Lesson 22: Self-Excited Dc Generators

ET 332a

Dc Motors, Generators and Energy Conversion Devices

Learning Objectives

After this presentation you will be able to:

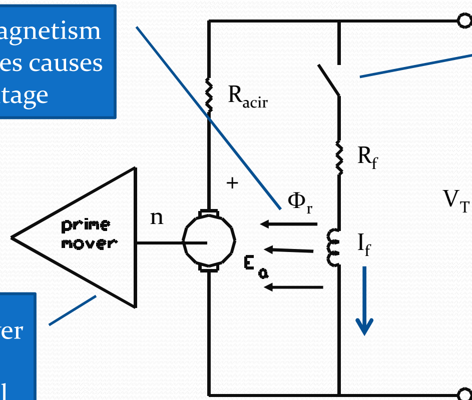
- Explain how a self-excited dc generator operates
- Explain how voltage builds in self-excited dc generators
- Use magnetization curves and dc machine formulas to find an unloaded generator's terminal voltage
- Identify the voltage characteristics of compound generators.

Self-Excited Generator Connection

With field switch open only residual flux can produce E_a

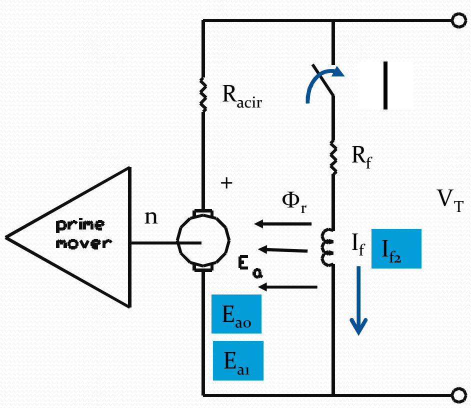
Residual magnetism in pole pieces causes induced voltage

Shunt field is connected in parallel with armature



Prime mover provides mechanical power

Voltage Buildup in Self-Excited Generators



1.) Residual magnetism causes E_{ao} with I_f=0

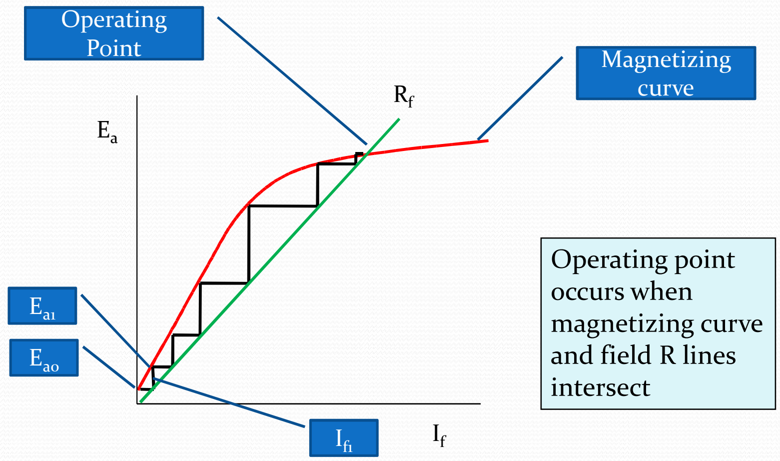
2.) Close switch and parallel armature and field E_a=V_T

3.) $E_{ao}/R_f = I_{f1}$ causes E_a to increase due to field flux increase

4.) E_a increases to E_{a1} causing I_{f2}

5.) Process repeats until operating point reached

Self-Excited Generator Graphical Analysis



Field Resistance and Voltage Buildup

Analytic methods

$$E_a = n \cdot \Phi_p \cdot k_G = n \cdot \left[\frac{N_f \cdot I_f}{\mathfrak{R}}\right] \cdot k_G$$

Reluctance is nonlinear w.r.t. I_f

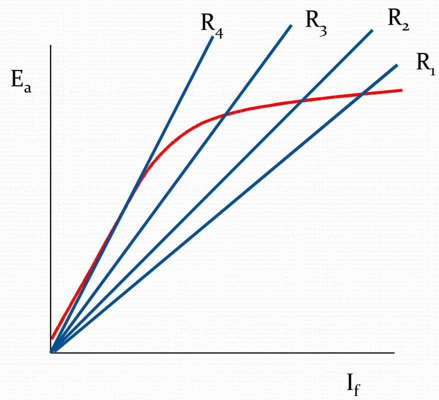
In field circuit $R = R_f + R_{rheo}$ and $V_T = E_a$ so

Equate field and armature circuit equations

$$I_f \cdot (R_f + R_{rheo}) = n \cdot \left[\frac{N_f \cdot I_f}{\mathfrak{R}}\right] \cdot k_G$$

Non-linear equation with respect to (w.r.t.) I_f. Difficult to solve.

Field Resistance and Voltage Buildup



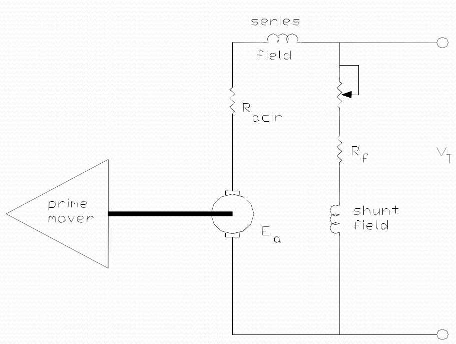
R_4 is critical resistance
E_a will not build up due to excessive field resistance

$R_4 > R_3 > R_2 > R_1$

$R = R_f + R_{rheo}$

Voltage Buildup and Speed

Speed of rotation effects the voltage buildup. Lower speed - lower E_a



Adjusting the rheostat controls terminal voltage. Critical resistance prevents voltage buildup at all speeds

Self-Excited Generator Example

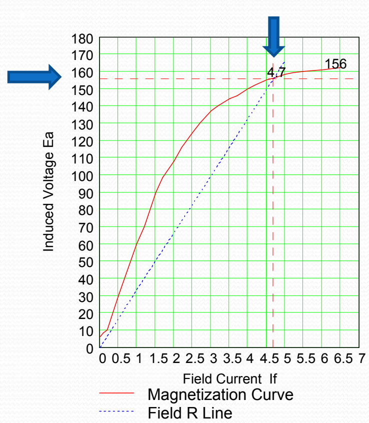
Example 22-1: Given a generators magnetization curve (Fig 12-4, p443, text). Self-excited generator ratings: 125 Vdc, 50 kW, 1750 rpm. No-load voltage with rheostat shorted 156 V

Determine:

a.) field circuit resistance
b.) field rheostat setting for no-load voltage of 140 Vdc
c.) armature voltage if rheostat is set at 14.23 ohms
d.) rheostat setting that will give critical resistance
e.) armature voltage at 80% rated speed and rheostat shorted
f.) rheostat setting for no-load voltage of 140 Vdc at 1750 rpm if field is separately excited from 120 Vdc source

Example 22-1 Solution (1)

Part a.) Field circuit resistance (rheostat shorted)



For voltage of 156 Vdc, graph gives current of 4.7 A

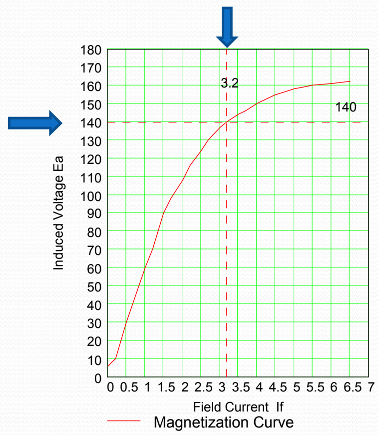
Use Ohm's Law to find the value of field resistance

$E_a = 156 \cdot V \qquad I_f = 4.7 \cdot A$

$R_f = \frac{E_a}{I_f} \qquad R_f = 33.2\,\text{ohm}$ Answer

Example 22-1 Solution (2)

Part b.) Rheostat setting to give E_a = 140 Vdc



Field current value from graph is 3.2 A

$E_a = 140 \cdot V \qquad I_f = 3.2 \cdot A$

Subtract off field resistance to find rheostat setting

$$R_{rheo} = \left(\frac{E_a}{I_f}\right) - R_f$$

140 V

33.2 Ω

3.2 A

$R_{rheo} = 10.6 \text{ ohm}$ Answer

Example 22-1 Solution (3)

Part c.) Find value of E_a when field rheostat increased to:

$$R_{rheo} = 14.23 \cdot \text{ohm}$$

Total field circuit resistance is: $R_f + R_{rheo} = 47.421 \text{ ohm}$

Graph this equation: $E_a = 47.421 \cdot I_f$

The value of E_a is where the above equation intersects the magnetization curve.

Example 22-1 Solution (4)

Part d.) Find the critical resistance value.

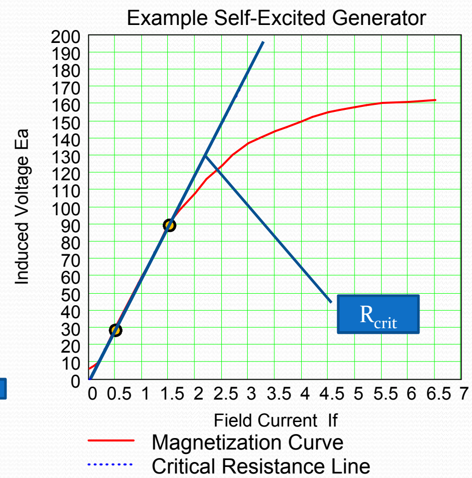
Critical resistance has the same value as the slope of the linear part of the generator's magnetization curve. Select two points and compute the slope

$E_{a1} = 90\ \text{V} \quad I_{f1} = 1.51\ \text{A}$

$E_{a2} = 30\ \text{V} \quad I_{f2} = 0.50\ \text{A}$

$$\frac{90 \cdot \text{V} - 30 \cdot \text{V}}{1.51 \cdot \text{A} - .5 \cdot \text{A}} = 59.4\ \text{ohm}$$ Ans

Plot the line $E_a = 59.4 \cdot I_f$ This is the critical resistance line

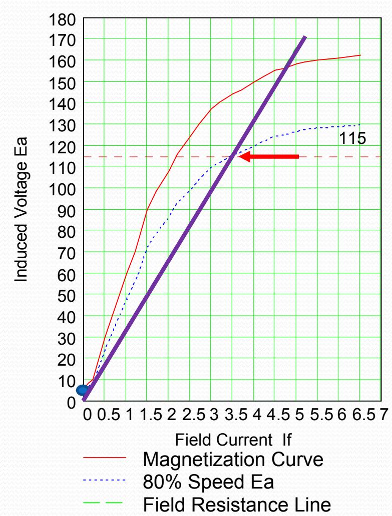


Example 22-1 Solution (5)

Part e.) Armature voltage at 80% rated speed and rheostat shorted out.

Multiply the rated speed E_a curve data by 0.80 to get new curve then plot the line $E_a = 33.2 \cdot I_f$ line. The intersection is the solution

$E_a = 115\ \text{V}$ Ans



Example 22-1 Solution (6)

Part f.) Find the field rheostat for separately excited operation for a 120 V dc source if E_a = 140 V dc

$V_f = 120\cdot V$

$R_f = 33.191\ ohm$

Separately excited source voltage and R_f from part a.)

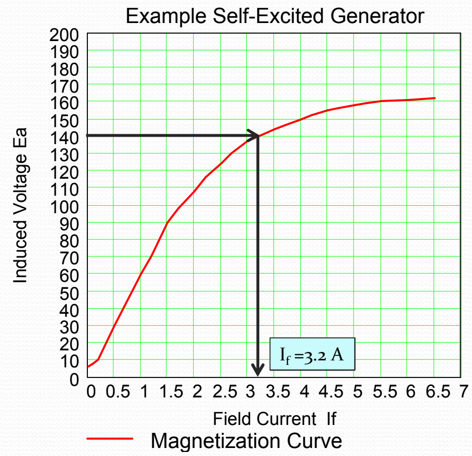
$$R_{rheo} = \frac{V_f}{I_f} - R_f$$

33.191 Ω

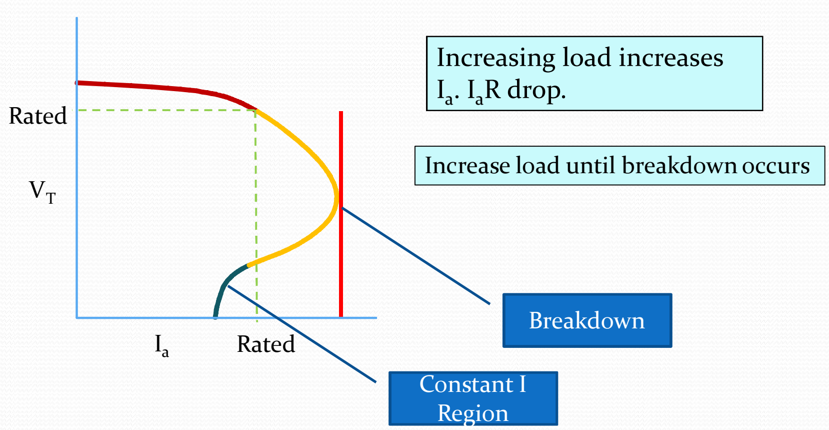
3.2 A

120 V

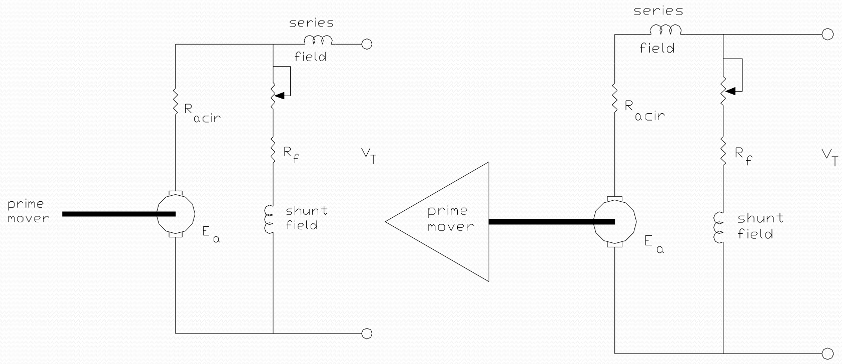
$R_{rheo} = 4.309\ ohm$ Ans



Terminal Voltage Characteristic



Compound Generator Connections



Short shunt connection
Avoids series field drop

Long shunt connection
Preferred in calculations

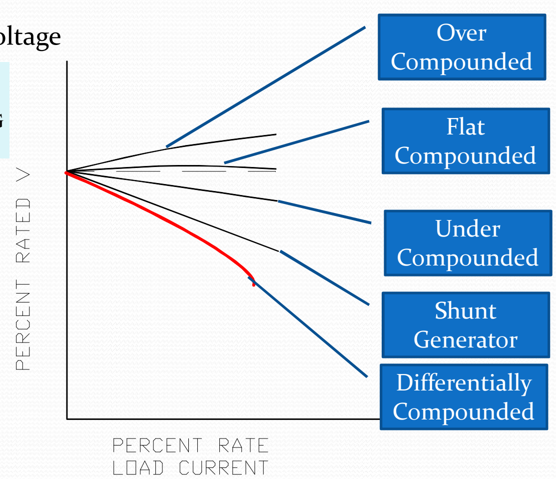
Compound Generator Characteristics

Loading effects on induced voltage

$$E_a = \left[\frac{\mathfrak{F}_f + \mathfrak{F}_s - \mathfrak{F}_d}{\mathfrak{R}}\right]\cdot k_G$$

$\mathfrak{F}_f$ = shunt field mmf
$\mathfrak{F}_s$ = series field mmf
$\mathfrak{F}_d$ = demagnetizing mmf

Series field flux related to load. Increasing load increases field flux which increase E_a.



End Lesson 22

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