

# Terminal Characteristic of a Separately Excited DC Generator VT EA IARA drop IARA dr

# 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

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

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

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### Nonlinear Analysis of a Separately Excited DC Generator

**Example 8-9.** A separately excited de 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:

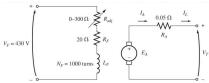
$$R_A = 0.05 \Omega$$

$$V_F = 430 \text{ V}$$

$$R_F = 20 \Omega$$

 $N_F = 1000$  turns per pole

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



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- (a) If the variable resistor  $R_{\rm adj}$  in this generator's field circuit is adjusted to 63  $\Omega$  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  $R_{\rm adj}$  to accomplish this?

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### Solution

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

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

then the field current in the machine is

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

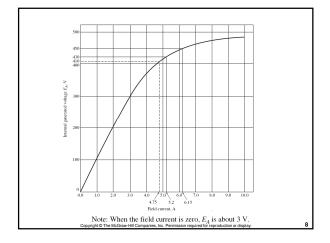
From the machine's magnetization curve, this much current would produce a voltage  $E_{A0}=430~{\rm V}$  at a speed of 1800 r/min. Since this generator is actually turning at  $n_m=1600~{\rm r/min}$ , its internal generated voltage  $E_A$  will be

$$\frac{E_A}{E_{A0}} = \frac{n_m}{n_0} \tag{8-13}$$

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

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

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(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

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

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

$$\frac{E_A}{E_{A0}} = \frac{n}{n_0}$$

$$E_A = \frac{1600 \text{ r/min}}{1800 \text{ r/min}} 410 \text{ V} = 364 \text{ V}$$
(8–13)

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.

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- (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  $R_{\rm adj}$  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

$$\frac{E_A}{E_{A0}} = \frac{n_m}{n_0}$$

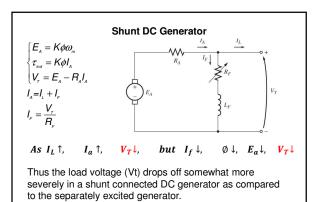
$$E_{A0} = \frac{1800 \text{ r/min}}{1600 \text{ r/min}} 400 \text{ V} = 450 \text{ V}$$
(8–13)

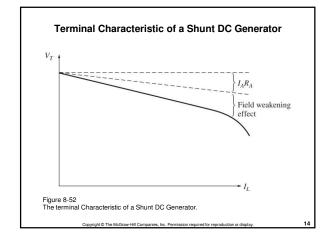
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From the magnetization curve, this voltage would require a field current of  $I_F = 6.15$  A. The field circuit resistance would have to be

$$\begin{split} R_F + R_{\rm adj} &= \frac{V_F}{I_F} \\ 20 \ \Omega + R_{\rm adj} &= \frac{430 \ \rm V}{6.15 \ \rm A} = 69.9 \ \Omega \\ R_{\rm adj} &= 49.9 \ \Omega \approx 50 \ \Omega \end{split}$$

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## Voltage Buildup in a Shunt Generator

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

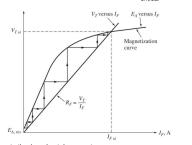


Figure 8-50 Voltage buildup on starting in a shunt dc generator.

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