload) or Infinity. If a resistance measurement is detected that would indicate a short between the windings in the stator. To test a brushed stator: Isolate the stator by removing the connections to the AVR (automatic voltage regulator) as well as the wires running from the stator to the electrical panel. Set your multi-meter to test resistance. One of the test leads should be connected to a clean frame ground, and the other used to test each of the leads from the stator. Each lead should read "OL" (overload) or Infinity. If any of the leads give a resistance measurement that would indicate a short to ground and a bad Stator.

Automatic Voltage Regulator

The AVR is a circuit that regulates and balances the amount of voltage being output from the generator. All AVRs will have an adjustment screw which allows for the fine-tuning of the voltage output. Diagnosing a faulty AVR is done by a process of elimination; Start by testing the generators main circuit breaker. If the breaker tests good for continuity, next test the wiring within the electrical panel and from the breaker to the stator. If the wiring tests good, try adjusting the AVR to make sure it is not out of adjustment. If there is no change in output then check the rotor brushes to make sure they are in good condition and are making contact with the rotor. If everything tests good up until this point, test the stator itself. If the stator is producing power then the AVR is faulty and will need to be replaced.

Circuit Breaker

If your generator engine is running but is producing no or low output, the circuit breaker is the first thing you should check. The breaker is a safety feature designed to automatically switch off if a surge of electricity or overload is detected. A surge can be caused by using a device that draws more power than the breaker is rated for, using multiple 'heavy load' devices at the same time, or if a short occurs within the circuit. Some breakers will have colored indicators to show if they have been tripped, but some will not give any indication at all. Cycle the breaker off and on and try the outlet again. If the outlet is still not working, confirm that the breaker is set to the on position and use a multi-meter to measure resistance on the lead wire connections on the inside of the electrical panel. If any resistance is read, than the breaker is good. If the meter reads 'OL' (overload) or Infinity, the breaker is bad and should be replaced.

Content/Topic 4 Checking, repairing general faults occurring in generators

- ✓ **Engine faults**
  - Engine not turning
  - Engine not firing
  - Engine fires but fails to pick up speed
  - Engine misfires
  - Overheating
  - Exhaust emits black smoke

- ✓ **Control equipment faults**

The faults liable to occur in this equipment will depend upon the design of the control scheme supplied. It is only possible to give general recommendations regarding fault findings on this equipment.

- Circuit fuses blowing
- Circuit operating satisfactorily only intermittently

- Overheating cable ends and terminations
- ✓ **Alternator faults**
    - No output voltage
    - Output voltage unstable
    - Output voltage incorrect
    - Output voltage too high and cannot be reduced on controls

L.O. 5.4 Test an electrical generator

<u>Content/Topic 1 Preparation of the inspection checklist</u>

✓ **General condition of prime mover**

- Check general condition of prime mover/generator

Condition of belts & hoses
Engine oil level
Lube oil heater
Coolant level
Water pump
Jacket water heater
Radiator
Electrical/Generator breaker state

✓ **Battery system(Electrolyte level charger)**

Unit will not start due to battery - 80% of generators' failures to start are due to faults in the set's battery. Weak or low charged batteries are a common occurrence. Even a well-charged, well-maintained lead-acid battery will deteriorate over time. Batteries must be replaced when they no longer hold a proper charge. Battery charger systems and alternators should be checked weekly on sets used for standby and emergency applications, and at least monthly on other applications the main thing checked on battery are Electrolyte level and charger

✓ **Exhaust system**

- Checking of the condition of Exhaust system

•Exhaust system: With the generator set operating, inspect the entire exhaust system including the exhaust manifold, muffler and exhaust pipe. Check for leaks at all connections, welds, gaskets and joints, and make sure that the exhaust pipes are not heating surrounding areas excessively. Repair any leaks immediately.

✓ **Fuel system**

- Checking of the condition of Fuel system:

Unit will not start due to fuel - Lack of fuel or low quality fuel are often reasons generator-set engines fail to start or to give rated power. Fuel quality should be checked as part of any planned maintenance visit. Technicians working on diesel-fuelled units will check if water or other contaminants are in the fuel or in the unit's filtration or delivery systems. Having no fuel in diesel and gaseous units could be due to a lack of storage capacity or poor delivery from the on-site storage or tank vents. Also Filters leading to reduced performance - The air, oil and fuel filter elements must be changed per manufacturer's recommendations or whenever necessary due to site or operating conditions. Any blockage will restrict flow and result in reduced performance. Air and oil filter blockages also contribute to excessive engine wear.

Testing

- ✓ Engine(rotating speed)
- ✓ Control equipment
- ✓ Generator (Voltage)

L.O.5.5: Clean the workplace

Content/Topic 1 Collection and arrangement of tools and equipment

Tools and equipment arranged in their category after repairing and maintenance of generator in order to make sure that every tools are available on the second action. Tools and equipment are arranged in the following way:

- ❖ Electrician Toolbox
- ❖ Measuring equipment
- ❖ Mechanical tool set
- ❖ Storing of non-used materials
- ❖ fuel, lubricating oil
- ❖ faulty parts

Content/Topic2 Arrangement of non-used materials(consumables)

All non- used materials need proper protection and stored in an orderly fashion this prevent loss due to damaging of items. By having a good system in place that provides an overview of where which item is stored, everything can be found quickly

Content/Topic3 Cleaning the working area

- ✓ **Cleaning Techniques**

Blowing
Sweeping
Brushing
Wiping

- ✓ **Tools used in cleaning**

Air blaster
Air knife
Broom
Blush
Camel-hair brush

Content/Topic 4 Waste materials management

- ✓ **Types of waste materials**

Recyclable: This types of waste can be converted into product that can be used again

Bio-degradable:A biodegradable material can be defined as a material which can be decomposed by b bacteria or other natural organisms and not be adding to pollution

Non-bio-degradable: A Non-Biodegradable material can be defined as a kind of substance which cannot be broken down by natural organisms and acts as a source of pollution.

- ✓ **Treatment of waste materials**

Whether it is biodegradable or non-biodegradable, they harm human life and ruin other organisms and their environment. Thus, a proper treatment of wastes has to be done. This is not only the responsibility of the Government, but of every individual as well. The three Rs- Recycle, Reuse, and Reduce are the simplest steps which can be followed by each person to do their part. This can save energy and other resources as well. Another step is separate biodegradable from non-biodegradable and disposes of them separately.

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