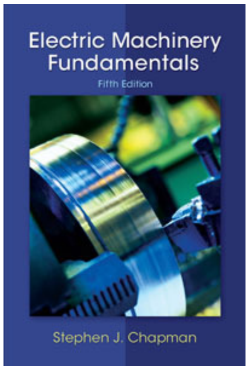


Chapter 8

DC Generators

The Equivalent Circuit of a DC Generator

- Terminal relationship is given by Kirchhoff's voltage law.

$$V_T = E_A - I_A R_A$$

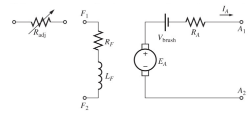


Figure 8-42
The equivalent circuit of a dc generator

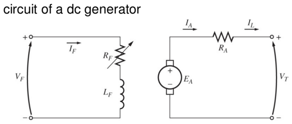


Figure 8-43
A simplified equivalent circuit eliminating the brush voltage drop and combining R_{adj} with the internal field resistance.

Terminal Characteristic of a Separately Excited DC Generator

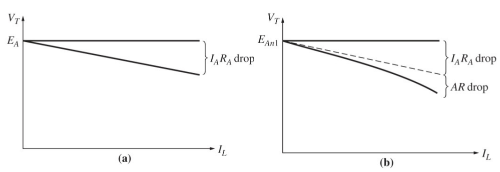


Figure 8-45
The terminal characteristic of a separately dc generator (a) with and (b) without compensating windings.

Nonlinear Analysis of a Separately Excited DC Generator

- The net mmf and the equivalent field current of the generator in the presence of the armature reaction are given by

$$F_{net} = N_F I_F - F_{AR}$$

$$I_F^* = I_F - \frac{F_{AR}}{N_F}$$

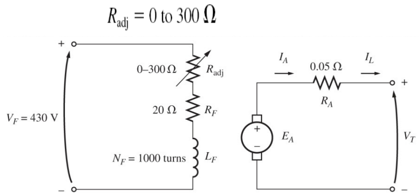
Nonlinear Analysis of a Separately Excited DC Generator

Example 8–9. A separately excited dc generator is rated at 172 kW, 430 V, 400 A, and 1800 r/min. It is shown in Figure 8–47, and its magnetization curve is shown in Figure 8–48. This machine has the following characteristics:

$R_A = 0.05\ \Omega$ $\quad V_F = 430$ V

$R_F = 20\ \Omega$ $\quad N_F = 1000$ turns per pole

$R_{adj} = 0$ to $300\ \Omega$



(*a*) If the variable resistor R_{adj} in this generator's field circuit is adjusted to 63 Ω and the generator's prime mover is driving it at 1600 r/min, what is this generator's no-load terminal voltage?

(*b*) What would its voltage be if a 360-A load were connected to its terminals? Assume that the generator has compensating windings.

(*c*) What would its voltage be if a 360-A load were connected to its terminals but the generator does not have compensating windings? Assume that its armature reaction at this load is 450 A • turns.

(*d*) What adjustment could be made to the generator to restore its terminal voltage to the value found in part *a*?

(*e*) How much field current would be needed to restore the terminal voltage to its no-load value? (Assume that the machine has compensating windings.) What is the required value for the resistor R_{adj} to accomplish this?

Solution

(a) If the generator's total field circuit resistance is

$$R_F + R_{adj} = 83\ \Omega$$

then the field current in the machine is

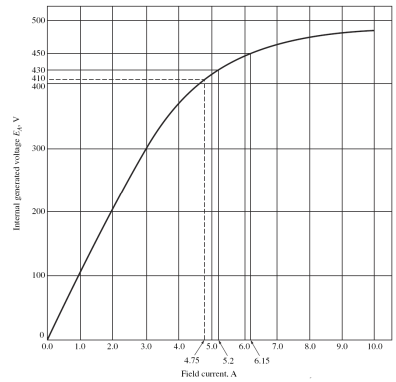
$$I_F = \frac{V_F}{R_F} = \frac{430\text{ V}}{83\ \Omega} = 5.2\text{ A}$$

From the machine's magnetization curve, this much current would produce a voltage $E_{A0} = 430$ V at a speed of 1800 r/min. Since this generator is actually turning at $n_m = 1600$ r/min, its internal generated voltage E_A will be

$$\frac{E_A}{E_{A0}} = \frac{n_m}{n_0} \qquad (8\text{–}13)$$

$$E_A = \frac{1600\text{ r/min}}{1800\text{ r/min}}\, 430\text{ V} = \boxed{382\text{ V}}$$

Since $V_T = E_A$ at no-load conditions, the output voltage of the generator is $V_T =$ 382 V.



Note: When the field current is zero, E_A is about 3 V.

(b) If a 360-A load were connected to this generator's terminals, the terminal voltage of the generator would be

$$V_T = E_A - I_A R_A = 382\text{ V} - (360\text{ A})(0.05\ \Omega) = 364\text{ V}$$

(c) If a 360-A load were connected to this generator's terminals and the generator had 450 A • turns of armature reaction, the effective field current would be

$$I_F^* = I_F - \frac{\mathscr{F}_{AR}}{N_F} = 5.2\text{ A} - \frac{450\text{ A} \bullet \text{turns}}{1000\text{ turns}} = 4.75\text{ A}$$

From the magnetization curve, $E_{A0} = 410$ V, so the internal generated voltage at 1600 r/min would be

$$\frac{E_A}{E_{A0}} = \frac{n}{n_0} \qquad (8\text{–}13)$$

$$E_A = \frac{1600\text{ r/min}}{1800\text{ r/min}}\, 410\text{ V} = 364\text{ V}$$

Therefore, the terminal voltage of the generator would be

$$V_T = E_A - I_A R_A = 364\text{ V} - (360\text{ A})(0.05\ \Omega) = 346\text{ V}$$

It is lower than before due to the armature reaction.

(d) The voltage at the terminals of the generator has fallen, so to restore it to its original value, the voltage of the generator must be increased. This requires an increase in E_A, which implies that R_{adj} must be decreased to increase the field current of the generator.

(e) For the terminal voltage to go back up to 382 V, the required value of E_A is

$$E_A = V_T + I_A R_A = 382\text{ V} + (360\text{ A})(0.05\ \Omega) = 400\text{ V}$$

To get a voltage E_A of 400 V at $n_m = 1600$ r/min, the equivalent voltage at 1800 r/min would be

$$\frac{E_A}{E_{A0}} = \frac{n_m}{n_0} \qquad (8\text{–}13)$$

$$E_{A0} = \frac{1800\text{ r/min}}{1600\text{ r/min}}\, 400\text{ V} = 450\text{ V}$$

From the magnetization curve, this voltage would require a field current of $I_F =$ 6.15 A. The field circuit resistance would have to be

$$R_F + R_{adj} = \frac{V_F}{I_F}$$

$$20\ \Omega + R_{adj} = \frac{430\text{ V}}{6.15\text{ A}} = 69.9\ \Omega$$

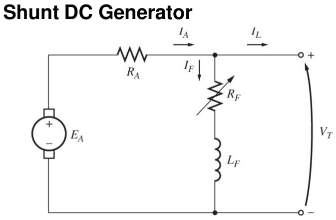
$$R_{adj} = 49.9\ \Omega \approx 50\ \Omega$$

Shunt DC Generator

$$\begin{cases} E_A = K\phi\omega_m \\ \tau_{ind} = K\phi I_A \\ V_T = E_A - R_A I_A \end{cases}$$

$$I_A = I_L + I_F$$

$$I_F = \frac{V_T}{R_F}$$



$As\ I_L \uparrow,\quad I_a \uparrow,\quad V_T \downarrow,\quad but\ \ I_f \downarrow,\quad \emptyset \downarrow,\quad E_a \downarrow,\quad V_T \downarrow$

Thus the load voltage (Vt) drops off somewhat more severely in a shunt connected DC generator as compared to the separately excited generator.

Terminal Characteristic of a Shunt DC Generator

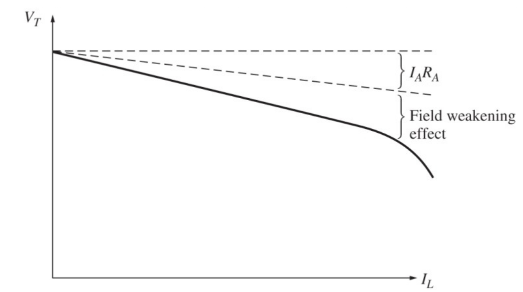


Figure 8-52
The terminal Characteristic of a Shunt DC Generator.

Voltage Buildup in a Shunt Generator

- Requires residual flux in the poles of the generator
- The field resistance should be less than $R_{critical}$

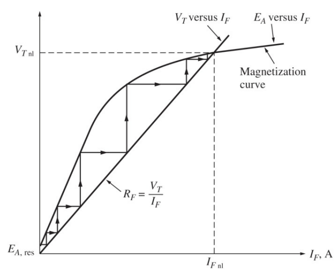


Figure 8-50
Voltage buildup on starting in a shunt dc generator.

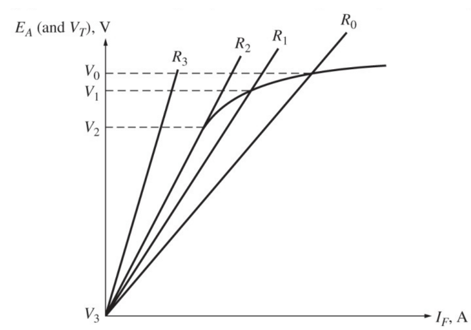


Figure 8-51
The effect of the shunt field resistance on no-load terminal voltage in a dc generator. If $R_F > R_2 = R_{critical}$, then generator's voltage will never build up.

The Analysis of a Shunt DC Generator

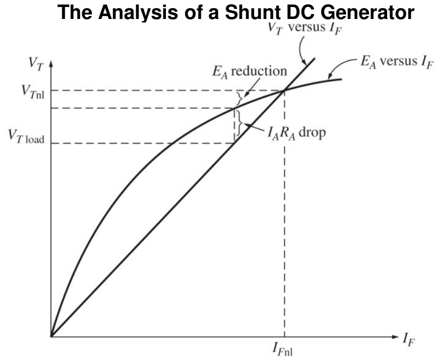


Figure 8-53
Graphical Analysis of a shunt dc generator with compensating windings.

The Analysis of a Shunt DC Generator Including Armature Reaction

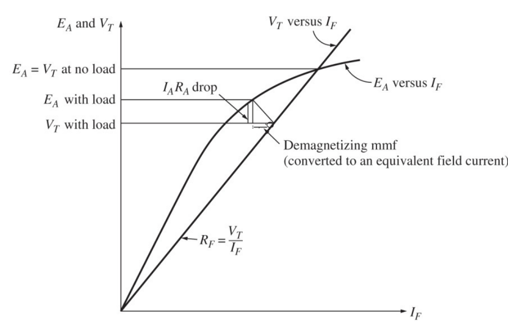
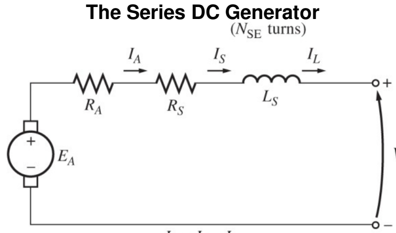


Figure 8-55
Graphical Analysis of a shunt dc generator with armature reaction.

The Series DC Generator



$I_A = I_S = I_L$
$V_T = E_A - I_A(R_A + R_S)$

Since $E_a = K\emptyset\omega = KK_f I_f \omega = KK_f I_a \omega$

For no-load, $I_L = 0,\ I_a = 0,\ I_f = 0, \emptyset = 0, E_a = 0$
With load $I_L \uparrow, E_a \uparrow, and\ V_t \uparrow = E_a - I_a(R_a + R_s + R_L)$

Terminal Characteristic of a Series DC Generator

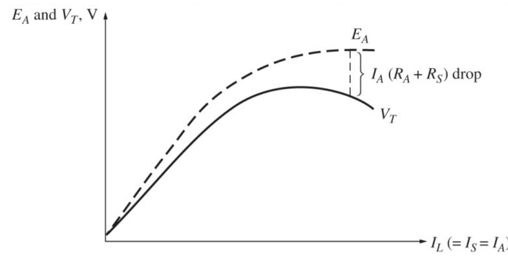


Figure 8-57
Terminal Characteristic of a series dc generator

Terminal Characteristic of a Series DC Generator Including Armature Reaction

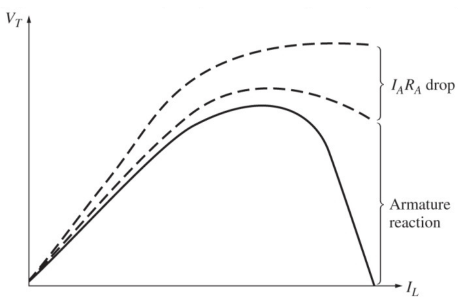
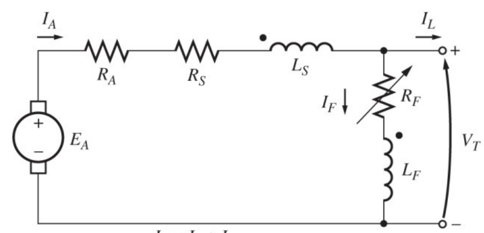


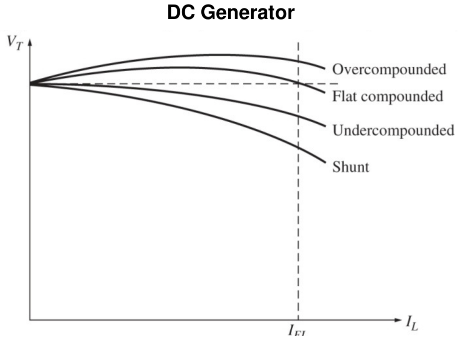
Figure 8-58
Terminal Characteristic of a series dc generator with large armature reaction effect, suitable for electric Welders.

The Cumulatively Compounded DC Generator



$I_A = I_L + I_F$
$V_T = E_A - I_A(R_A + R_S)$
$I_F = \frac{V_T}{R_F}$
$\mathscr{F}_{net} = N_F I_F + N_{SE} I_A - \mathscr{F}_{AR}$

Terminal Characteristic of a Cumulatively Compounded DC Generator



The Analysis of a Cumulatively Compounded DC Generator

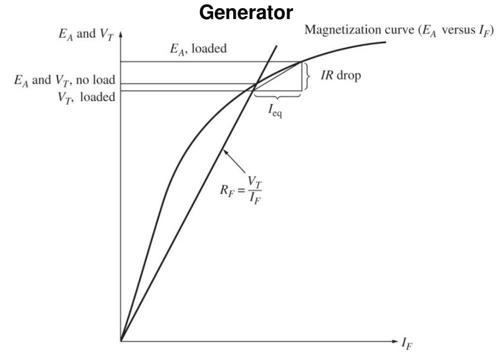
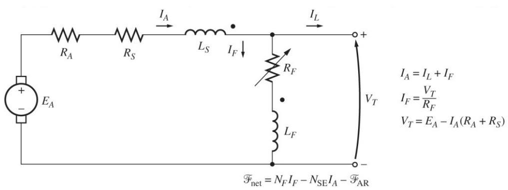
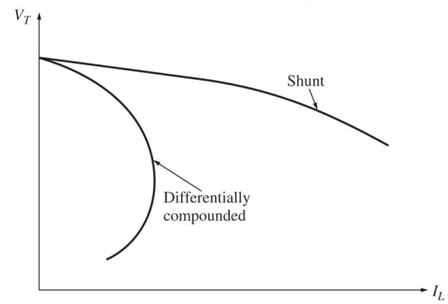


Figure 8-63
Graphical Analysis of a cumulatively compounded dc generator.

The Differentially Compounded DC Generator



Terminal Characteristic of a Differentially Compounded DC Generator



The Analysis of a Differentially Compounded DC Generator

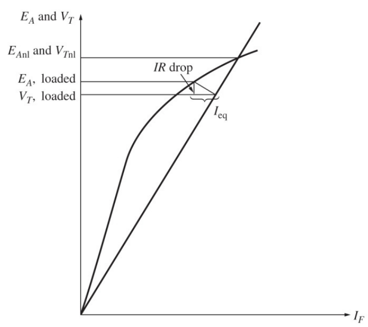
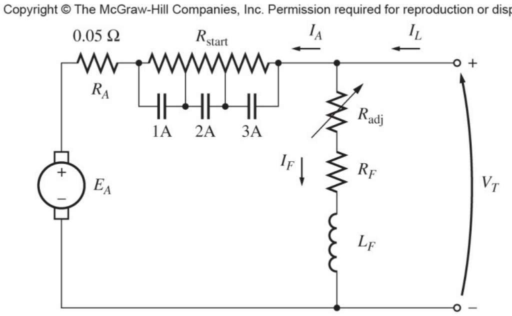
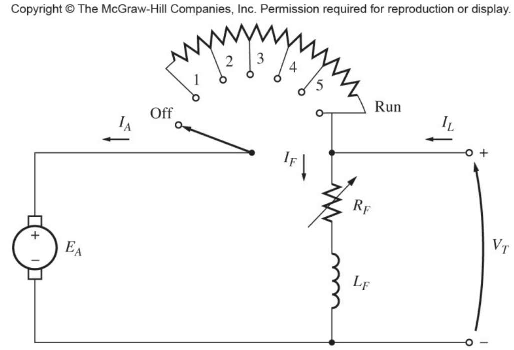


Figure 8-67
Graphical Analysis of a differentially compounded dc generator.

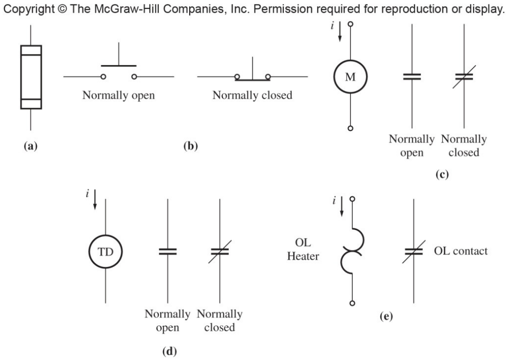
DC Motor Starting Circuits



Hand operated starting resistors

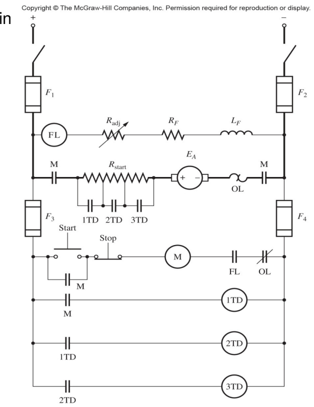


Starting circuit components



a) Fuse b) push button c) relay d)TD relay e) Over load

1. Press Start to energize main relay M.
2. All M contacts close.
3. 1TD Energized
4. 2TD energized
5. 3TD energized



1. Press Start to energize main relay M.
2. All M contacts close.
3. 1 AR, 2 AR, 3 AR Energized
4. 1A energized
5. 2A energized
6. 3A energized