Salahaddin University – Erbil

College of Engineering

Mechanical engineering Department

Third year Students

Electrical Machine

D.C. Generator

Direct Current Generators

Introduction

D.C. Generators d.c machine used as generators, there is no real difference between a generator and a motor except for the direction of power flow.

There are major types of d.c. generators, classified according to the manner in which their field flux is produced. The various types of d.c. generators differ in their terminal (Voltage – Current) characteristics, and therefore in the applications to which they suited.

DC. Generators are compared by their voltages, power ratings, efficiencies, and voltage regulation ($\mathbf{V_R}$) is defined by the equation:

$$\mathbf{V_R} = [(\mathbf{V_{nL}} - \mathbf{V_{FL}}) / \mathbf{V_{FL}}] \times 100\% \qquad \ldots\ldots \ (2.1)$$

Where: $\mathbf{V_{nL}}$ – Is the No- Load Terminal Voltage of the generator.

$\mathbf{V_{FL}}$ – Is The Full- Load Terminal Voltage of the generator.

All generators are driven by a source of mechanical power, which is usually called the PRIME MOVER of the generator. A prime mover for a d.c. generator may be a steam turbine, a diesel engine, or even an electric motor.

Since prime mover can vary widely in their speed characterize, it is customary to compare the voltage regulation and output (O/P) characteristics of different generators, assuming Constant – Speed Movers.

Characteristics of DC. Generators

The properties of generators are analyzed with the aid of characteristics which give the relations between fundamental quantities determining the operation of a generator, these include the voltage across the generator terminals ($\mathbf{V_T}$), the field or exciting current ($\mathbf{I_F}$), the armature current (**Ia),** and the speed of rotation.

The three most important characteristics of DC. Generators are given below:

1 – No Load saturation characteristics (**E_0/ I_F**)

It is also known as magnetic or open Circuit Characteristic (O.C.C.).

This characteristic shows the relation between No-Load generated emf in the armature (E_0) and field of exciting current (**I_F**) at a given fixed speed. Fig (2.1).

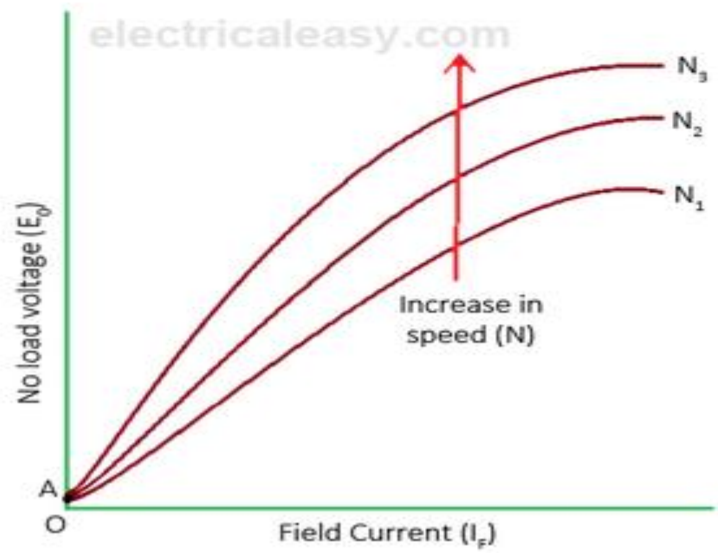


Fig (2.1) The open Circuit Characteristic (O.C.C.).

The O.C.C. curve is just the magnetization curve for the material of the electromagnets, and it is practically similar for all type of generators, whether they are separately excited or self – excited, 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.

2 – Internal or Total Characteristic

It gives the relationship between the emf (**E_a**) actually induced in the armature after subtracting the drop due to demagnetizing effect of armature reaction and the armature current (**Ia**). The generated emf **E_a** is always less than **E_0** due to the armature reaction.

This Characteristic is of interest manly to the designer.

3 – External Characteristic (**V_T/ I_L**)

a) This Characteristic is also referred to as PERFORMANCE CHARACTERISTIC, or sometimes Voltage – regulating curve.

b) It gives the relation between terminal voltage (**V_T**) and the load current (**I_L**).

c) The curve lies below the Characteristic it takes into account the voltage drop in the armature circuit resistance.

The values of **(V_T)** are obtained by subtracting (**IaRa)** from internal voltage (**E_a**):

For Generator: $$V_T = E_a - IaRa \qquad \text{...... (2.2)}$$

d) The characteristic is of great importance in judging the suitability of a generator for a particular purpose.

The External Characteristic can be obtained by the following two ways:

i) By making simultaneous measurements with a suitable Voltmeter and an Ammeter on a loaded Generator.

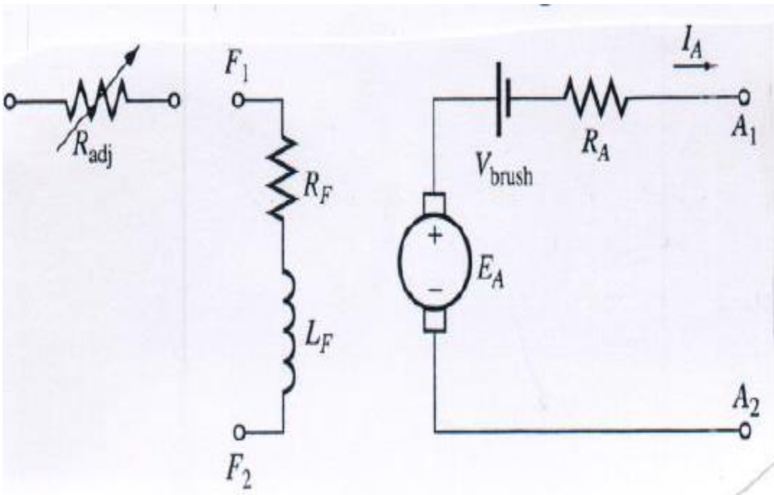
ii) Graphically from the O.C.C. provided the armature and field resistance are known and also if demagnetizing effect of the armature reaction is known.

The Equivalent Circuit of DC. Generators

DC. Generators are quite rare in modern electrical power systems, but we can find d.c. Generator in d.c. power systems such as those in automobile's.

Although now we can use A.C. Generators plus Rectifiers to produce d.c. power.

The equivalent circuit of a d.c. Generator is shown in Fig (2.2).



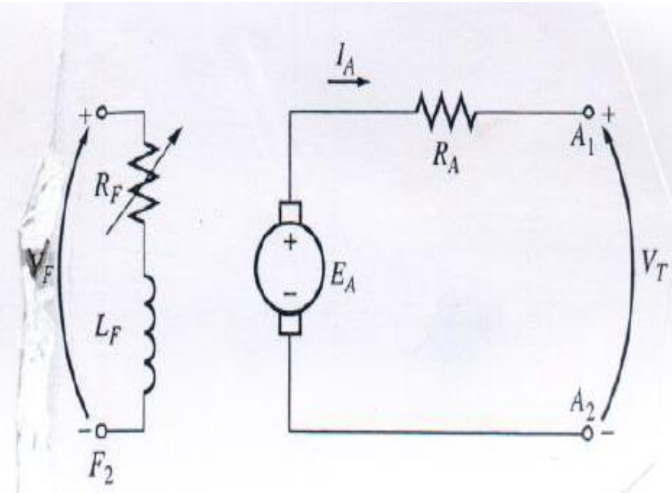


Fig (2.2). Equivalent Circuit of DC. Generators. Fig (2.3) A simplified Equivalent Circuit of DC. Generators.

And a simplified version of the Equivalent Circuit is shown in Fig (2.3).

The Equivalent Circuit look similar to the Equivalent Circuit of DC. Motor, except that the direction of current flow and the Brush losses are reversed.

Types of DC. Generators:

A – Separately Excited DC. Generator

A – Separately Excited d.c. Generator is a generator whose field current is supplied by a separate external DC. Voltage Source.

The Equivalent Circuit of such a machine is shown in Fig (2.4). In this circuit:

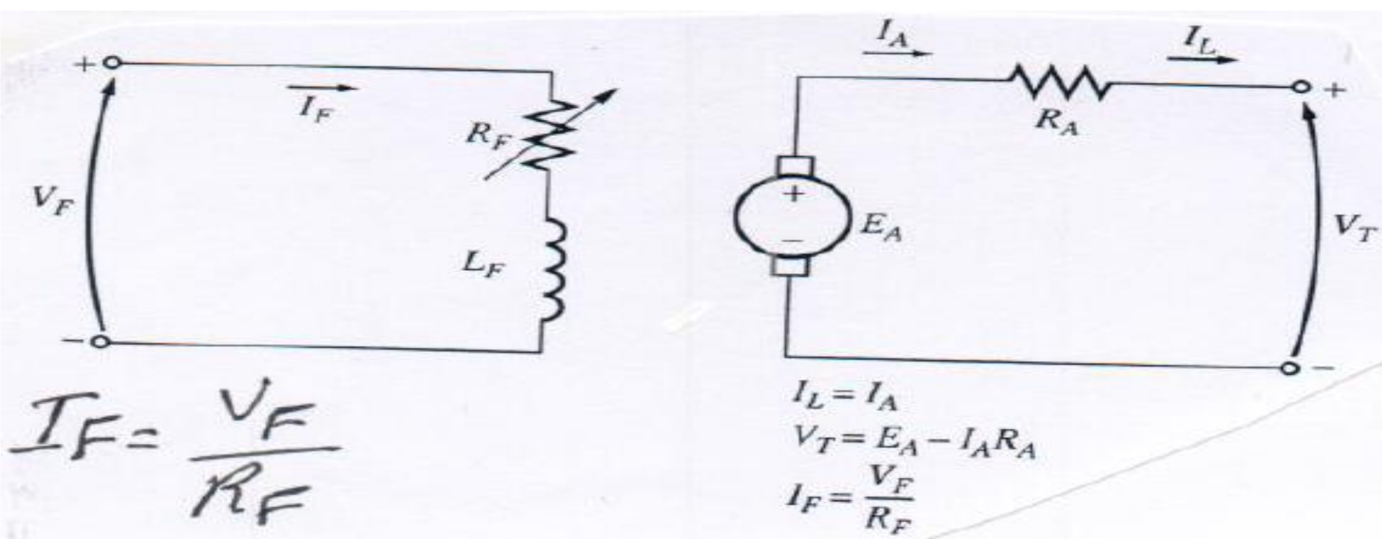


Fig (2.4). **Separately Excited DC. Generator**

V_T – Terminals Voltage.

I_L – The current flowing in the lines connected to the Terminals (Load current).

E_a – The internal Generated Voltage. **Ia –** The armature current.

It is clear that armature current is equal to line current in Separately Excited d.c. Generator: **$I_L = Ia$** …… (2.3)

The terminal characteristic of a Separately Excited d.c. Generator:

The Terminal characteristic of a device is a plot of the output quantities of the machine versus each other.

For a DC. Generator, the output quantities are the Terminals Voltage (**V_T**) and The Line current (**I_L**) for a constant speed (**ω**).

By Kirchhoff's Voltage Law, the terminal Voltage is:

$$V_T = E_a - IaRa \qquad \text{…… (2.2)}$$

Since the internal Voltage (**E_a**) is independent, the armature current **(Ia),** the terminal characteristic of Separately Excited d.c. Generator is a straight line, as shown in Fig (2.5).

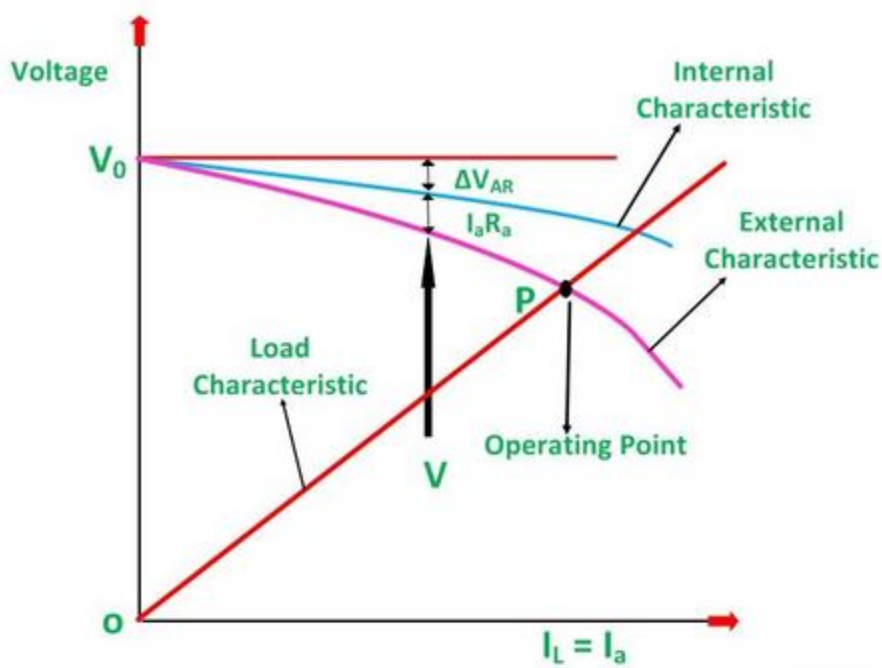


Fig (2.5) **terminal characteristic of a Separately Excited d.c. Generator**

When the load supplied by the generator is increased, I_L (and therefore **Ia)** increase. As the armature current increase, the **(IaRa)** drop increase, so the terminal Voltage of the generator falls.

In generators without compensating windings, an increase in **(Ia)** causes an increase in armature reaction, and armature reaction causes flux weaking. Thus, the flux weaking causes a decrease in (E_a):

$$E_a = K \phi \omega \qquad \ldots\ldots (2.3)$$

The resulting, further decrease in terminal voltage. As shown in Fig (2.5).

Example 1:

A 4 pole, Lap wound separately excited DC. Generator has an armature resistance of 0.4Ω and is driven at 750 r.p.m. The armature has 720 conductors and the flux per pole is 0.03 wb., if the load resistance is 12 Ω. Determine the terminal voltage.

Solution:

To find (V_T) the terminal voltage: Recalling equation (2.2);

$$V_T = E_a - IaRa$$

With: $I_L = Ia$ in Separately Excited d.c. Generator:

For the Lap winding, number of current parallel bath (**a**)

a= Number of poles → **a** = **p** =4

Therefore:

$$E_a = (\phi \times n \times Z \times P)/60\,a = (0.03 \times 750 \times 720 \times 4)/60 \times 4 = 270 \text{ volt.}$$

$$I_L = Ia = V_T/R_L \qquad R_L \text{ – load resistance}$$

$$E_a = V_T + (I_L \times Ra) = V_T + [(V_T/R_L) \times Ra]$$

$$E_a = [1 + (Ra/R_L)] \times V_T \quad \rightarrow \quad V_T = 270/[1 + (0.4/12)] = 261.29 \text{ volt.}$$

Example 2:

A separately excited DC. Generator, when driven at 1500 r.p.m. supplies a load current of 200 A at 250 V to a circuit of a constant resistance. What will be the current and voltage if the speed is reduced to 1250 r.p.m. keeping field current unaltered? Armature resistance = 0.05 Ω; Brush contact drop = 2 volt.

Neglect the effect of armature reaction.

Data: N_1 = 1500 r.p.m., I_{L1} = 200 A, V_{T1} = 250 V, R_L = constant; I_F = constant.

N_2 = 1250 r.p.m.; **Ra** = 0.05 Ω, V_{BR} = 2V. I_{L2}? : V_{T2}?

Solution:

$R_L = V_{T1}/ I_{L1}$ = 250/200 = 1.25 Ω : $I_L = Ia$ in Separately Excited d.c. m/C.

$E_{a1} = V_{T1} + (I_{L1} \times Ra) + V_{BR}$ = 250 + (200× **0.05**) +2 = 262 Volt.

At constant field current and neglecting armature reaction:

$\phi_2 = \phi_1$

Hence $E_{a2} = E_{a1} \times (N_2/N_1)$ = 262× (1250/1500) = 218.33 Volt

$E_{a2} = V_{T2} + (I_{L2} \times Ra) + V_{BR} = (I_{L2} \times R_L) + (I_{L2} \times Ra) + V_{BR}$

$I_{L2} = (E_{a2} - V_{BR})/ (R_L + Ra)$ = (218.33– 2)/ (1.25+ 0.05) = 166.25A.

$V_{T2} = I_{L2} \times R_L$ = 166.25× 1.25 = 207.81 volt.

Example 3:

The open circuit characteristic (O.C.C.) of a separately excited generator, at 600 rpm is:

Field current (A)	**1.6**	3.2	4.8	6.4	8.0	9.6	11.2
O.C.C . (V)	148	285	390	460	520	560	590

Find:

i) The voltage to which the machine will excite as a shunt d.c. generator with a field circuit resistance of 60 Ω.

ii)The critical resistance.

Solution:

Plot of o.c.c.(E_0/ I_F) is shown in Fig (2.6).

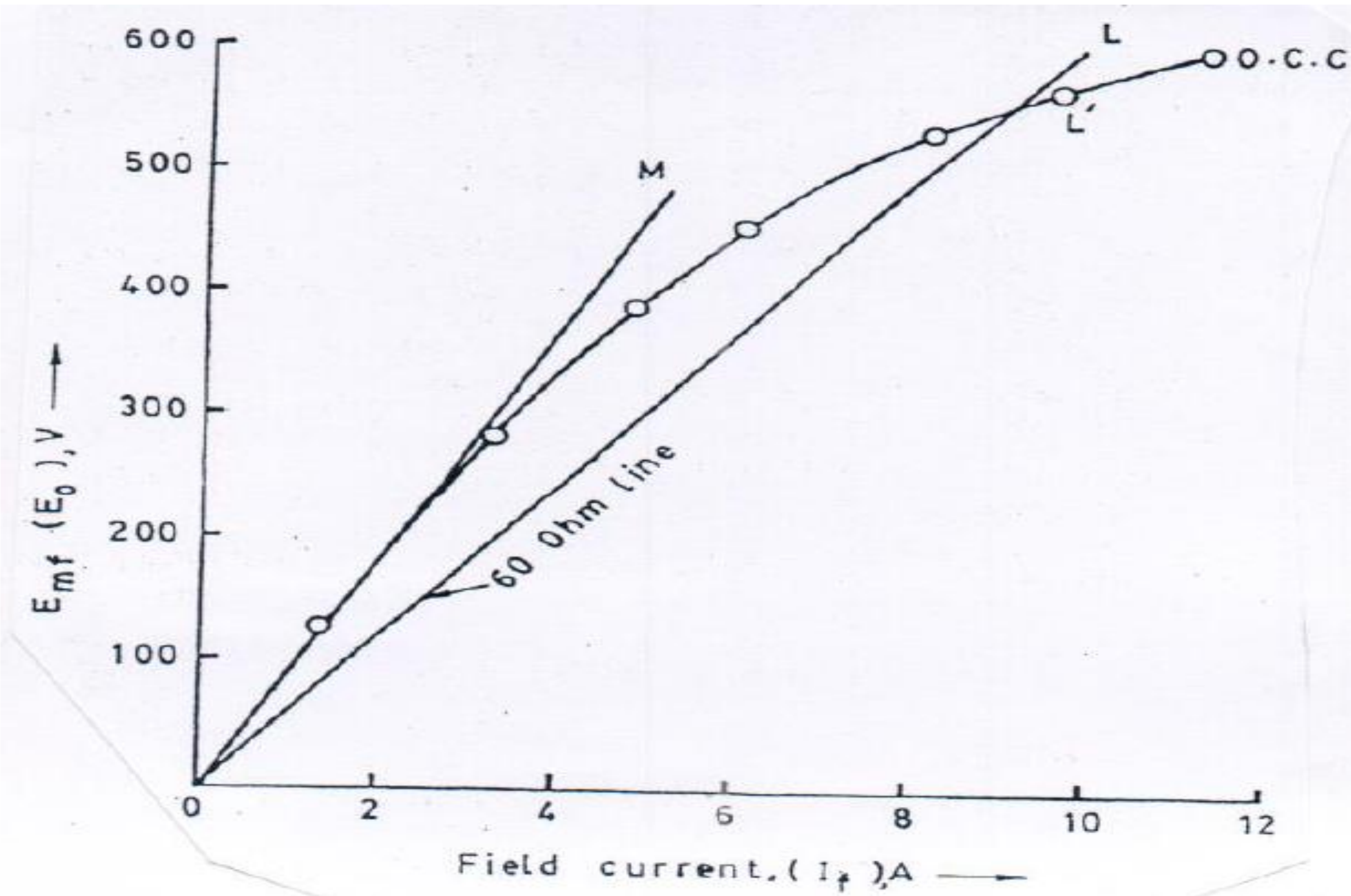


Fig (2.6). Open circuit characteristic (O.C.C.) of a separately excited generator, at 600 rpm

- Line (OL) represents 60 Ω line.

i) The voltage to which the machine will excite as a shunt generator is given by point (L′) i.e the intersection of o.c.c. curve and 60 Ω line. The machine will excite at 550V

ii) Draw a tangent Line (**OM**) to the **o.c.c.** curve, the slope of this Line represents Critical Resistance. This value of Critical Resistance = 91 Ω.

B – The Self Excited Shunt DC. Generator:

A Shunt DC. Generator is a d.c. generator that supplies its own field current by having its field connected directly across the terminals of the machine. The equivalent circuit of a shunt d.c. generator is shown in Fig (2.7).

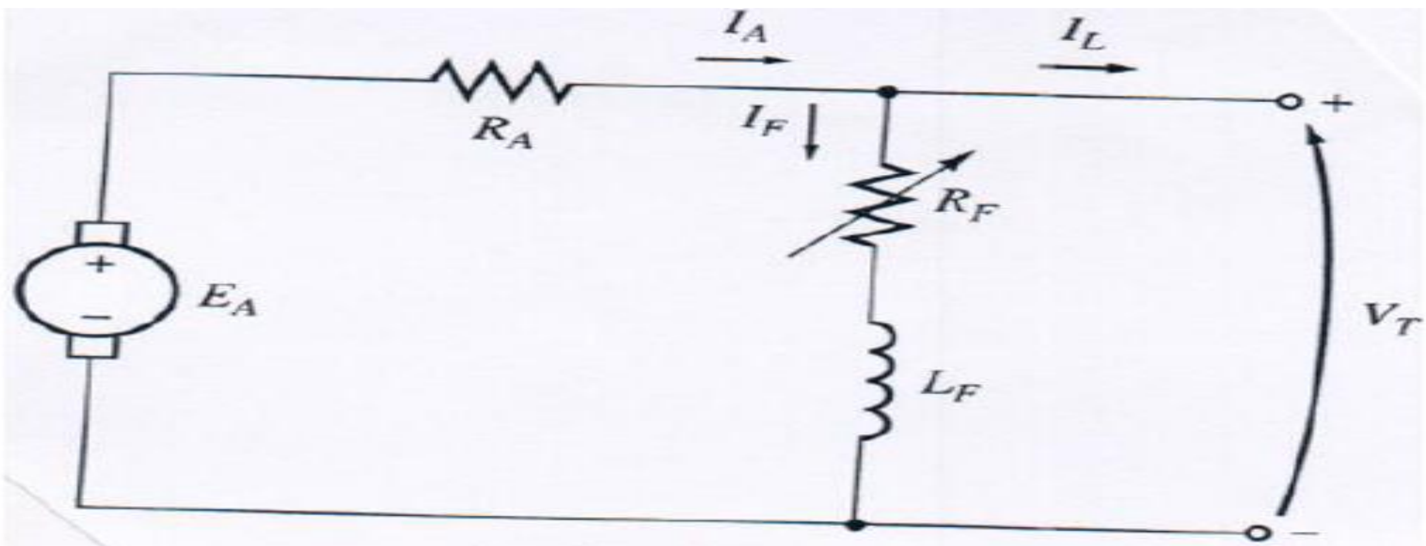


Fig (2.7). The equivalent circuit of a shunt d.c. generator.

In this circuit, the armature current (**Ia)** of the machine supplies both the field current (**I_F**) and the load current (**I_L**) attached to the machine:

$$\mathbf{Ia = I_F + I_L} \qquad \text{……. (2.4)}$$

The Kirchhoff's Voltage low equation for the armature circuit is:

$$\mathbf{V_T = E_a - IaRa} \qquad \text{……. (2.5)}$$

And the field current is:

$$\mathbf{I_F = V_T / R_F} \qquad \text{……. (2.6)}$$

This type of generator has a distinct advantage over the separately excited d.c. Generator in that NO external power supply is required for the field circuit. But an important question here leaved unanswered:

If the Generator supplies its own field circuit, how does it get the initial field flux to start when it is first turned on?

The terminal characteristic of a Shunt Excited d.c. Generator:

The terminal characteristic of a Shunt d.c. Generator differs from that of a separately Excited d.c. Generator, because the amount of the field current in the machine depends on its terminal voltage.

To understand the terminal characteristic of a Shunt d.c. Generator, start with NO load condition and add load.

As the load on the generator is increased **(I_L)** increase

$$Ia = I_F + I_L\uparrow \qquad \textbf{Ia} \text{ also increase.}$$

An increase in **(Ia)** cause's increasing in the armature voltage drop **(IaRa)**

$$(IaRa)\uparrow \qquad \text{Increase causing;}$$

$$\downarrow V_T = E_a - (IaRa)\uparrow \qquad \text{the terminal voltage to decrease.}$$

However:

When V_T decrease, the field current in the machine decreases, decreasing E_a.

Decreasing E_a causes a further decrease in the terminal voltage:

$$V_T = E_a\downarrow - (IaRa)$$

The resulting terminal characteristic is shown in Fig (2.8).

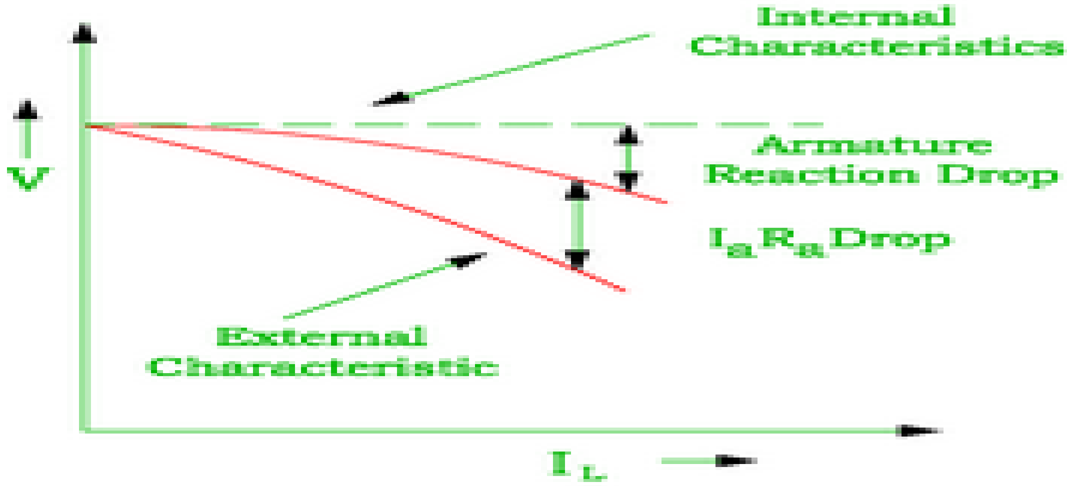


Fig (2.8) The terminal characteristic of a Shunt d.c. Generator.

Notice that:

The voltage drop – off is steeper than just **(IaRa)** drop in a separately excited generator.

In other words, the voltage regulation of this generator is worse than the voltage regulation of a separately excited for the same piece of equipment (i.e for the same machine size).

Voltage control for a Shunt d.c. Generator:

As with the separately excited generator, there are two ways to control the Voltage of a Shunt d.c. Generator.

1) Change the shaft speed ($\boldsymbol{\omega_m}$) of the generator.

2) Change the field resistor of the generator, thus changing the field current. Changing the field resistor is principal method used to control terminal Voltage in real shunt Generator.

If the field resistor $\mathbf{R_F}$ is decreased, then the field current $\mathbf{I_F}$:

$\mathbf{I_F} = \mathbf{V_T} / (\mathbf{R_F}\downarrow)$ increase. When $\mathbf{I_F}$ increase, causes machine flux $\boldsymbol{\phi}$ to increase.

→ causing the internal generated voltage $\mathbf{E_a}$ to increase, the increase in $\mathbf{E_a}$ causes the terminal **Voltage V_T** of generator to increase

Example 4:

A 4 pole Lap connected d.c. Shunt Generator having field and armature resistance of 50Ω and 0.15 Ω respectively supplies 75 Lamps of 200V, 60Watt calculate:

Armature current (**Ia**)? , the induced voltage e.m.f.? , Brush contact drop is 2Volt.

Solution:

The terminal Power ($P_{O/P}$) = 75×60 = 4500

$I_L = (P_{O/P}) / V_T$ =4500/ 200= 22.5 Amp.

For d.c. Shunt Generator: $\mathbf{Ia = I_F + I_L}$

$I_F = V_T / (R_F)$ = 200/50 = 4 Amp the field current.

Now: Armature current ($\mathbf{Ia}$) = $I_F + I_L$ = 22.5+4 = 26.5 Amp.

the induced voltage e.m.f. E_a gives as:

$E_a = V_T + (Ia \times Ra) + V_{BR}$ = 200+ (26.5 ×0.15)+ 2 = 205.975 volt.

Example 5:

A 6 pole, wave wound, 500r.p.m. d.c. Shunt Generator has armature and field resistance of 0.5Ω and 250 Ω respectively. The armature has 250 conductors and flux per pole 40 m.wb. , If the load resistance is 15 Ω, determine the terminal voltage and load current.

Solution:

N.B.: for the wave wound machine the number of parallel paths (**a**) is:

a =2

Induced voltage $E_a = (\phi \times n \times Z \times P)/60\,a = [(40 \times 10^{-3} \times 500 \times 250)/60] \times (60/2)$ =250V.

$E_a = V_T + (Ia \times Ra) = V_T + [(I_F + I_L) \times Ra]$

$250 = V_T + [V_T/(R_L) + V_T/(R_F)] \times Ra$ == $V_T + [(V_T/15) + (V_T/250)] \times 0.5$

$V_T = 241.476$ Volt.

And the load current I_L is given as: $I_L = 241.476/R_L = 16.098$ Amp.

Example 6:

A d.c Shunt generator running at 1000 r.p.m. gave the following O.C.C.:

Field current(A)	1	2	3	4	5	6	7	8
O.C.C. Volts(V)	52.5	107.5	155	196.5	231	256.5	275	287.5

Calculate the voltage to which the machine will build up if the speed is 800 r.p.m. and field circuit resistance is 30 Ω.

Solution:

The plot at a constant speed of 1000 r.p.m., as given in the data is shown in Fig (2.9).

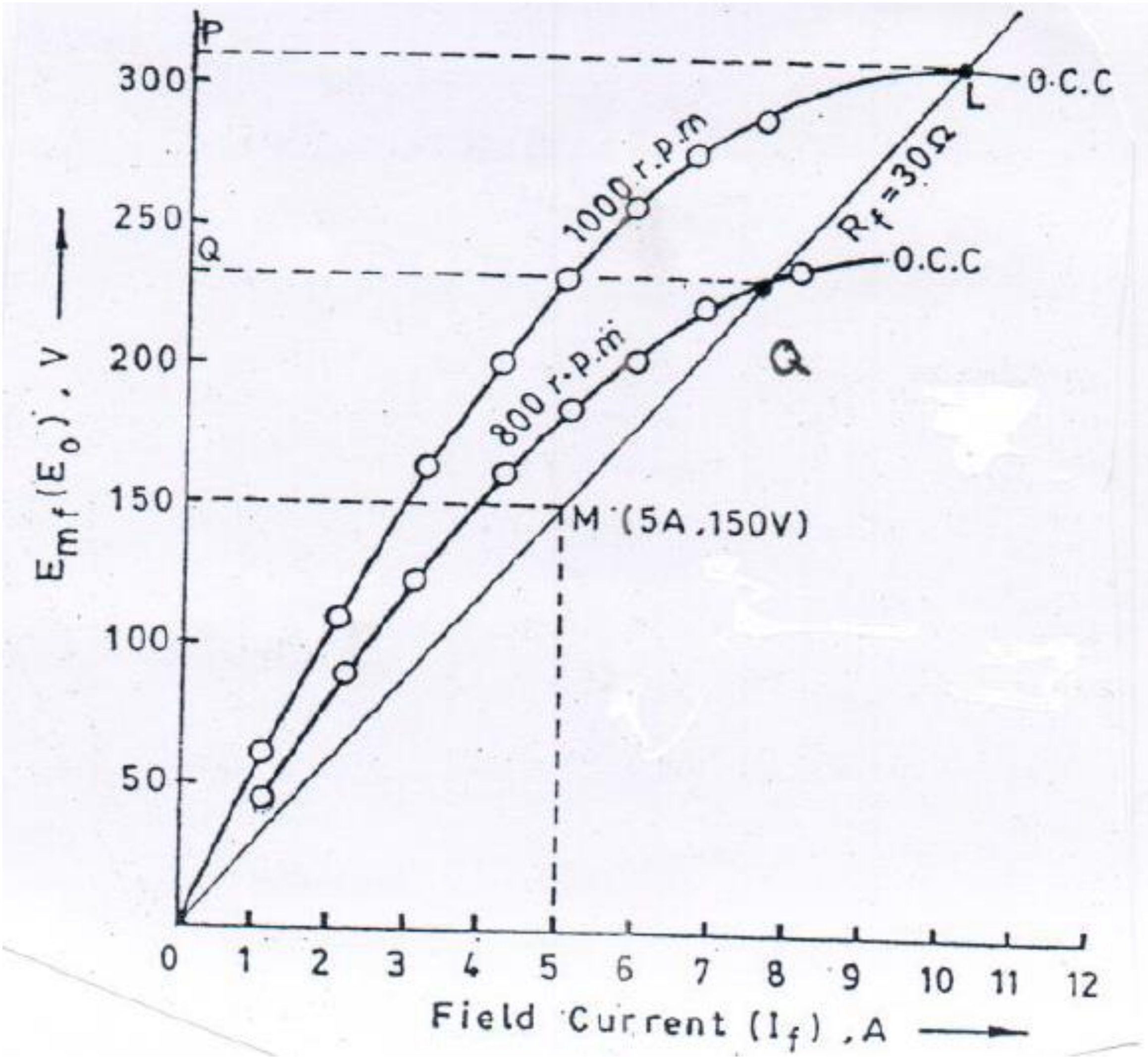


Fig (2.9). Plot of o.c.c. (E_0/ I_F).

1- Draw the resistance Line (OL) as follows

- We take 5 Amp current   and   5×30 = 150 Volt.

Hence join the Coordinate, 5 A   and 150V to get the point M (5 A, 150V).

Now draw a line joining the origin and (M) point.

This line gives 30 Ω resistance line, and it cuts the **o.c.c. at point L**

2- Draw a horizontal line from point **L** cutting o.c.c. axis of E_o at point **p** (**OP** = 310 V)

OP = max. Voltage to which the machine will build up with 30 Ω resistance in the shunt field at 1000 r.p.m.

3- To find e.m.f. induced voltage (**E_a**) at 800 r.p.m. draw a new curve since the e.m.f. is directly proportional to Speed:

$$(\mathbf{E_a} \text{ at } n = 800 \text{ r.p.m.}) = [(\mathbf{E_a} \text{ at } n = 1000 \text{ r.p.m.})] \times (800/1000).$$

So for the same field current the o.c.c at 800 rpm is as follows:

Field current(A)	1	2	3	4	5	6	7	8
O.C.C. Volts(V)	42	86	124	157.2	184.8	205	220	230

Plot the o.c.c as before. The value of e.m.f. with R_F = 30 Ω, is: OQ = 230 Volt.

C – Self Excited Series DC. Generator

A series d.c. Generator is a machine whose field is connected in series with its armature. Since the armature has a much higher current than a shunt field machine, the series field in a generator have only a very few of turns with much thicker wires.

The equivalent circuit of a series DC. Generator is shown in Fig (2.10).

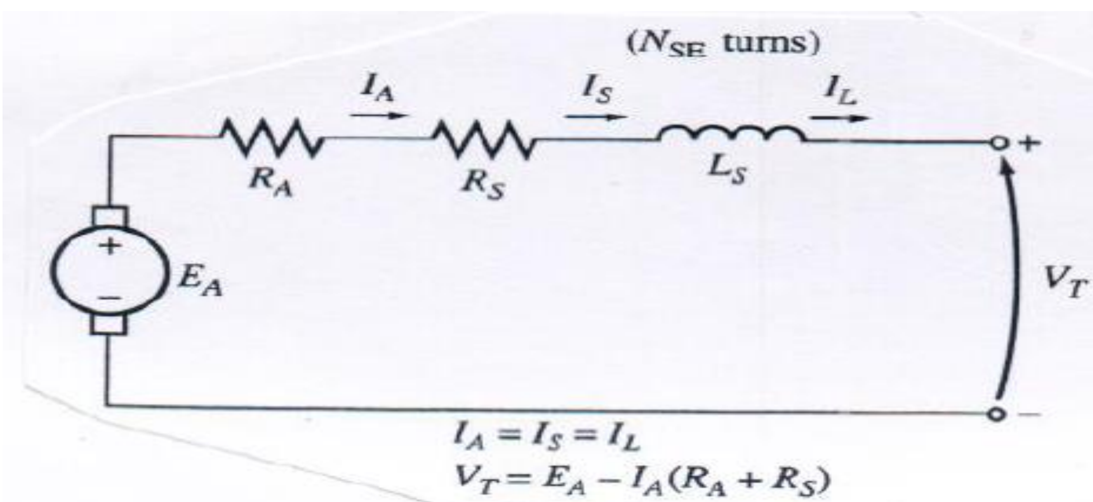


Fig (2.10) The equivalent circuit of a Series DC. Generator.

Here, the armature current, field current, and line current all have the same value:

$$\mathbf{I_a = I_s = I_L} \qquad \text{……. (2.7)}$$

The Kirchhoff's voltage law equation for this generator is:

$$\mathbf{V_T = E_a - I_a\,(R_a + R_s)} \qquad \text{.....(2.8)}$$

The terminal characteristic of a Series Excited d.c. Generator:

The magnetization curve of a series d.c. Generator looks very much like the magnetization curve of any other Generator.

At No load:

However, there is no field current, so $\mathbf{V_T}$ is reduced to a small level given by residual flux in the machine. As the load increase, the field current rises, so $\mathbf{E_a}$ rises rapidly.

The **Ia (Ra+ Rs)** drop goes up too.

At first the increase in $\mathbf{E_a}$ goes up more rapidly than the **Ia (Ra+ Rs)** drop rises, so $\mathbf{V_T}$ increase.

After a while the machine approaches saturation, and $\mathbf{E_a}$ becomes constant, at the point, the resistive drop is predominate effect, and $\mathbf{V_T}$ start to fall (decrease).

This type of characteristic is shown in Fig (2.11). Is obvious that the series d.c.

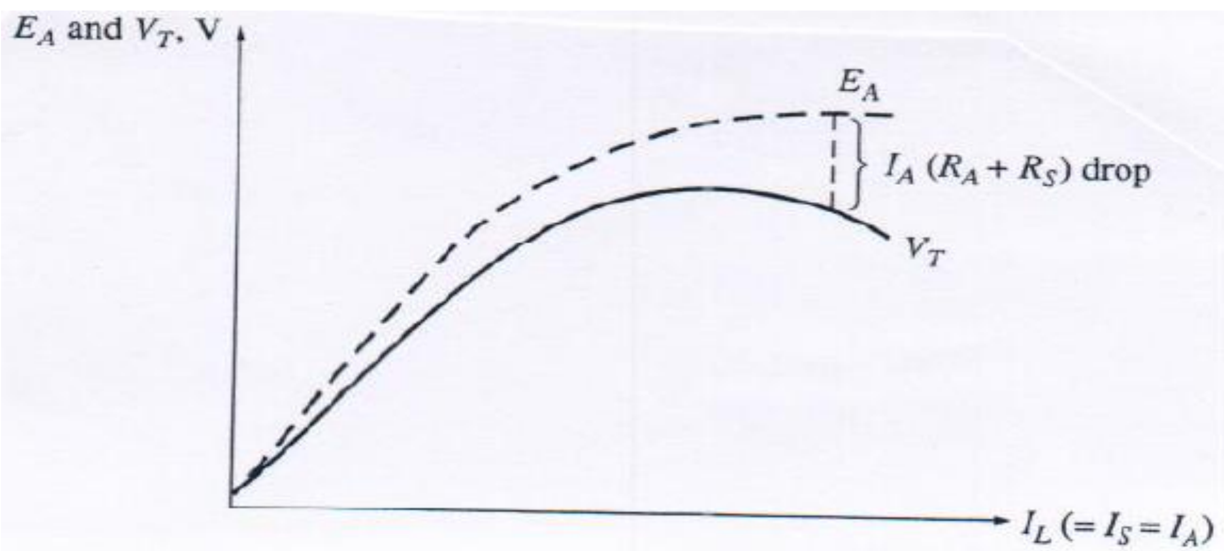


Fig (2.11). **Terminal characteristic of a Series Excited d.c. Generator**

Generator would make a bad constant – voltage drop.

DC. Series Generators are used only in a few specialized application, one such application is arc welding, the series d.c. voltage ensures that a welding arc is maintained through the air between the electrodes.

DC. Series machine also used in a constant illumination.

Example 7:

A d.c. Series Generator delivers a load of 20 Kw at 400Volt. It's armature and series field resistances are 0.3 Ω and 0.2 Ω respectively. Calculate the generated e.m.f. and the armature current, the Brush contact drop is = 2 Volt.

Solution:

$\mathbf{P_{out} = V_T \times I_L} \quad \rightarrow \quad \mathbf{I_L} = \mathbf{P_{out} / V_T}$ = 20Kw/ 400 Volt = 50 Amp.

In Self Excited Series DC. Generator:

$\mathbf{Ia = Is = I_L} \quad \rightarrow \quad \mathbf{Ia} =$50 Amp.

The voltage equation in series d.c. Generator:

$\mathbf{E_a = V_T + Ia\ (Ra + Rs) + V_{BR}}$ = 400+ 50 (0.3+0.2) + 2 = 427 Volt.

Example 8:

The external characteristic of a series Generator from zero to 70 Volt at 350 Amp., Is a straight line.

This generator is connected as a boaster between a Station Bus – Bar and a feeder of 0.35 **Ω** resistance. Find the voltage between the Bus – Bar and far end of the feeder at a current of 200Amp.

Solution:

The increase of voltage for 350 Amp. = 70Volt.

Increase of voltage per Ampere = 70/350 = 0.2

- Increase of voltage for 200A = 0.2× 200 = 40V.

-Voltage drop in the feeder = 0.35×200 = 70 V.

- Net voltage drop between Bus – Bar and far end of the feeder

= 70 – 40 = 30 Volt.

Hence, voltage between the Bus – Bar and far end of the feeder= 30 Volt.

D – Compound Wound DC. Generator

In case of a series Generator the voltage regulation is very poor but the ability of the series field to produce additional useful magnetization in response to increased load cannot be denied.

The useful characteristic of the series field, combined with the relatively constant voltage characteristic of the Shunt Generator led to Compound Generator, Fig (2.12) shows connection diagrams for the compound Generator

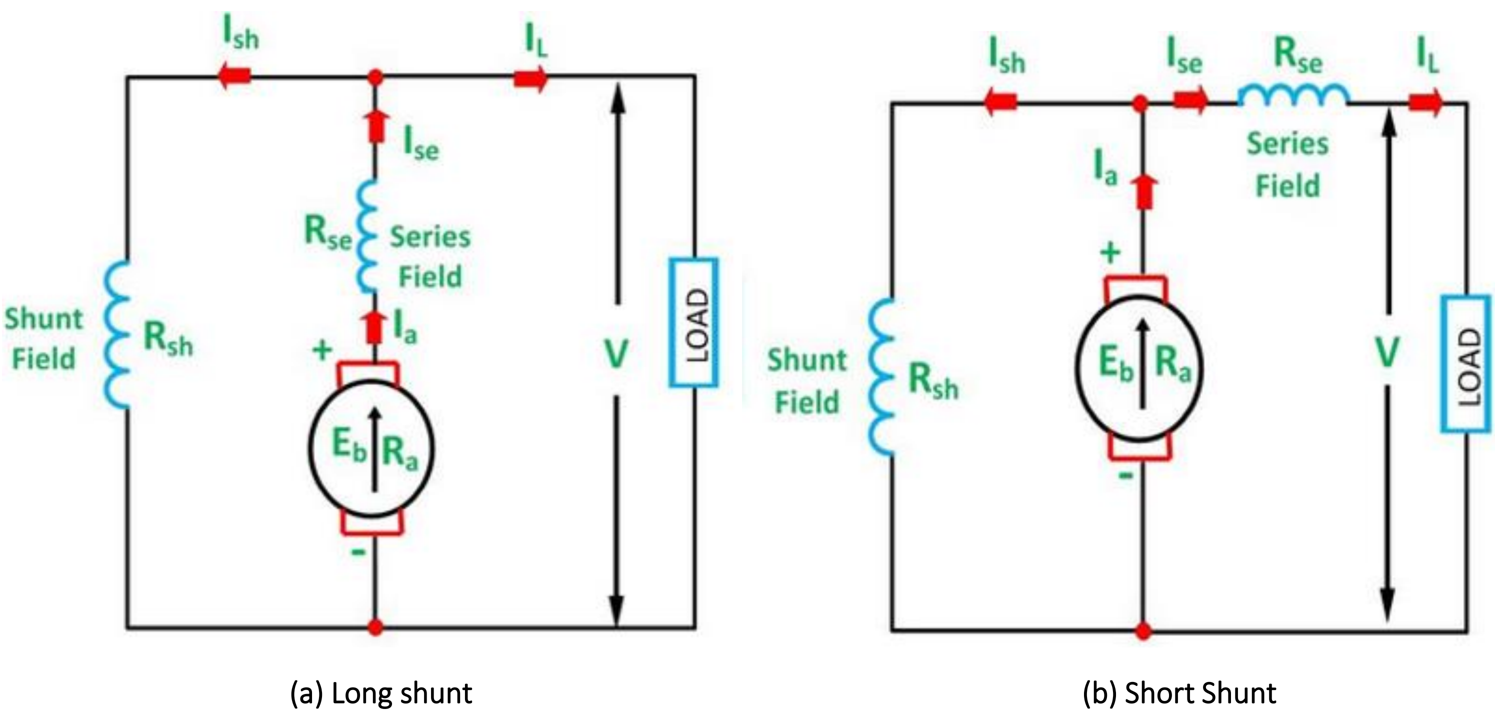


Fig (2.12) Connection diagrams for a **Compound Wound DC. Generator.**

Regardless of the connection method, the terminal voltage (**V_T**) of the short shunt or long shunt Compound DC. Generator is the same:

$$V_T = E_a - (I_{se} \times R_{se} + I_a \times R_a) \quad \text{....... (2.9)}$$

Long Shunt Cumulatively Compounded DC. Generator:

The equivalent circuit of a Cumulatively Long Shunt connection is shown in Fig (2.13)

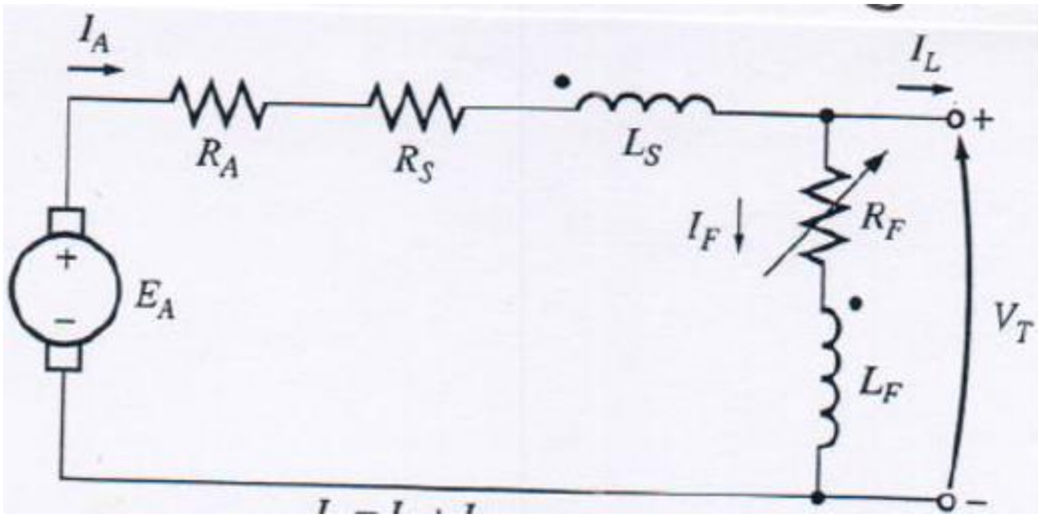


Fig (2.13) **The equivalent circuit of a Cumulatively Long Shunt connection**

The voltage and current relationships for this generator are:

$$I_a = I_F + I_L \qquad \text{...... (2.10)}$$

$$V_T = E_a - I_a \times (R_a + R_{se}) \qquad \text{....... (2.11)}$$

$$I_F = V_T / R_F \qquad \text{....... (2.12)}$$

Notice that armature current flows into the dotted end of the series field Coil and that shunt current (**I_F**) flows into the dotted end of the shunt field Coil. Therefore, the total magnetomotive force on this machine is:

$$\mathcal{F}_{net} = \mathcal{F}_F + \mathcal{F}_{se} - \mathcal{F}_{AR} \qquad \text{....... (2.12)}$$

$\mathcal{F}_{se}$ – the series magnetomotive force.

$\mathcal{F}_{AR}$ – the armature reaction magnetomotive force.

The equivalent effective shunt field current for this machine is given by:

$$N_F \times I_F^* = N_F \times I_F + N_{se} \times I_a - \mathcal{F}_{AR} \qquad \text{....... (2.13)}$$

$$I_F^* = I_F + (N_{se} / N_F) \times I_a - (\mathcal{F}_{AR} / N_F) \qquad \text{....... (2.14)}$$

Short – Shunt Cumulatively Compounded DC. Generator:

In the Short – Shunt connection, where the series field is outside the shunt field circuit and has (I_L) flowing through it instead of (**Ia**).

A Short – Shunt Cumulatively Compounded DC. Generator is shown in Fig (2.14)

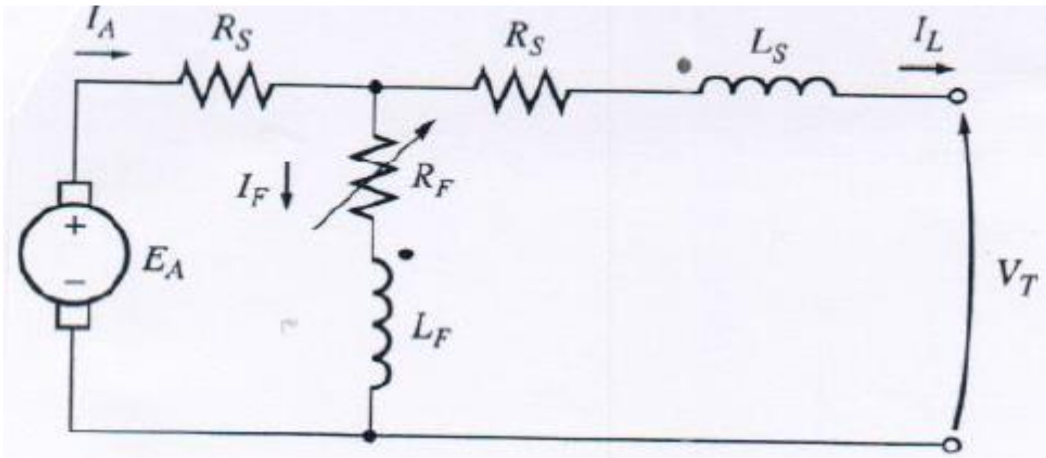


Fig (2.14) **The equivalent circuit of a Cumulatively Compounded Short Shunt connection**

The terminal characteristic of a Cumulatively Compounded d.c. Generator:

Suppose that the load on the generator is increased, then as the load increases, the load current (I_L) increases. Since:

$$\mathbf{Ia = I_F + I_L\uparrow}$$

The armature current (**Ia**) increases too. At this increases of **Ia** two effects occur in the generator:

1-As **Ia** increases, the:

Ia × **(Ra+ Rse)** voltage drop increase as well, This tends to cause a decrease in the terminal Voltage:

$$\mathbf{V_T = E_a - Ia\uparrow (Ra + Rse)}$$

2-As **Ia** increases, the series field magnetomotive force:

$\mathcal{F}_{se} =$ Nse × **Ia** increase too. This increase of $\mathcal{F}_{se}$ causes the total magnetomotive force: $\mathcal{F}_{TOT} = N_F \times I_F + (Nse \times Ia)\uparrow$ to increase, and as a result the flux in generator increase. The increased flux in generator increases $\mathbf{E_a}$ when in turns tends to make:

$$V_T = E_a\uparrow - I_a (R_a + R_{se}), \quad \text{so } V_T \text{ rise.}$$

If:

V_T full load > V_T No load, the generator is over Compounded.

V_T full load = V_T No load, the generator is flat Compounded.

V_T full load < V_T No load, the generator is under Compounded.

All these possibilities are illustrated in Fig (2.15).

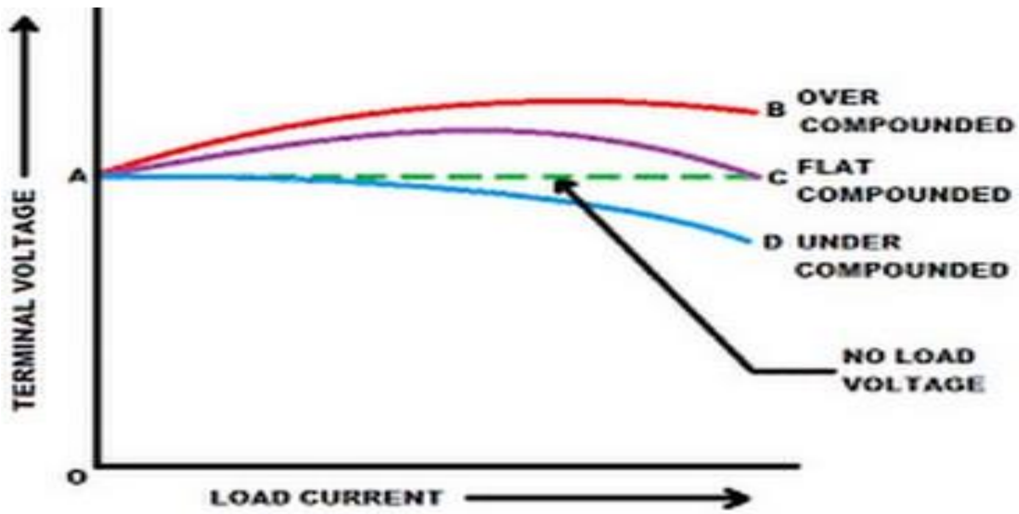


Fig (2.15). **The terminal characteristic of a Cumulatively Compounded d.c. Generator**

For:

a) Few Series turns (**Nse** small) →→ under Compounded.

b) More Series turns (**Nse** larger) →→ Flat Compounded.

c) Even more turns (Large) →→ Over Compounded.

The differentially Compounded d.c. Generator:

A differentially Compounded d.c. Generator is a generator with both shunt and series field, but this time their magnetomotive force subtract from each other, the equivalent circuit of a differentially Compounded d.c. Generator is shown in Fig(2.16).

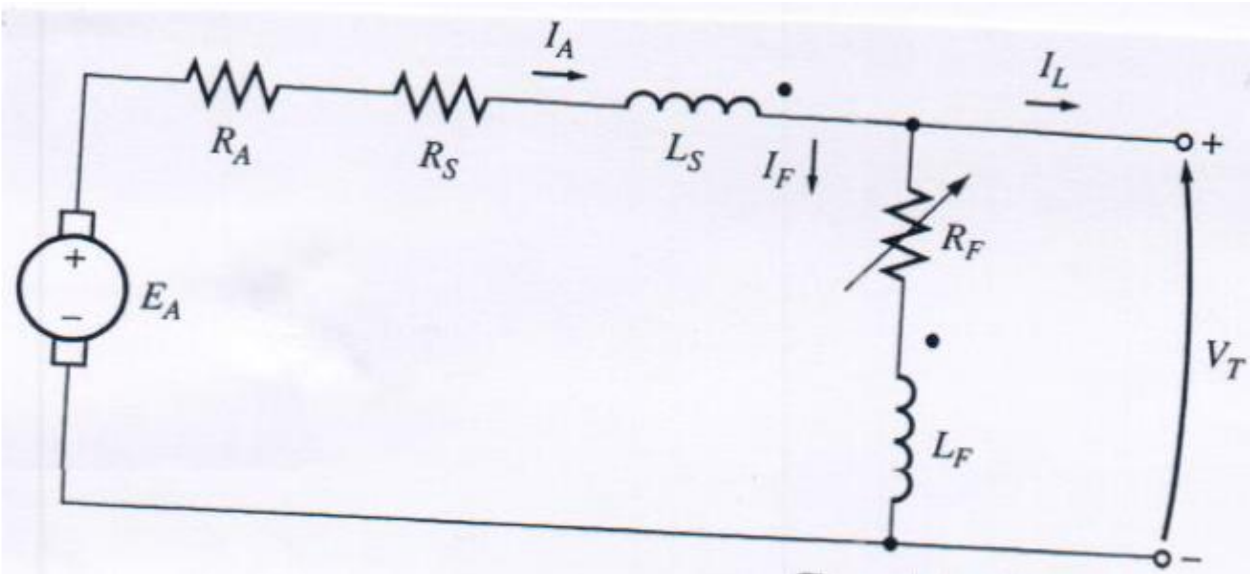


Fig (2.16). **The differentially Compounded d.c. Generator with long – shunt connection**

Notice that the armature current is now flowing OUT OF a dotted Coil end, while the shunt field current is flowing INTO a dotted end.

In this machine, the net magnetomotive force is:

$$\mathcal{F}_{net} = \mathcal{F}_F - \mathcal{F}_{se} - \mathcal{F}_{AR} \qquad \ldots\ldots\ (2.15)$$

$$= N_F \times I_F - N_{se} \times I_a - \mathcal{F}_{AR} \qquad \ldots\ldots\ (2.16)$$

$$I_a = I_F + I_L \qquad \ldots\ldots\ (2.17)$$

$$I_F = V_T / R_F \qquad \ldots\ldots\ (2.18)$$

$$V_T = E_a - I_a (R_a + R_{se}) \qquad \ldots\ldots\ (2.19)$$

The terminal characteristic of a differentially Compounded d.c. Generator:

In the differentially Compounded d.c. Generator, the same two effects occur that were present in the cumulatively Compounded d.c. Generator.

The effects both act in the same direction, they are:

1)As **Ia** increases, the: **Ia (Ra+ Rse)** voltage drop increase, this increase tends to cause the terminal voltage V_T to decrease:

$$V_T = E_a - I_a\uparrow (R_a + R_{se})$$

2) As **Ia** increase, the series magnetomotive force increase too:

$$\mathcal{F}_{se} = N_{se} \times I_a$$

This increase in series magnetomotive force, reduce the net magnetomotive force of the generator:

$\mathcal{F}_{TOT} = N_F \times I_F - N_{se} \times I_a$ $\rightarrow$ $\mathcal{F}_{TOT}$ decrease, and as($\mathcal{F}_{TOT}$) decrease which in turn reduces the net flux in the generator, a decrease in flux decreases $\mathbf{E_a}$, which in turn decreases $\mathbf{V_T}$.

Since both these effects tend to decrease $\mathbf{V_T}$, the voltage drops drastically as load is increased on the generator. A typical terminal characteristic for a differentially Compounded d.c. Generator as shown in Fig (2.17).

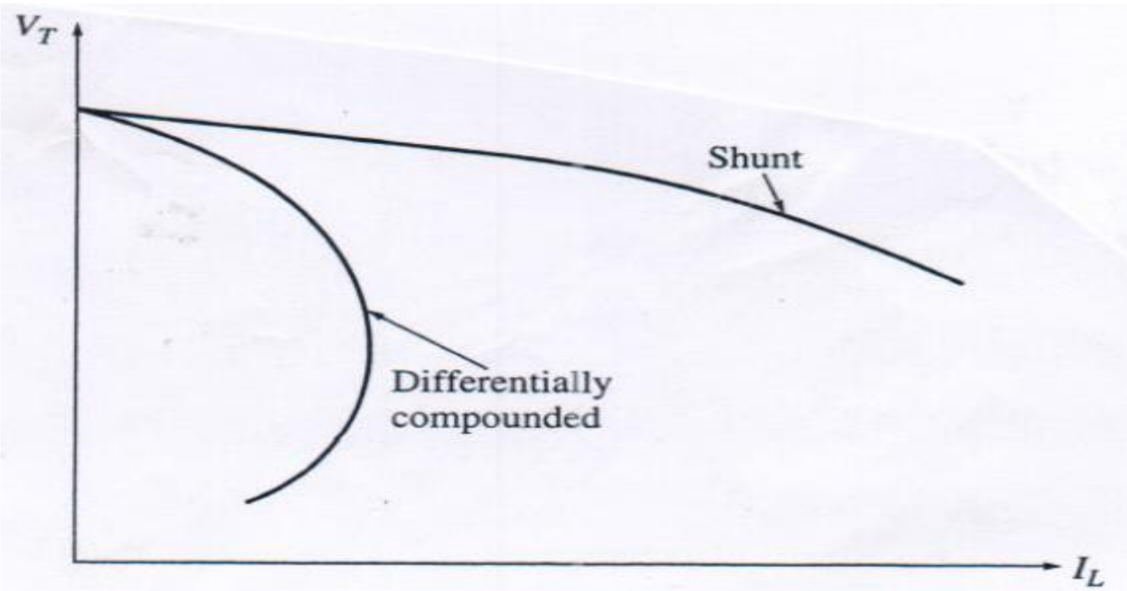


Fig (2.17) **terminal characteristic of a differentially Compounded d.c. Generator**

Applications of DC. Generators:

1) Separately Excited Generators

The Separately Excited are usually more expensive.

-Are used in Ward Leonard Systems of speed control.

- Because of their ability of giving wide range of voltage output, they are generally used for testing purpose in the laboratory

-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.

2) Shunt field DC. Generators

The application of shunt generators is very much restricted for its dropping voltage characteristic. They are used for general lighting.

1. Shunt DC. Generators are used to charge battery because they can be made to give constant output voltage.

2. They are used for giving the excitation to A.C. alternators.

3.They are also used for small power supply (such as a portable generator)

4. They are used for general lighting.

3. Series 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.

i) Series arc lightening.

ii) Series incandescent lightening

iii) As a series booster for increasing the voltage across the feeder carrying current furnished by some other sources.

iv) Special purpose such as supplying the field current for regenerative braking DC. Locomotives.

4. Compound Generators

The Compound Generators is used for more than any other type.

i) It may be built and adjusted automatically to supply an approximately constant voltage at the point of use.

ii) Differentially Compound Generators finds useful application as an arc welding generator.

iii) Compound Generators are used to supply power to:

-Railway Circuits.

-Motors of electrified steam Rail – Road.

-Industrial Motors in many fields of Industry.

-Elevator Motors.