EEE 205 Energy Conversion II

Synchronous Generator 2

A H Chowdhury, PhD
Professor
EEE, BUET

July 2018

Topic Content

Parallel operation of generators

- Requirement of parallel operation
- Conditions of parallel operation
- Synchronizing, effect of synchronizing current, hunting and oscillation, synchronoscope, phase sequence indicator
- Load distribution of alternators in parallel
  - Droop setting
  - Frequency control
  - Voltage control
  - House diagrams

Synchronous Generator Operating Alone

- Behavior of a synchronous generator under load varies greatly depending on
  - Power factor of the load
  - Whether generator is operating alone or in parallel with other synchronous generators

Synchronous Generator Operating Alone

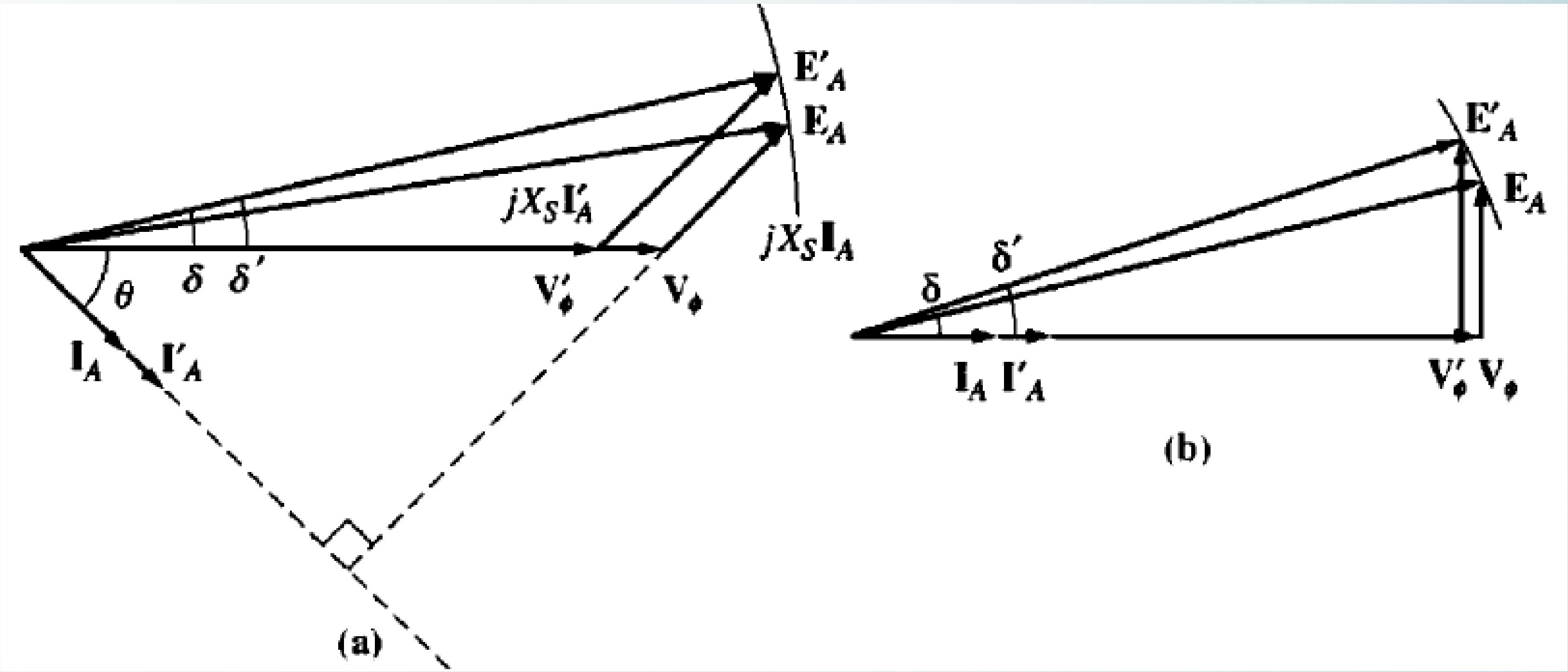
Effect of Load Changes

- Increase in load → increase in real and/or reactive power drawn from generator → increase in load current drawn from generator
- Since,
  - Field current constant → flux φ constant
  - Prime mover constant speed ω kept constant

Magnitude of internal generated voltage ($E_A = K\varphi\omega$) constant

Since E_A is constant, what does vary with a changing load?

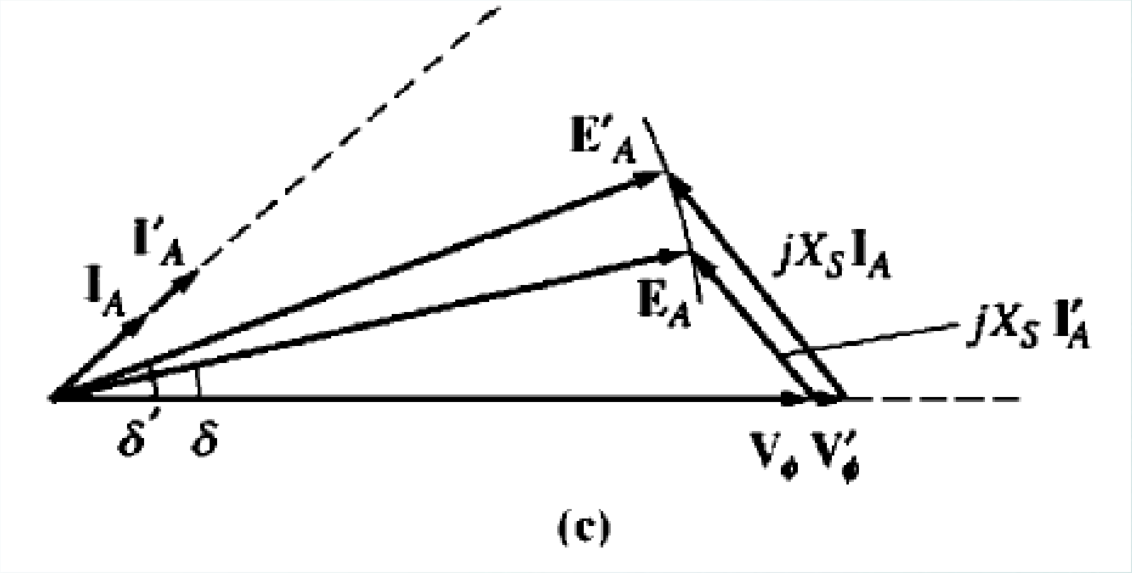
Synchronous Generator Operating Alone



Effect of increase in generator loads at constant power factor

(a) Lagging power factor load, (b) unity power factor load

Synchronous Generator Operating Alone



Effect of increase in generator loads at constant power factor

(c) Leading power factor load

Note the effect of terminal voltage *Vφ*

Synchronous Generator Operating Alone

- General conclusions from this discussion of synchronous generator behavior are

  1. Lagging loads → V_φ and V_T decrease significantly
  2. Unity-power-factor loads → slight decrease in V_φ and V_T
  3. Leading loads → V_φ and V_T will rise

Synchronous Generator Operating Alone

- A convenient way to compare voltage behavior of two generators is by their **voltage regulation**

$$\text{Voltage regulation} = \frac{V_{nl} - V_{fl}}{V_{fl}} \times 100\%$$

V_{nl} - no-load voltage of generator
V_{fl} - full-load voltage of generator

- Generator operating at
  - lagging power factor → fairly large positive voltage regulation
  - unity power factor → small positive voltage regulation
  - Leading power factor → often has a negative voltage regulation

Synchronous Generator Operating Alone

- Normally, it is desirable to keep voltage supplied to a load constant, even though the load itself varies
- **How can terminal voltage variations be corrected for?**

Synchronous Generator Operating Alone

Example 5–2. A 480-V, 60-Hz, Δ-connected, four-pole synchronous generator has the OCC shown in Figure 5–23a. This generator has a synchronous reactance of 0.1 Ω and an armature resistance of 0.015 Ω. At full load, the machine supplies 1200 A at 0.8 PF lagging. Under full-load conditions, the friction and windage losses are 40 kW, and the core losses are 30 kW. Ignore any field circuit losses.

(a) What is the speed of rotation of this generator?

(b) How much field current must be supplied to the generator to make the terminal voltage 480 V at no load?

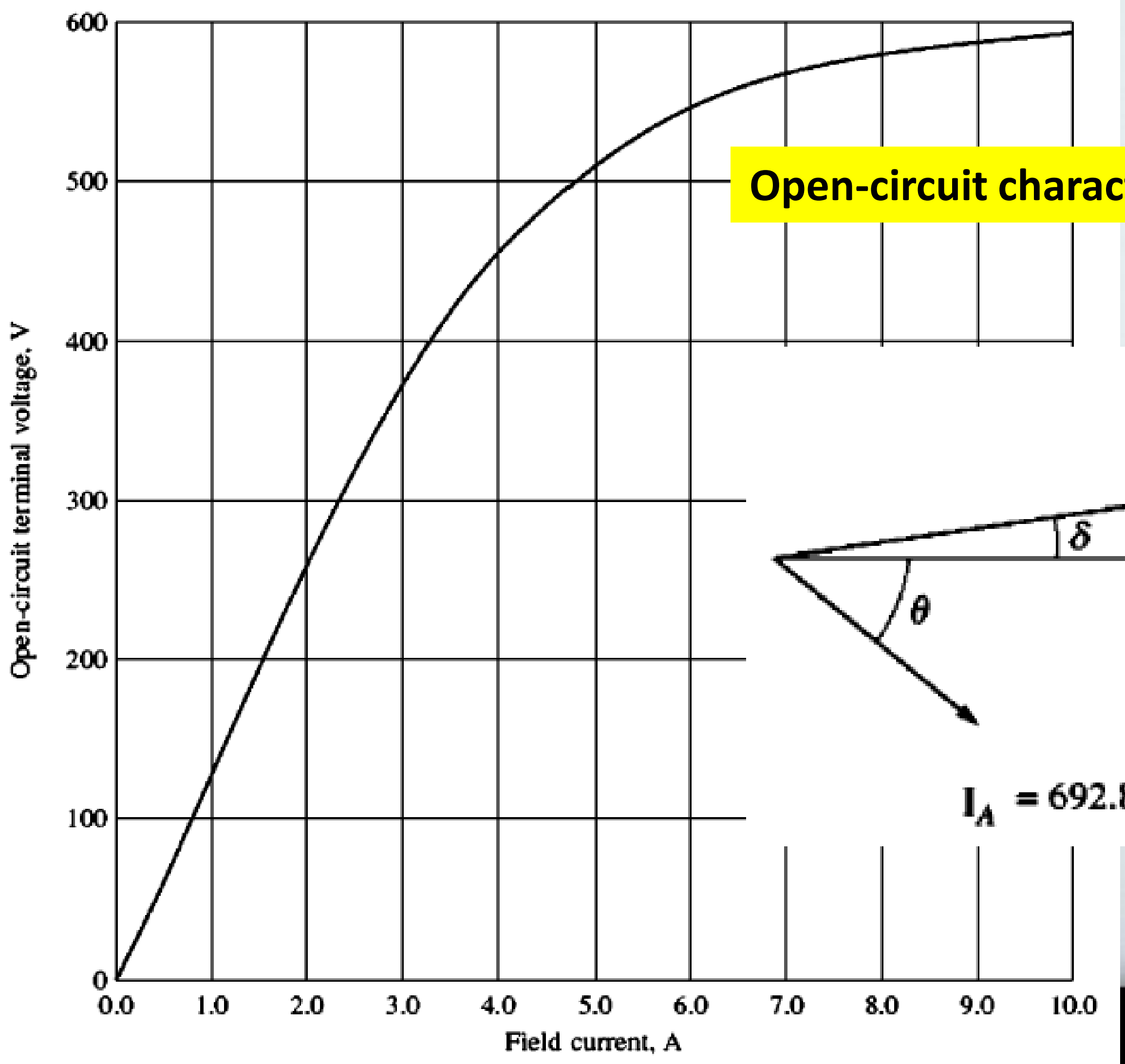
(c) If the generator is now connected to a load and the load draws 1200 A at 0.8 PF lagging, how much field current will be required to keep the terminal voltage equal to 480 V?

(d) How much power is the generator now supplying? How much power is supplied to the generator by the prime mover? What is this machine's overall efficiency?

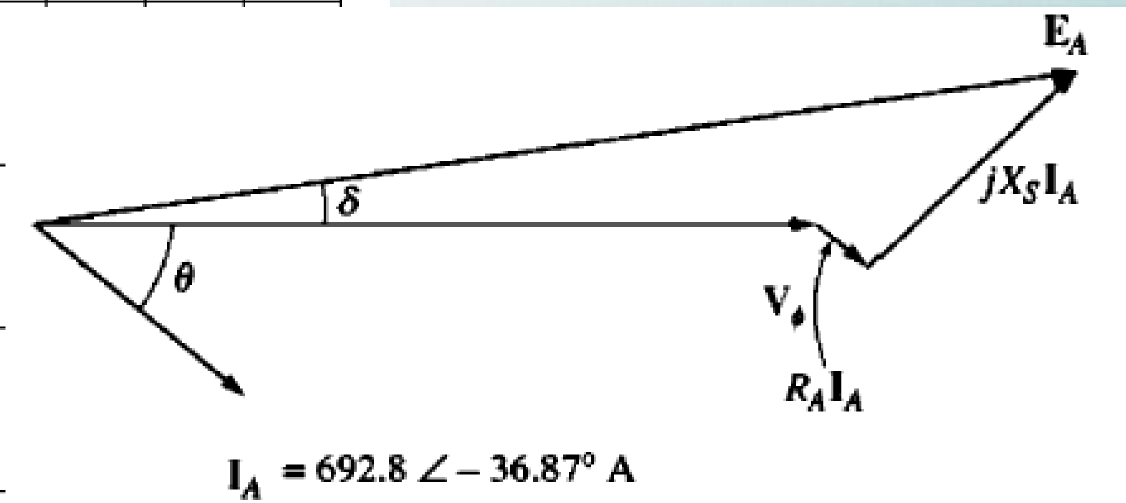
(e) If the generator's load were suddenly disconnected from the line, what would happen to its terminal voltage?

(f) Finally, suppose that the generator is connected to a load drawing 1200 A at 0.8 PF *leading*. How much field current would be required to keep V_T at 480 V?

Synchronous Generator Operating Alone



Open-circuit characteristic of the generator



Phasor diagram of the generator

Synchronous Generator Operating Alone

Solution

This synchronous generator is Δ-connected, so its phase voltage is equal to its line voltage $V_\phi = V_T$, while its phase current is related to its line current by the equation $I_L = \sqrt{3} I_\phi$.

(a) The relationship between the electrical frequency produced by a synchronous generator and the mechanical rate of shaft rotation is given by Equation (4–34):

$$f_e = \frac{n_m P}{120} \tag{4–34}$$

Therefore,

$$n_m = \frac{120 f_e}{P}$$

$$= \frac{120(60\text{ Hz})}{4\text{ poles}} = 1800\text{ r/min}$$

(b) In this machine, $V_T = V_\phi$. Since the generator is at no load, $\mathbf{I}_A = 0$ and $\mathbf{E}_A = \mathbf{V}_\phi$. Therefore, $V_T = V_\phi = E_A = 480$ V, and from the open-circuit characteristic, $I_F = 4.5$ A.

Synchronous Generator Operating Alone

(*c*) If the generator is supplying 1200 A, then the armature current in the machine is

$$I_A = \frac{1200 \text{ A}}{\sqrt{3}} = 692.8 \text{ A}$$

The phasor diagram for this generator is shown in Figure 5–23b. If the terminal voltage is adjusted to be 480 V, the size of the internal generated voltage $\mathbf{E}_A$ is given by

$$\begin{aligned}
\mathbf{E}_A &= \mathbf{V}_\phi + R_A\mathbf{I}_A + jX_S\mathbf{I}_A \\
&= 480\angle 0° \text{ V} + (0.015\ \Omega)(692.8\angle -36.87° \text{ A}) + (j0.1\ \Omega)(692.8\angle -36.87° \text{ A}) \\
&= 480\angle 0° \text{ V} + 10.39\angle -36.87° \text{ V} + 69.28\angle 53.13° \text{ V} \\
&= 529.9 + j49.2 \text{ V} = 532\angle 5.3° \text{ V}
\end{aligned}$$

To keep the terminal voltage at 480 V, $\mathbf{E}_A$ must be adjusted to 532 V. From Figure 5–23, the required field current is 5.7 A.

Synchronous Generator Operating Alone

(d) The power that the generator is now supplying can be found from Equation (5–16):

$$P_{out} = \sqrt{3}V_T I_L \cos\theta \qquad (5\text{–}16)$$
$$= \sqrt{3}(480\text{ V})(1200\text{ A})\cos 36.87°$$
$$= 798\text{ kW}$$

To determine the power input to the generator, use the power-flow diagram (Figure 5–15). From the power-flow diagram, the mechanical input power is given by

$$P_{in} = P_{out} + P_{elec\ loss} + P_{core\ loss} + P_{mech\ loss} + P_{stray\ loss}$$

The stray losses were not specified here, so they will be ignored. In this generator, the electrical losses are

$$P_{elec\ loss} = 3I_A^2 R_A$$
$$= 3(692.8\text{ A})^2(0.015\ \Omega) = 21.6\text{ kW}$$

Synchronous Generator Operating Alone

The core losses are 30 kW, and the friction and windage losses are 40 kW, so the total input power to the generator is

$$P_{in} = 798\ \text{kW} + 21.6\ \text{kW} + 30\ \text{kW} + 40\ \text{kW} = 889.6\ \text{kW}$$

Therefore, the machine's overall efficiency is

$$\eta = \frac{P_{out}}{P_{in}} \times 100\% = \frac{798\ \text{kW}}{889.6\ \text{kW}} \times 100\% = 89.75\%$$

(e) If the generator's load were suddenly disconnected from the line, the current $\mathbf{I}_A$ would drop to zero, making $\mathbf{E}_A = \mathbf{V}_\phi$. Since the field current has not changed, $|\mathbf{E}_A|$ has not changed and $\mathbf{V}_\phi$ and V_T must rise to equal $\mathbf{E}_A$. Therefore, if the load were suddenly dropped, the terminal voltage of the generator would rise to 532 V.

Synchronous Generator Operating Alone

(f) If the generator were loaded down with 1200 A at 0.8 PF leading while the terminal voltage was 480 V, then the internal generated voltage would have to be

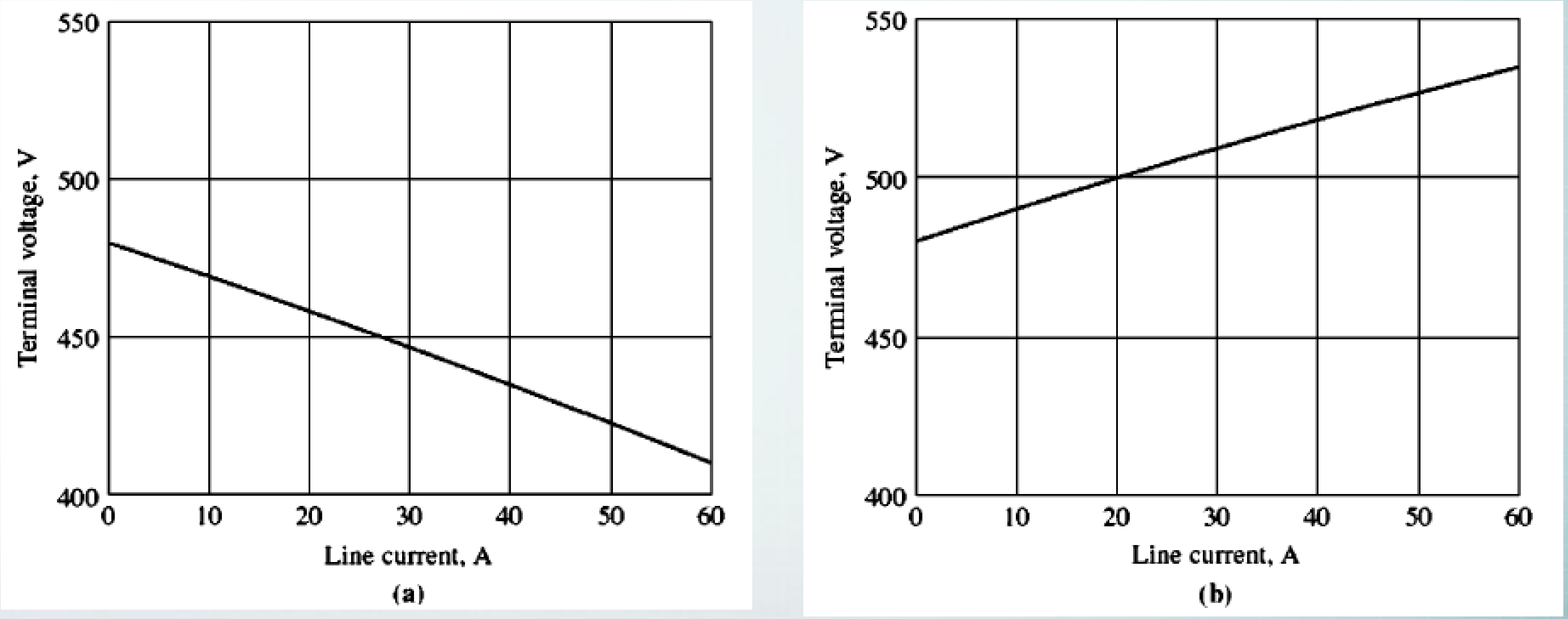
$$\mathbf{E}_A = \mathbf{V}_\phi + R_A\mathbf{I}_A + jX_S\mathbf{I}_A$$

$$= 480\angle 0° \text{ V} + (0.015\ \Omega)(692.8\angle 36.87° \text{ A}) + (j0.1\ \Omega)(692.8\angle 36.87° \text{ A})$$
$$= 480\angle 0° \text{ V} + 10.39\angle 36.87° \text{ V} + 69.28\angle 126.87° \text{ V}$$
$$= 446.7 + j61.7 \text{ V} = 451\angle 7.1° \text{ V}$$

Therefore, the internal generated voltage E_A must be adjusted to provide 451 V if V_T is to remain 480 V. Using the open-circuit characteristic, the field current would have to be adjusted to 4.1 A.

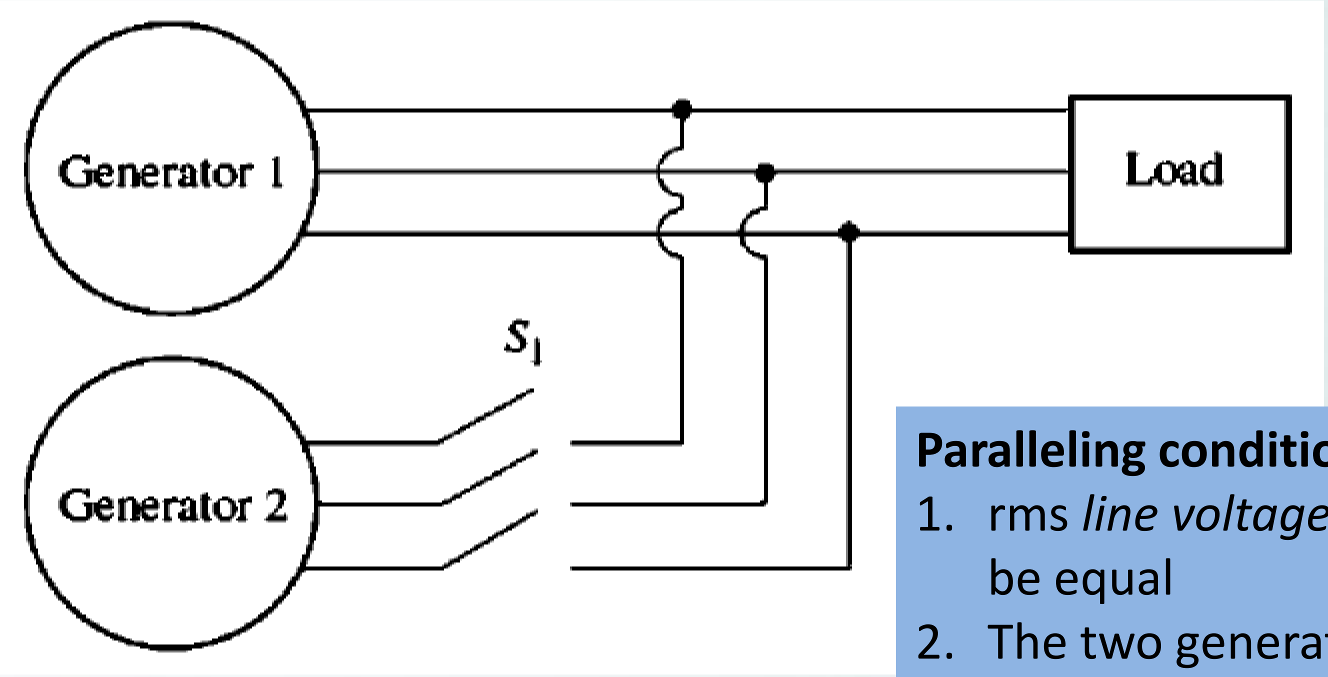
Synchronous Generator Operating Alone

Terminal characteristic of a synchronous generator



(a) When loaded with an 0.8 PF lagging load (b) When loaded with an 0.8 PF leading load

Parallel Operation of Synchronous Generator



Paralleling conditions

1. rms *line voltages* of two generators must be equal
2. The two generators must have same *phase sequence*
3. Phase angles of the two *a* phases must be equal
4. Frequency of *oncoming generator*, must be slightly higher than frequency of running system

Parallel Operation of Synchronous Generator

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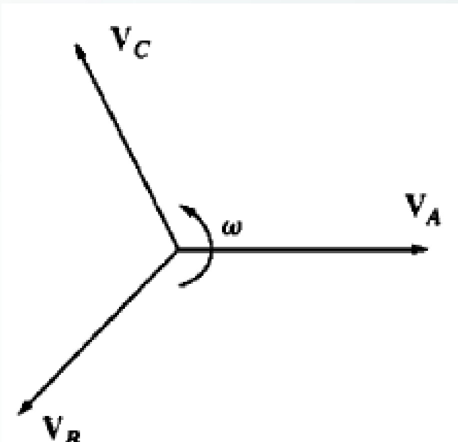
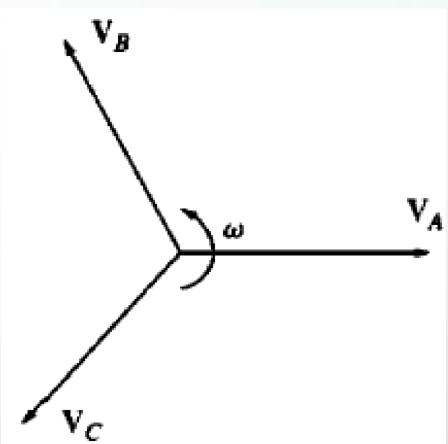
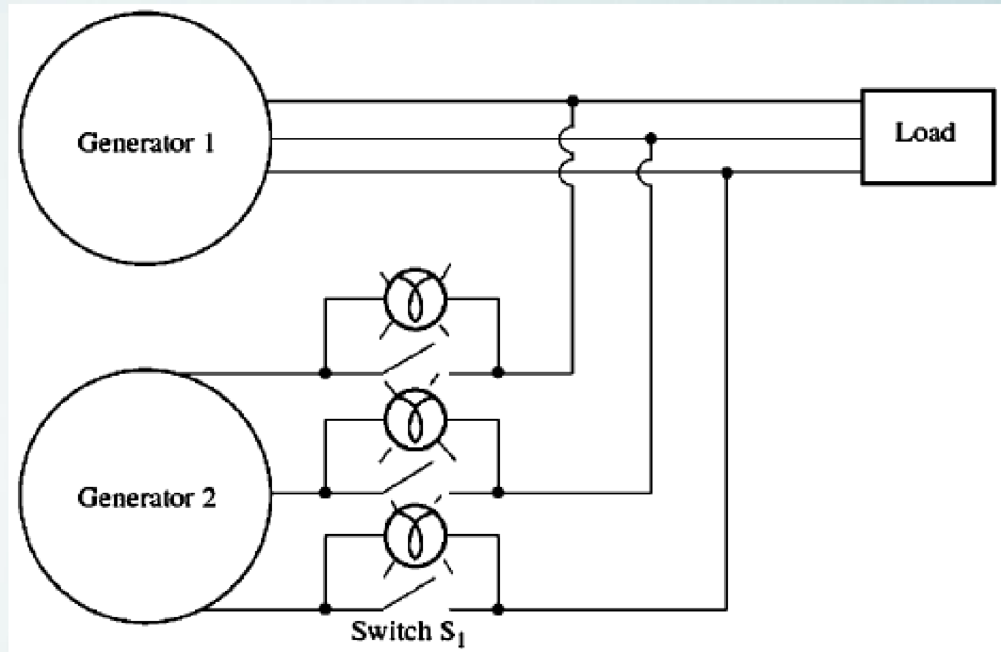


abc phase sequence



acb phase sequence

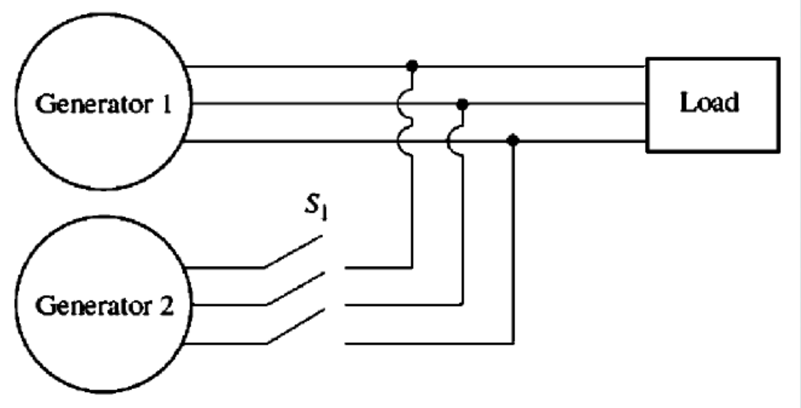


Three-light-bulb method to check phase sequence

- If all three bulbs get bright and dark together, systems have the same phase sequence
- If bulbs brighten in succession, systems have opposite phase sequence

General Procedure for Paralleling Generators

G2 is on coming generator



1. Field current of G2 adjusted until its V_T equal to line voltage of running system
2. Phase sequence of G2 compared to phase sequence of running system

- Alternately connect a small induction motor to terminals of each of the two generators
- If motor rotates in the same direction each time, phase sequence same for both generators

3. When frequencies are very nearly equal , voltages in two systems change phase with respect to each other very slowly → phase changes observed, and when phase angles are equal, switch is closed

Frequency-Power & Voltage-Var Characteristics

- All generators are driven by a prime mover (steam turbine, gas turbines, water turbines, wind turbines, diesel engines etc.)
- Prime movers slows down as power drawn from them increases
  - Decrease in speed is in general nonlinear, but governor mechanism make speed change linear with change in power demand
  - Slight drooping characteristic with increasing load
- Speed droop (SD) of a prime mover $$\mathrm{SD} = \frac{n_{\mathrm{nl}} - n_{\mathrm{fl}}}{n_{\mathrm{fl}}} \times 100\%$$ Generally 2-4%

  - n_{nl} - no-load prime-mover speed; n_{fl} - full-load prime-mover speed
- Most governors have some type of set point adjustment to allow the no-load speed of the turbine to be varied.

Frequency-Power & Voltage-Var Characteristics

- Shaft speed is related to resulting electrical frequency

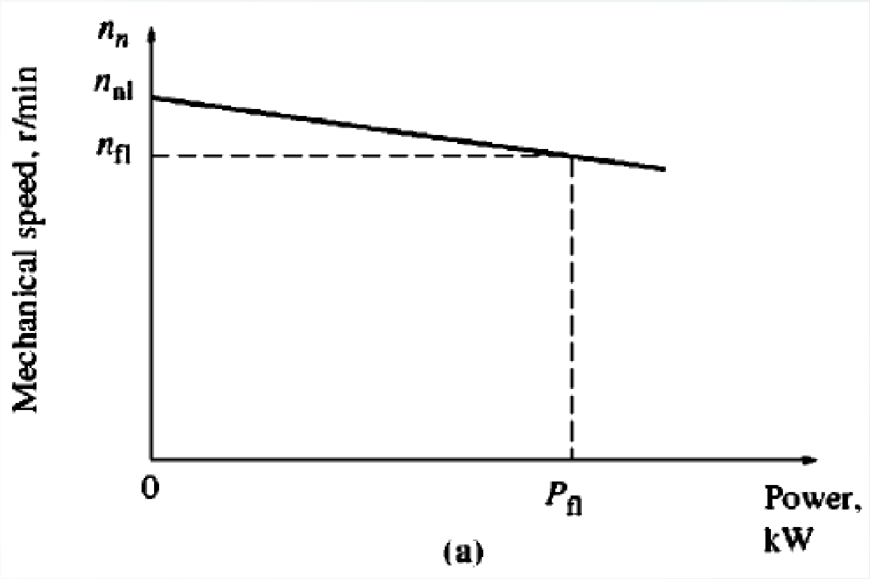
$$f_e = \frac{n_m P}{120}$$

- So, power output of a synchronous generator is related to its frequency
- Relationship between frequency and power can be described quantitatively by the equation

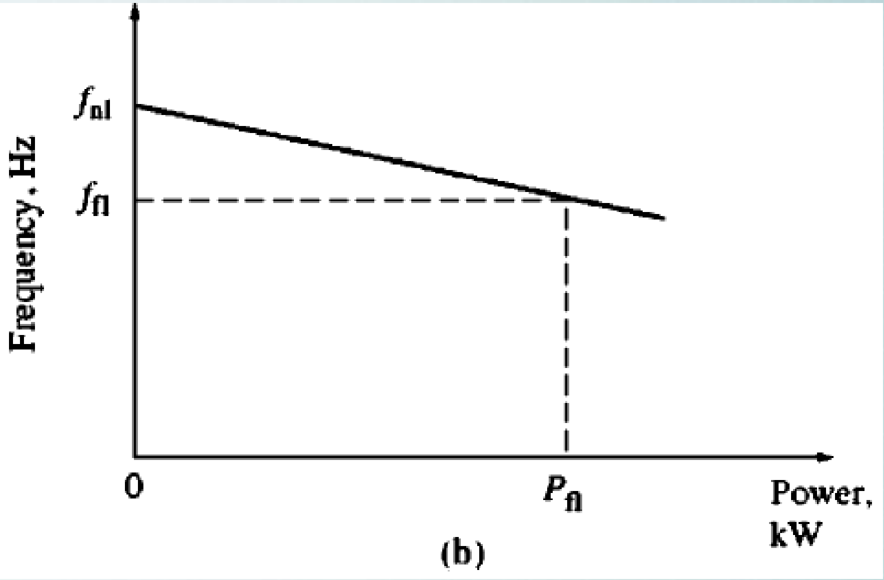
$$P = s_P(f_{\mathrm{nl}} - f_{\mathrm{sys}})$$

P = power output of the generator
f_{nl} = no-load frequency of the generator
f_{sys} = operating frequency of system
s_P = slope of curve, in kW/Hz or MW/Hz

Frequency-Power & Voltage-Var Characteristics

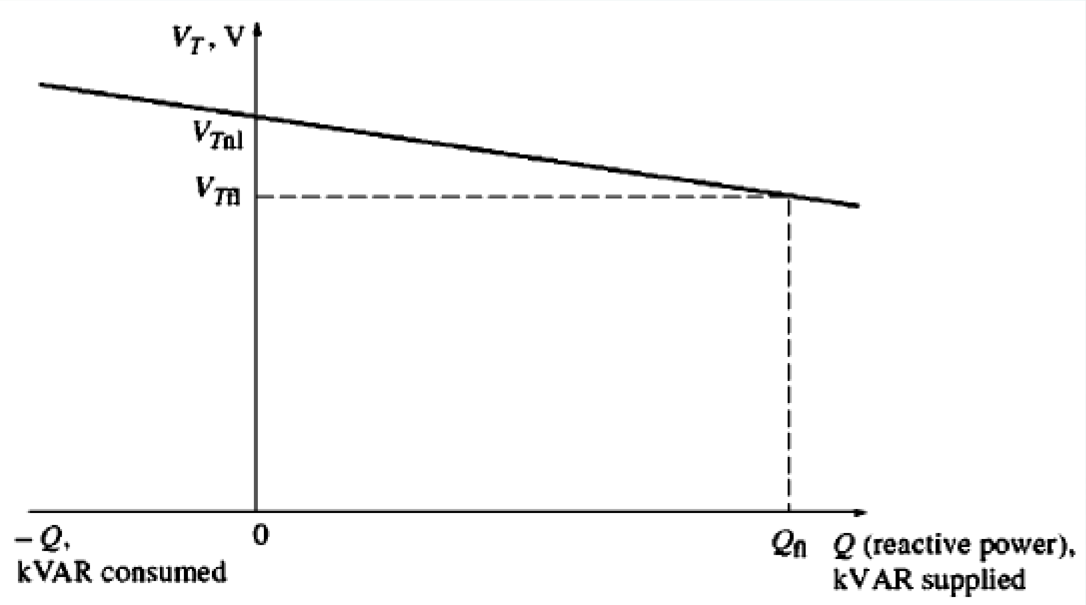


Speed-versus-power curve for a typical prime mover



Resulting frequency-versus-power curve for the generator

Frequency-Power & Voltage-Var Characteristics



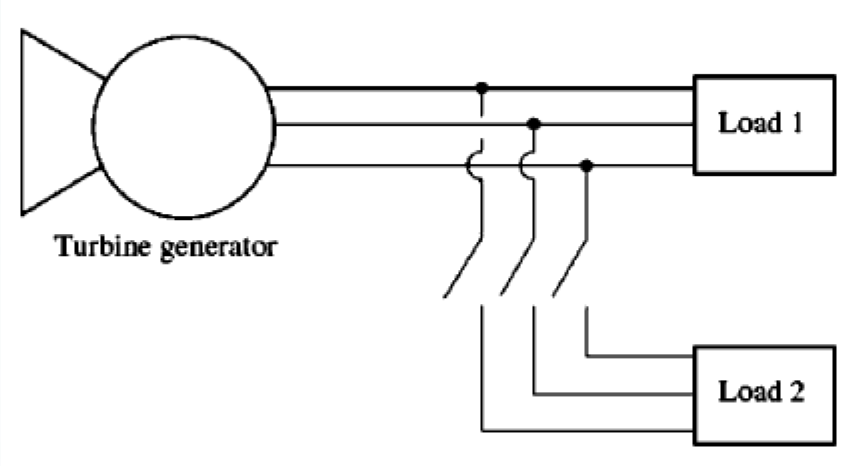
Terminal voltage (V_T) versus reactive power (Q) for a synchronous generator

- This characteristic is not intrinsically linear, but generator voltage regulators include a feature to make it so
- Characteristic curve can be moved up and down by changing no-load terminal voltage set point on the voltage regulator

Frequency-Power & Voltage-Var Characteristics

- When a single generator is operating alone,
- real power *P* and reactive power *Q* supplied by generator determined by the load connected to the generator
  - *P* and *Q* supplied cannot be controlled by generator's controls
- Therefore,
  - for any given ***P***, governor set points control generator's operating frequency f_e
  - for any given ***Q***, field current controls terminal voltage V_T

Frequency-Power & Voltage-Var Characteristics



Example 5–5. Figure above shows a generator supplying a load. A second load is to be connected in parallel with the first one. The generator has a no-load frequency of 61.0 Hz and a slope s_P of 1 MW/Hz. Load 1 consumes a real power of 1000 kW at 0.8 PF lagging, while load 2 consumes a real power of 800 kW at 0.707 PF lagging.

(a) Before the switch is closed, what is the operating frequency of the system?
(b) After load 2 is connected, what is the operating frequency of the system?
(c) After load 2 is connected, what action could an operator take to restore the system frequency to 60 Hz?

Frequency-Power & Voltage-Var Characteristics

Solution

This problem states that the slope of the generator's characteristic is 1 MW/Hz and that its no-load frequency is 61 Hz. Therefore, the power produced by the generator is given by

$$P = s_P(f_{nl} - f_{sys}) \tag{5–28}$$

so

$$f_{sys} = f_{nl} - \frac{P}{s_P}$$

(a) The initial system frequency is given by

$$\begin{aligned} f_{sys} &= f_{nl} - \frac{P}{s_P} \\ &= 61\text{ Hz} - \frac{1000\text{ kW}}{1\text{ MW/Hz}} = 61\text{ Hz} - 1\text{ Hz} = 60\text{ Hz} \end{aligned}$$

(b) After load 2 is connected,

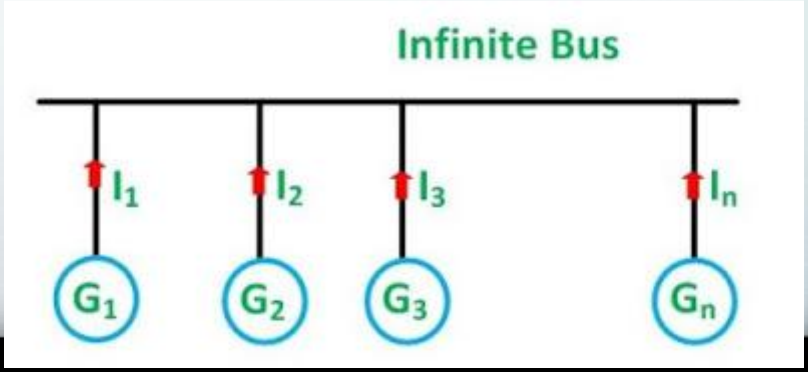
$$\begin{aligned} f_{sys} &= f_{nl} - \frac{P}{s_P} \\ &= 61\text{ Hz} - \frac{1800\text{ kW}}{1\text{ MW/Hz}} = 61\text{ Hz} - 1.8\text{ Hz} = 59.2\text{ Hz} \end{aligned}$$

Frequency-Power & Voltage-Var Characteristics

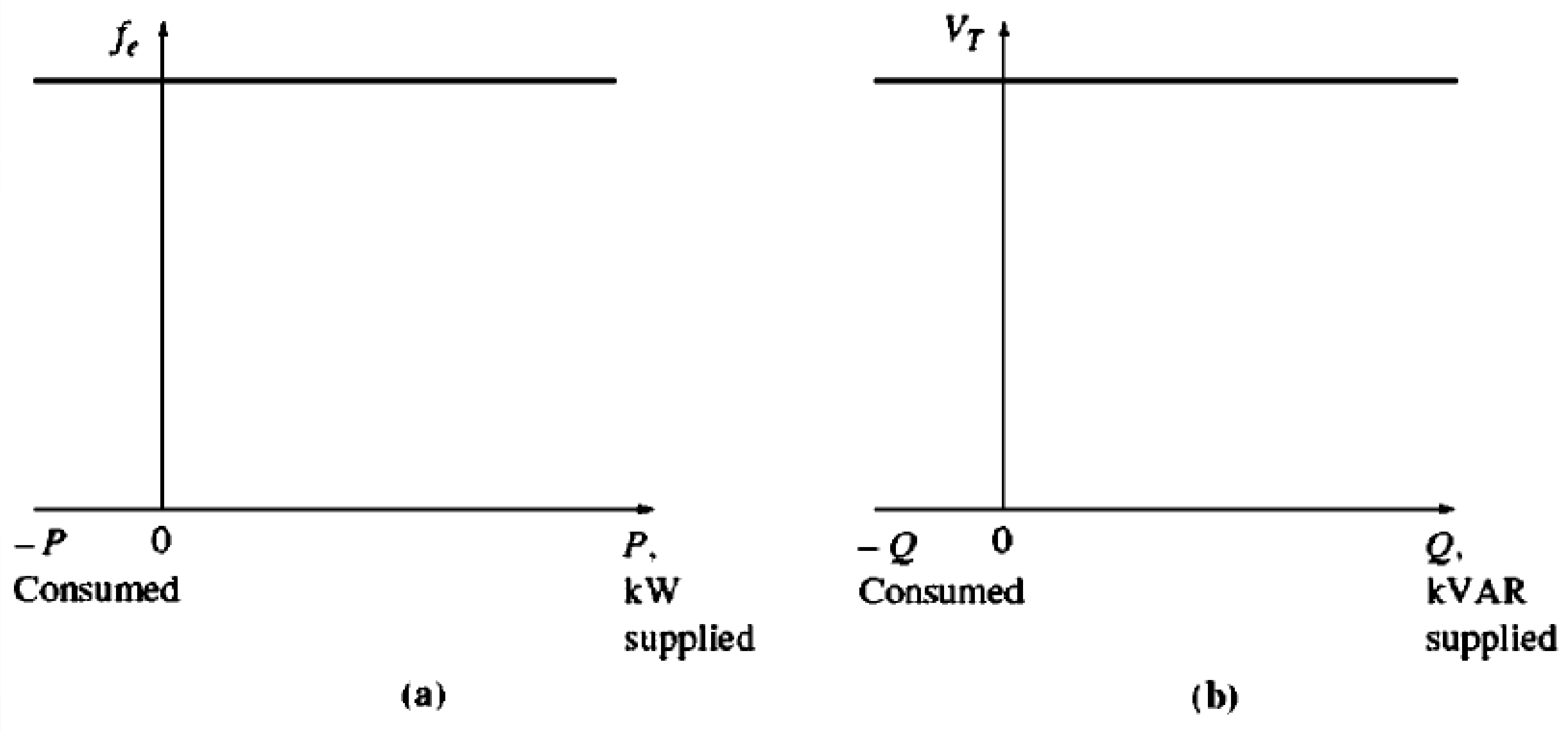
(c) After the load is connected, the system frequency falls to 59.2 Hz. To restore the system to its proper operating frequency, the operator should increase the governor no-load set points by 0.8 Hz, to 61.8 Hz. This action will restore the system frequency to 60 Hz.

Generators in Parallel with Large Power Systems

- An **infinite bus** is a power system so large that its voltage and frequency do not vary regardless of how much real and reactive power is drawn from or supplied to it
  - Represented by an equivalent generator having infinite moment of Inertia, so that there will be no change in speed for any load addition and zero synchronous reactance, X_s so that there is no voltage drop for any load current and $V_T = E_A$
- ***Example*** - alternators operating in parallel in a power system

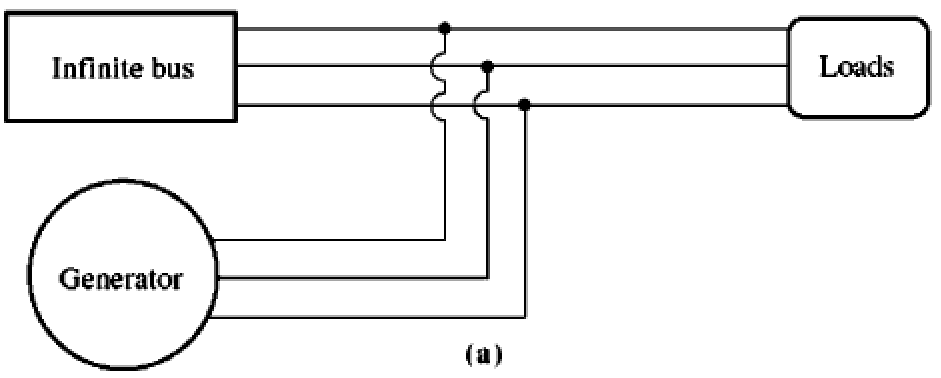


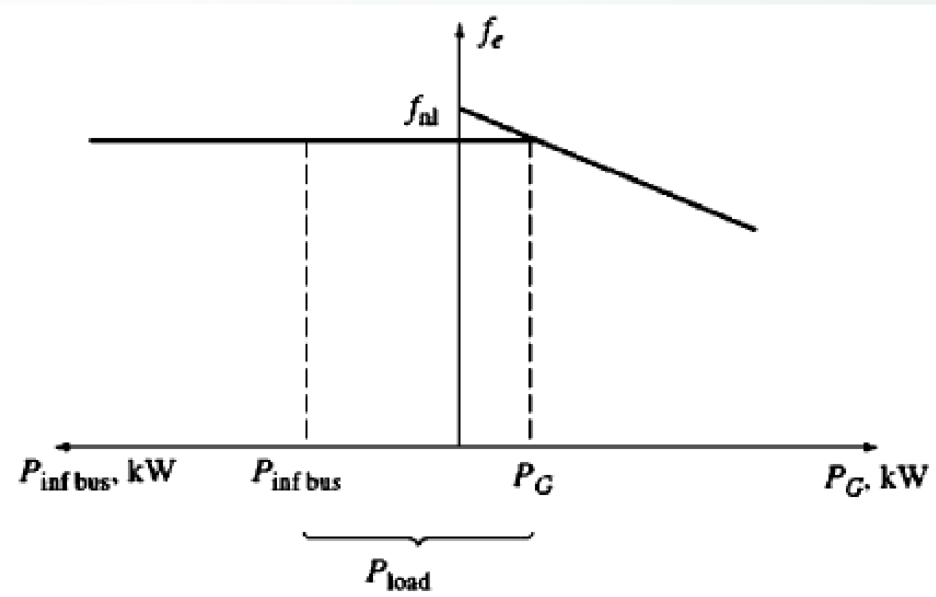
Generators in Parallel with Large Power Systems



Curves for an infinite bus: (a) frequency versus power and (b) terminal voltage versus reactive power

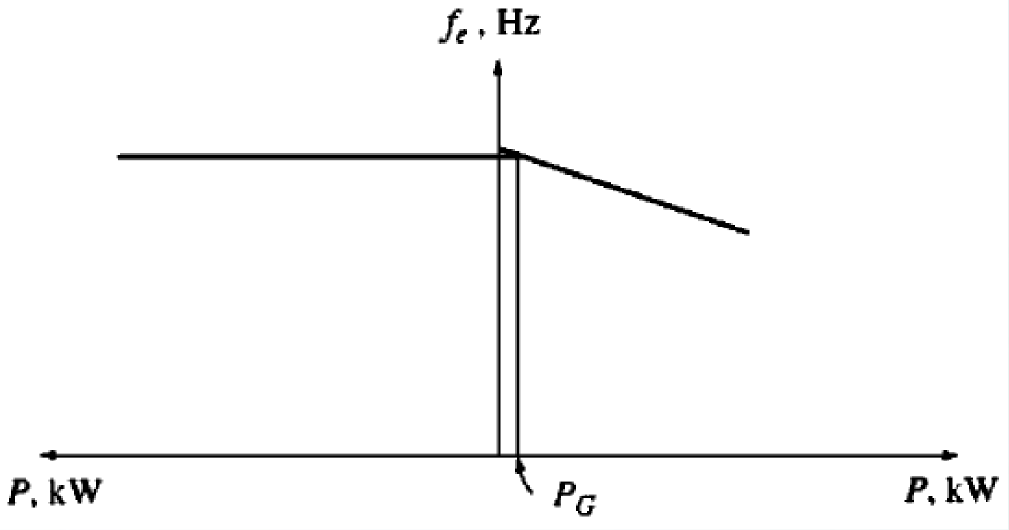
Generators in Parallel with Large Power Systems



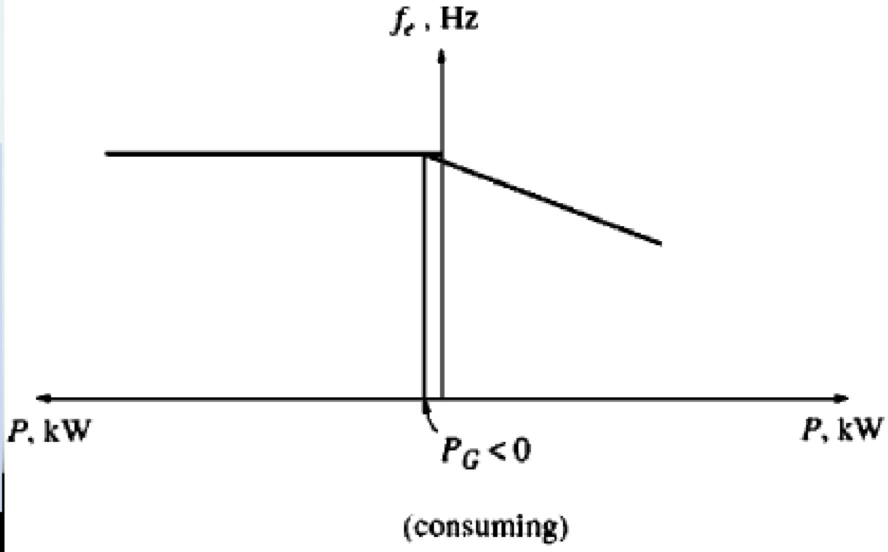


- When a generator is connected in parallel with another generator or a large system, *frequency* and *terminal voltage* of all the machines must be the same
- their *P-f* and *Q-*V_T can be plotted back to back, with a common vertical axis → called **house diagram**

Generators in Parallel with Large Power Systems

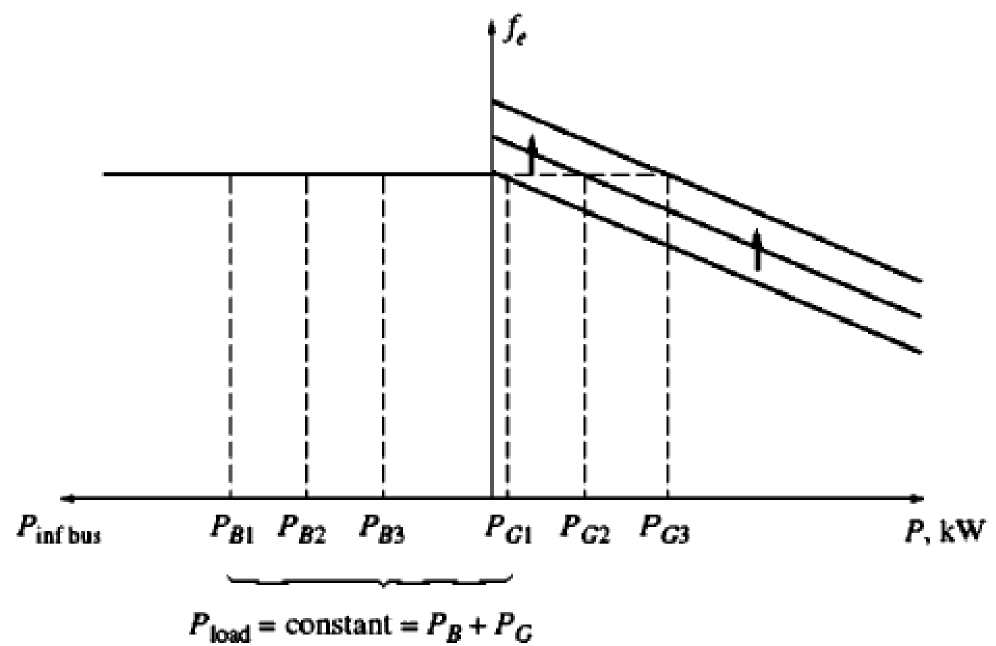


Generator has just been paralleled with infinite bus → generator is "floating" on the line → supplying small amount of ***P*** and little or no reactive ***Q***



Generator paralleled at a slightly lower frequency → no-load frequency of generator less than system frequency → ***P*** supplied by generator is negative **[may cause reverse power trip by relay]**

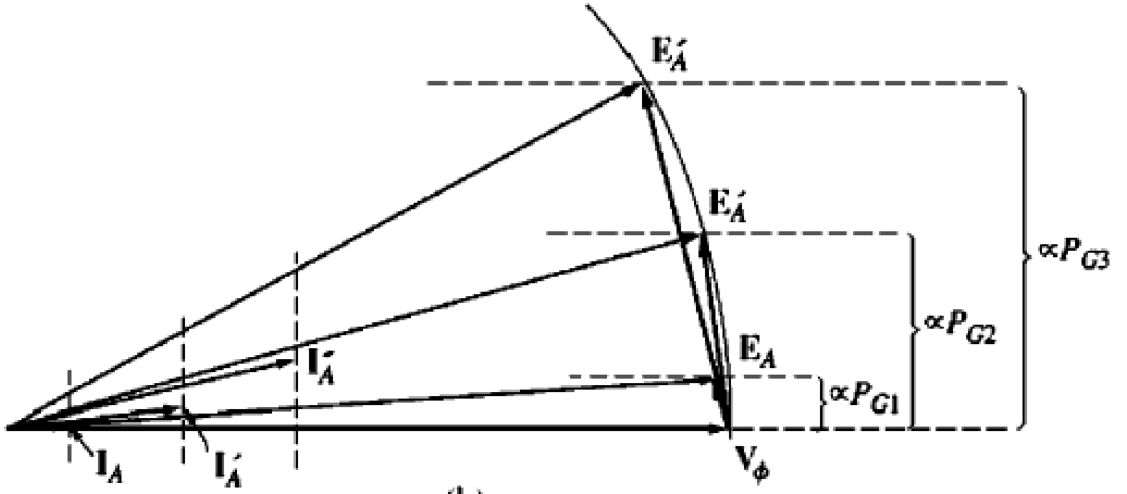
Generators in Parallel with Large Power Systems



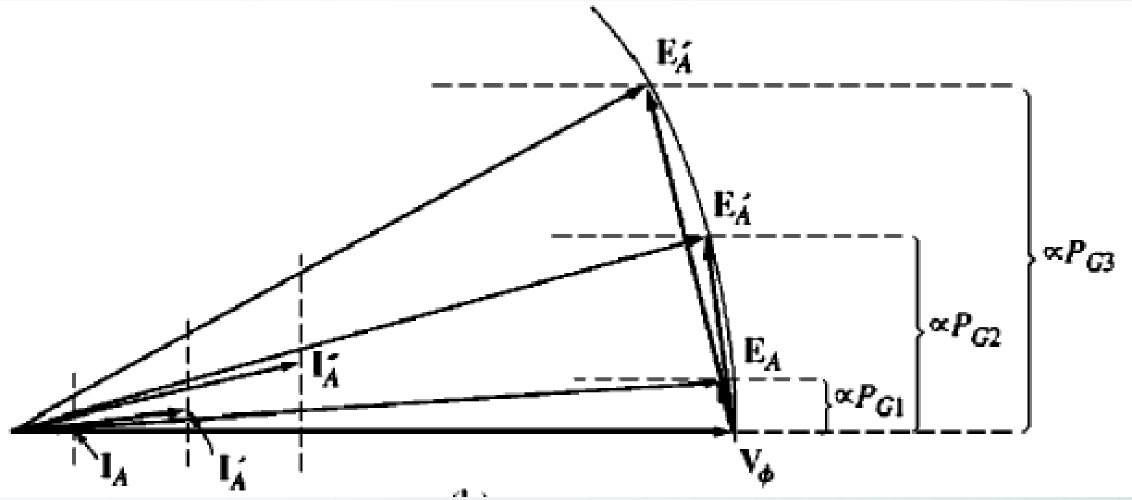
Generator connected to system and governor set points increased

- Shifts f_{nl} of generator upward
- f_{system} unchanged (infinite bus frequency cannot change) → power supplied by generator increases

E_A sin δ increased, magnitude of E_A (= *Kφω*) remains constant, since field current I_F and speed of rotation *ω* are unchanged



Generators in Parallel with Large Power Systems



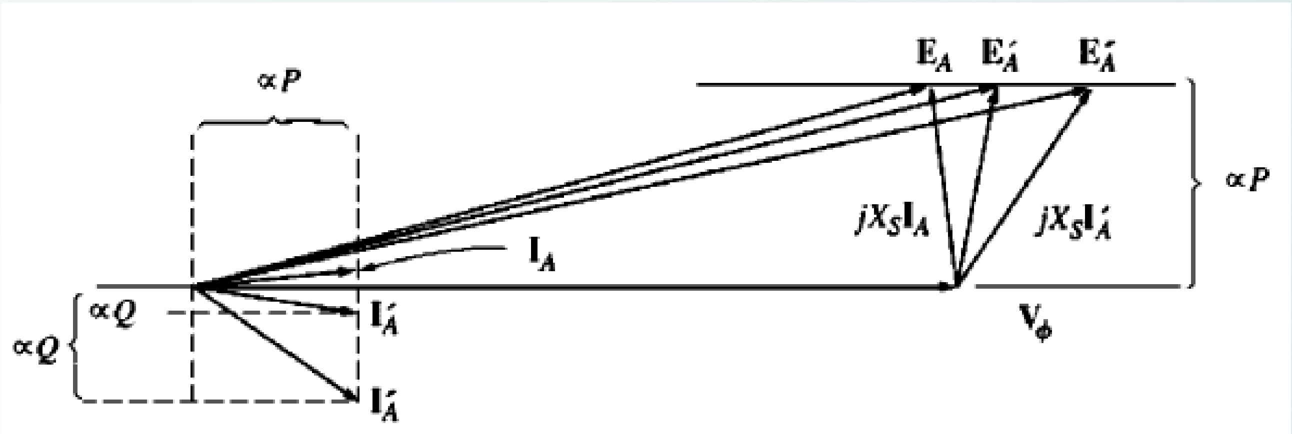
Generator operating at a slightly leading PF, supplying negative reactive power

→ i.e. **generator consuming reactive power**

HOW TO SUPPLY REACTIVE POWER?

→ *Adjust field current, I_F*

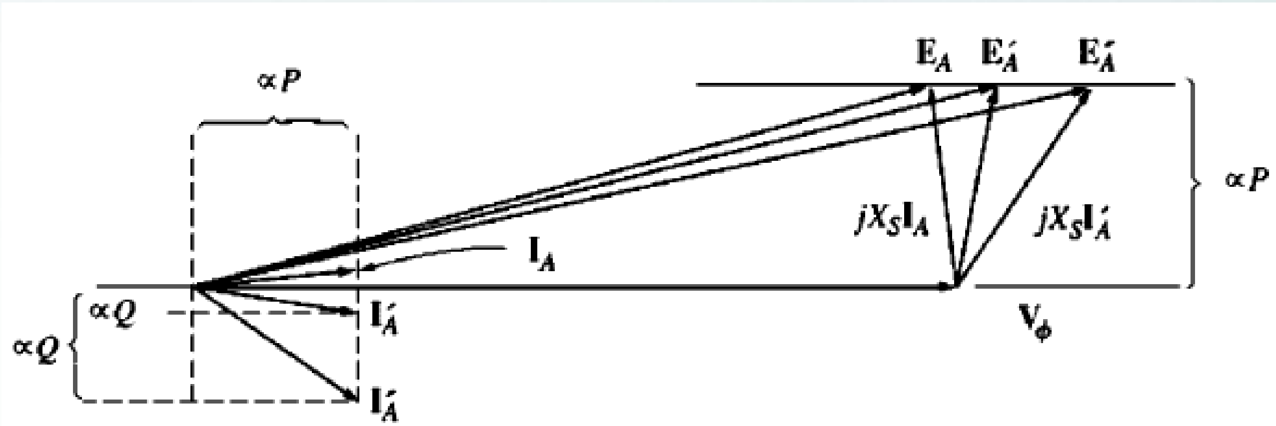
Generators in Parallel with Large Power Systems



Effect of increasing field current

- Power must remain constant when I_F is changed [$P_{in} = \tau_{in}\, \omega_m$]
- Prime mover of generator has a fixed torque-speed characteristic for any given governor setting
- Generator tied to infinite bus → its speed cannot change (and, since governor set points not changed) → power supplied by generator must remain constant

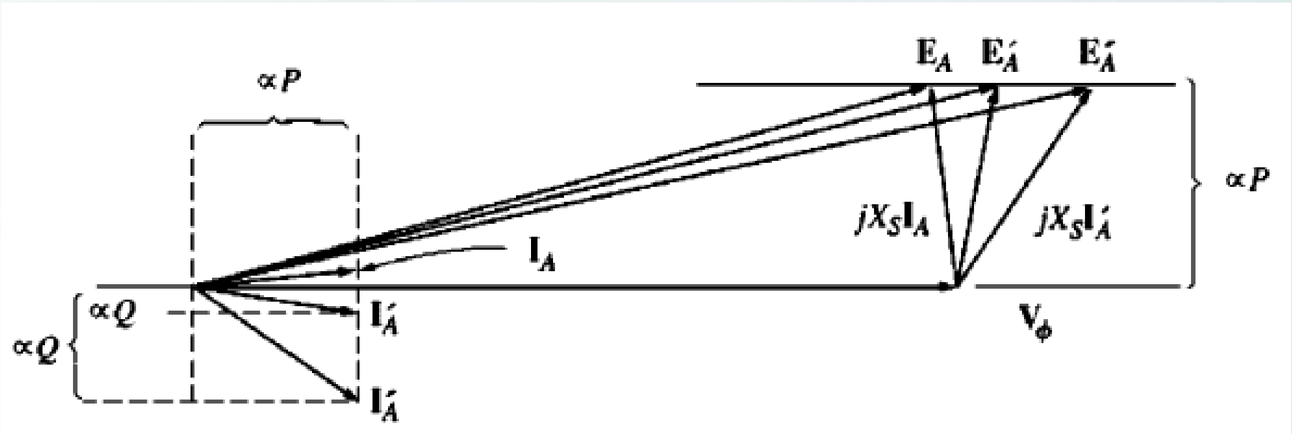
Generators in Parallel with Large Power Systems



Effect of increasing field current

- Power must remain constant when I_F is changed [$P_{in} = \tau_{in}\ \omega_m$]
- If power supplied is constant as I_F is changed, then distances proportional to power ($I_A \cos \vartheta$ and $E_A \sin \delta$) cannot change
- $I_F \uparrow \rightarrow$ flux $\varphi \uparrow \rightarrow E_A$ ($= K\varphi\uparrow\omega$) increases
- E_A increases, but $E_A \sin \delta$ must remain constant → phasor E_A must "slide" along line of constant power

Generators in Parallel with Large Power Systems



Effect of increasing field current

- V_φ constant → so, angle of jX_sI_A changes as shown → therefore angle and magnitude of I_A change → distance proportional to Q ($I_A \sin \vartheta$) increases
  - i.e. increasing field current in a synchronous generator operating in parallel with an infinite bus increases reactive power output of generator

Generators in Parallel with Large Power Systems

Generator operating alone

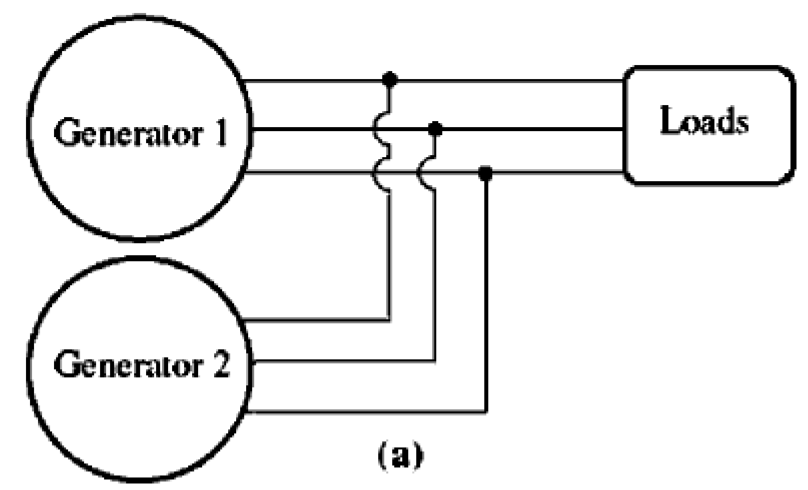
1. ***P*** and ***Q*** supplied by generator is the amount demanded by the attached load
2. Governor set points of generator control operating frequency of power system
3. I_F control terminal voltage of the power system

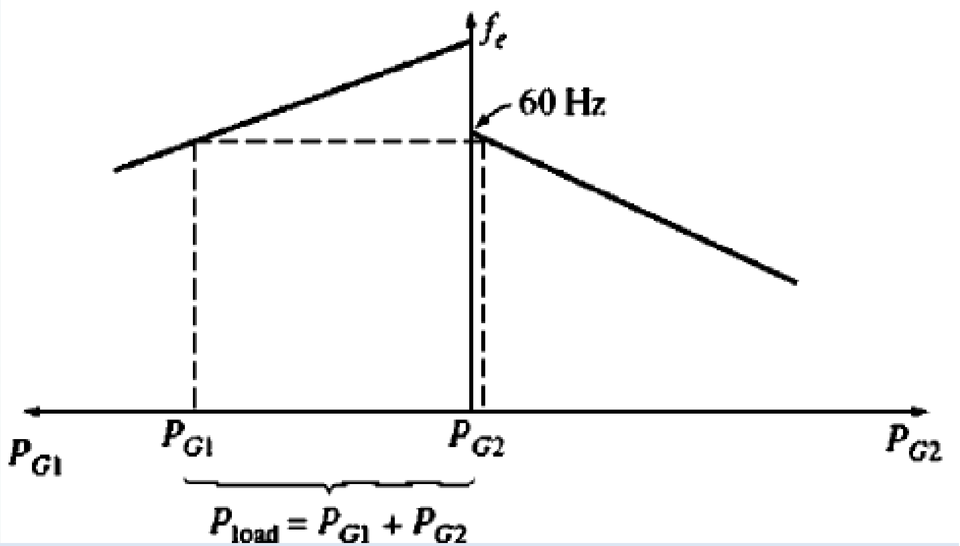
Generator connected to an infinite bus

1. Frequency and terminal voltage of generator controlled by system to which it is connected
2. Governor set points of generator control ***P*** supplied by generator to system
3. I_F controls ***Q*** supplied by generator to the system

Generators in Parallel with Same Size Units

A generator connected in parallel with another one of same size





House diagram at the moment generator 2 is paralleled with the system

Basic constraint

- *Sum of **P** and **Q** supplied by two generators must equal the **P** and **Q** demanded by load*
  - System frequency not constrained to be constant
  - Power of a given generator not constrained to be constant

$$P_{\text{tot}} = P_{\text{load}} = P_{G1} + P_{G2}$$

$$Q_{\text{tot}} = Q_{\text{load}} = Q_{G1} + Q_{G2}$$

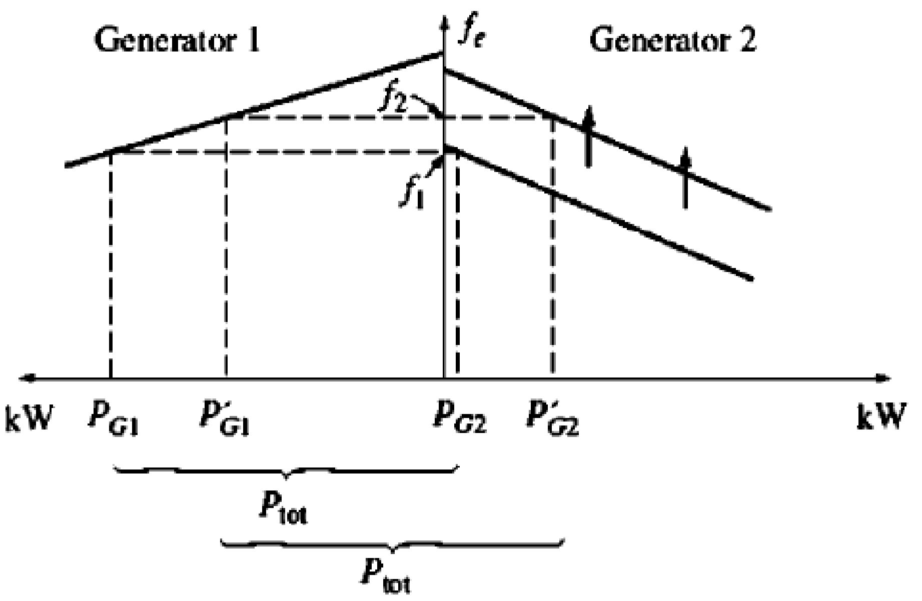
Generators in Parallel with Same Size Units

Effect of increasing generator 2's governor set points

At original frequency f_1, $(P_{G1} + P_{G2}) > P_{Load}$

Only at f_2 sum $(P_{G1} + P_{G2}) = P_{Load}$

- $f_2 > f_1$
- At f_2, G_1 supplies more power and G_2 supplies less power than before

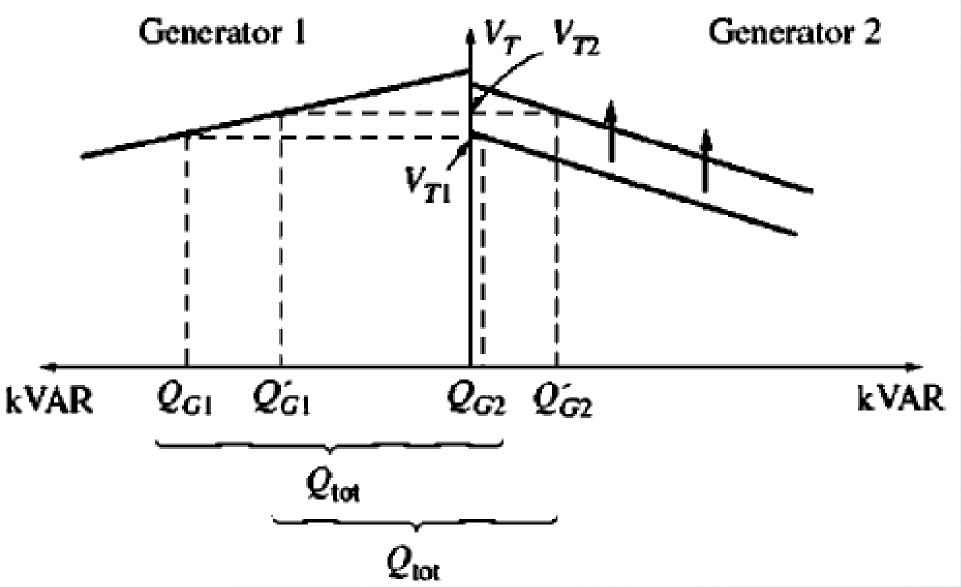


Therefore, when two generators are operating together, an increase in governor set points on one of them

1. Increases system frequency
2. Increases power supplied by that generator, while reducing power supplied by the other one

Generators in Parallel with Same Size Units

Effect of increasing generator 2's field current



1. System terminal voltage is increased
2. Reactive power (**Q**) supplied by that generator is increased, while reactive power supplied by the other generator is decreased

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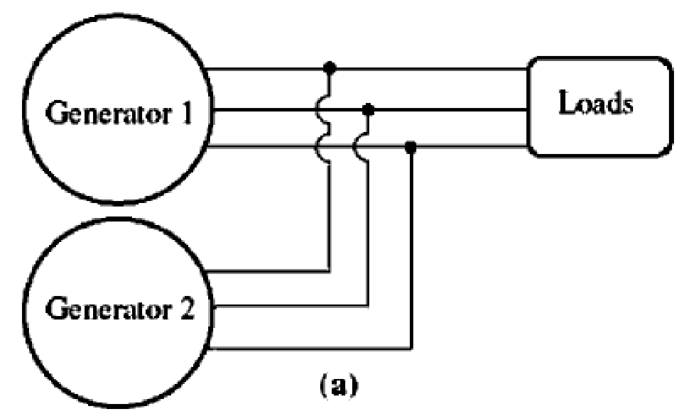

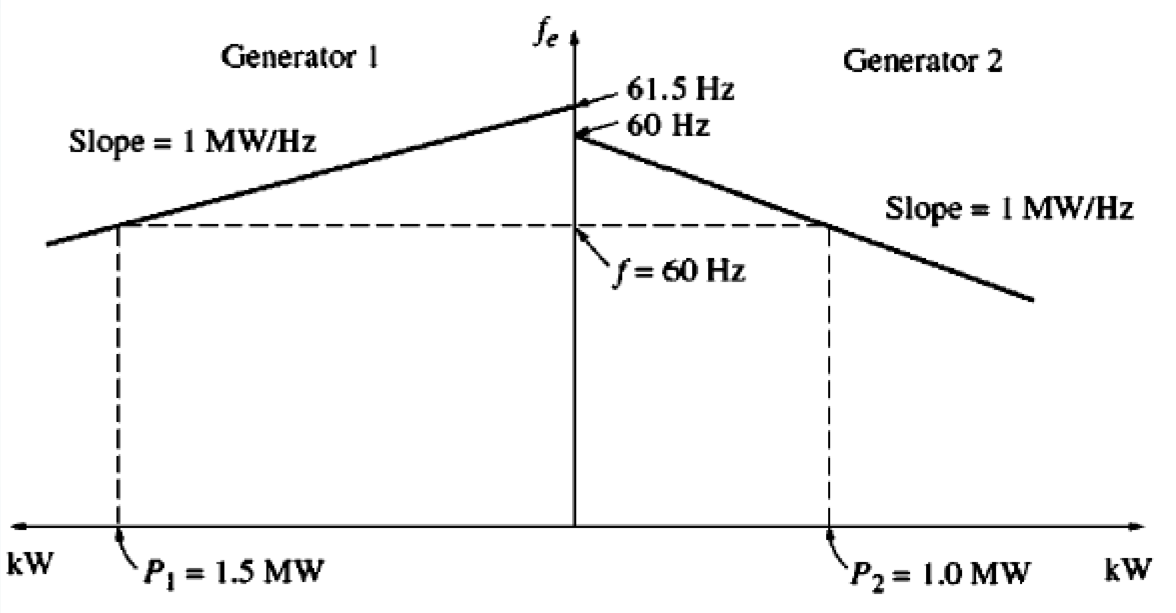

Example

Two generators are supplying a load. **G1** has a no-load frequency of 61.5 Hz and a slope s_{p1} of 1 MW/Hz. **G2** has a no-load frequency of 61.0 Hz and a slope s_{p2} of 1 MW/Hz. The two generators are supplying a real load totaling 2.5 MW at 0.8 PF lagging. The resulting system power-frequency or house diagram is shown in the figure.

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(a) At what frequency is this system operating, and how much power is supplied by each of the two generators?

(b) Suppose an additional 1-MW load were attached to this power system. What would the new system frequency be, and how much power would G_1 and G_2 supply now?

(c) With the system in the configuration described in part b, what will the system frequency and generator powers be if the governor set points on G_2 are increased by 0.5 Hz?

Solution

$$P_{load} = P_1 + P_2$$

$$P_1 = s_{P1}(f_{nl,1} - f_{sys})$$
$$P_2 = s_{P2}(f_{nl,2} - f_{sys})$$

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(a) In the first case, both generators have a slope of 1 MW/Hz, and G_1 has a no-load frequency of 61.5 Hz, while G_2 has a no-load frequency of 61.0 Hz. The total load is 2.5 MW. Therefore, the system frequency can be found as follows:

$$\begin{aligned}
P_{\text{load}} &= P_1 + P_2 \\
&= s_{P1}(f_{\text{nl},1} - f_{\text{sys}}) + s_{P2}(f_{\text{nl},2} - f_{\text{sys}}) \\
2.5\text{ MW} &= (1\text{ MW/Hz})(61.5\text{ Hz} - f_{\text{sys}}) + (1\text{ MW/Hz})(61\text{ Hz} - f_{\text{sys}}) \\
&= 61.5\text{ MW} - (1\text{ MW/Hz})f_{\text{sys}} + 61\text{ MW} - (1\text{ MW/Hz})f_{\text{sys}} \\
&= 122.5\text{ MW} - (2\text{ MW/Hz})f_{\text{sys}}
\end{aligned}$$

therefore $$f_{\text{sys}} = \frac{122.5\text{ MW} - 2.5\text{ MW}}{(2\text{MW/Hz})} = 60.0\text{ Hz}$$

The resulting powers supplied by the two generators are

$$\begin{aligned}
P_1 &= s_{P1}(f_{\text{nl},1} - f_{\text{sys}}) \\
&= (1\text{ MW/Hz})(61.5\text{ Hz} - 60.0\text{ Hz}) = 1.5\text{ MW} \\
P_2 &= s_{P2}(f_{\text{nl},2} - f_{\text{sys}}) \\
&= (1\text{ MW/Hz})(61.0\text{ Hz} - 60.0\text{ Hz}) = 1\text{ MW}
\end{aligned}$$

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(b) When the load is increased by 1 MW, the total load becomes 3.5 MW. The new system frequency is now given by

$$\begin{aligned}
P_{\text{load}} &= s_{P1}(f_{\text{nl},1} - f_{\text{sys}}) + s_{P2}(f_{\text{nl},2} - f_{\text{sys}}) \\
3.5\text{ MW} &= (1\text{ MW/Hz})(61.5\text{ Hz} - f_{\text{sys}}) + (1\text{ MW/Hz})(61\text{ Hz} - f_{\text{sys}}) \\
&= 61.5\text{ MW} - (1\text{ MW/Hz})f_{\text{sys}} + 61\text{ MW} - (1\text{ MW/Hz})f_{\text{sys}} \\
&= 122.5\text{ MW} - (2\text{ MW/Hz})f_{\text{sys}}
\end{aligned}$$

therefore $$f_{\text{sys}} = \frac{122.5\text{ MW} - 3.5\text{ MW}}{(2\text{MW/Hz})} = 59.5\text{ Hz}$$

The resulting powers are

$$\begin{aligned}
P_1 &= s_{P1}(f_{\text{nl},1} - f_{\text{sys}}) \\
&= (1\text{ MW/Hz})(61.5\text{ Hz} - 59.5\text{ Hz}) = 2.0\text{ MW} \\
P_2 &= s_{P2}(f_{\text{nl},2} - f_{\text{sys}}) \\
&= (1\text{ MW/Hz})(61.0\text{ Hz} - 59.5\text{ Hz}) = 1.5\text{ MW}
\end{aligned}$$

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(*c*) If the no-load governor set points of G_2 are increased by 0.5 Hz, the new system frequency becomes

$$P_{\text{load}} = s_{P1}(f_{\text{nl},1} - f_{\text{sys}}) + s_{P2}(f_{\text{nl},2} - f_{\text{sys}})$$

$$3.5 \text{ MW} = (1 \text{ MW/Hz})(61.5 \text{ Hz} - f_{\text{sys}}) + (1 \text{ MW/Hz})(61.5 \text{ Hz} - f_{\text{sys}})$$

$$= 123 \text{ MW} - (2 \text{ MW/Hz})f_{\text{sys}}$$

$$f_{\text{sys}} = \frac{123 \text{ MW} - 3.5 \text{ MW}}{(2\text{MW/Hz})} = 59.75 \text{ Hz}$$

The resulting powers are

$$P_1 = P_2 = s_{P1}(f_{\text{nl},1} - f_{\text{sys}})$$

$$= (1 \text{ MW/Hz})(61.5 \text{ Hz} - 59.75 \text{ Hz}) = 1.75 \text{ MW}$$

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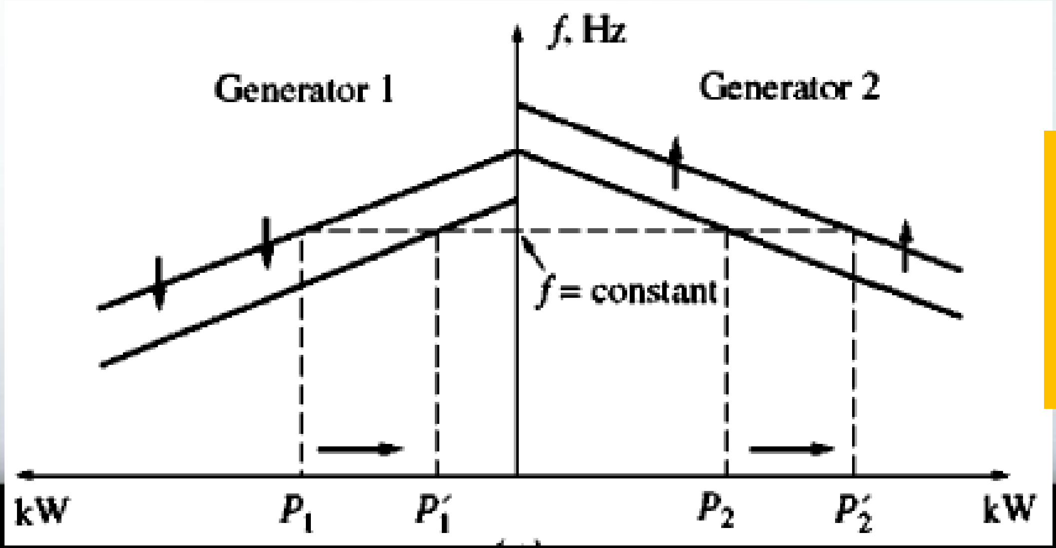
To summarize, in the case of two generators operating together:

1. System constraint: $\boxed{P_{load} = P_1 + P_2}$

   f_{sys} or V_T is not constrained to be constant

2. To adjust real power sharing between generators without changing f_{sys} simultaneously increase governor set points on one generator while decreasing governor set points on the other



The machine whose governor set point was increased will assume more of load

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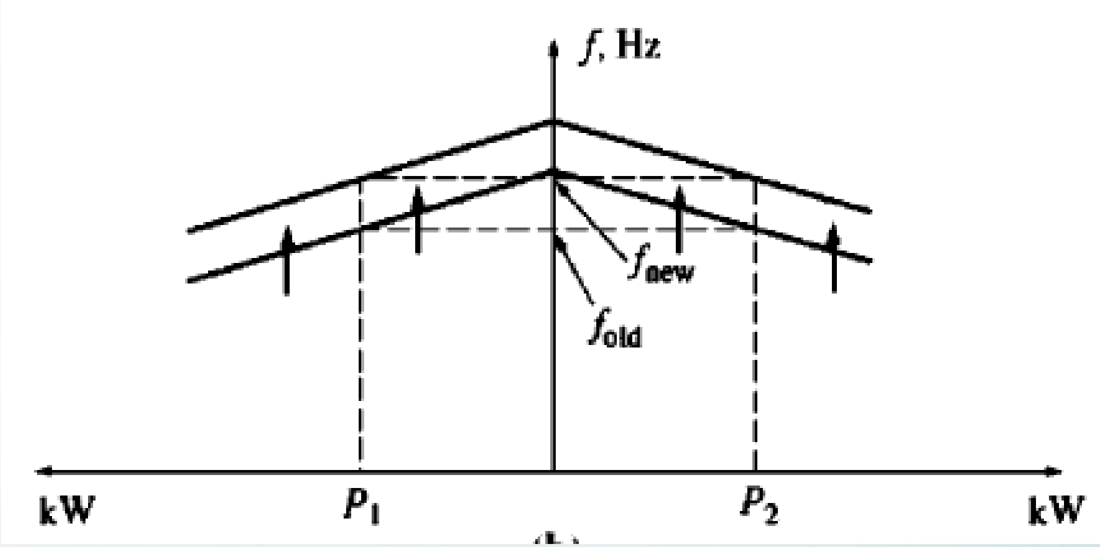
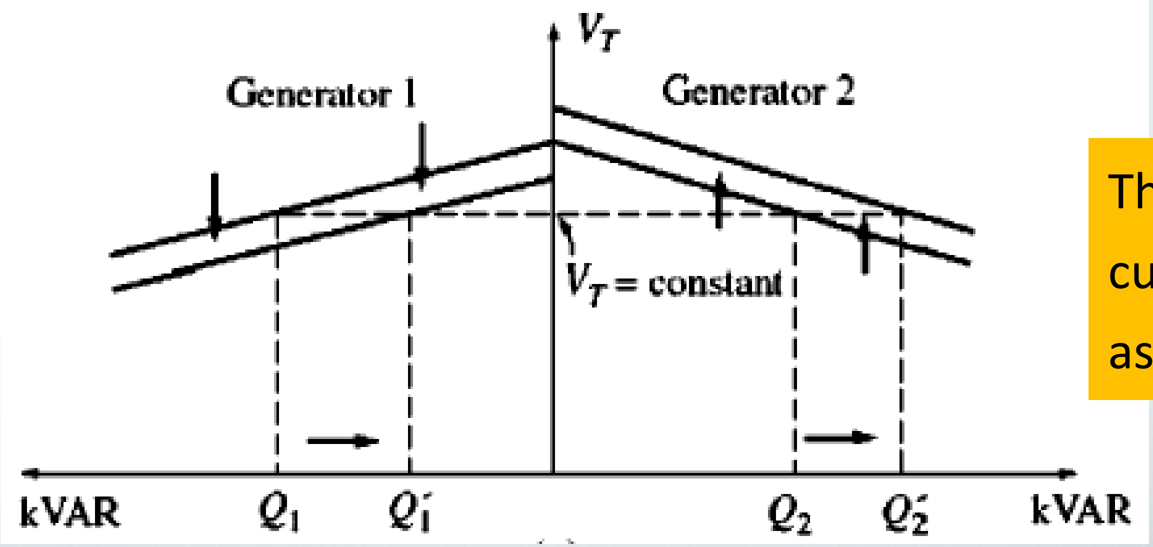
3. To adjust f_{sys} without changing real power sharing, simultaneously increase or decrease both generators' governor set points



Generators in Parallel with Same Size Units

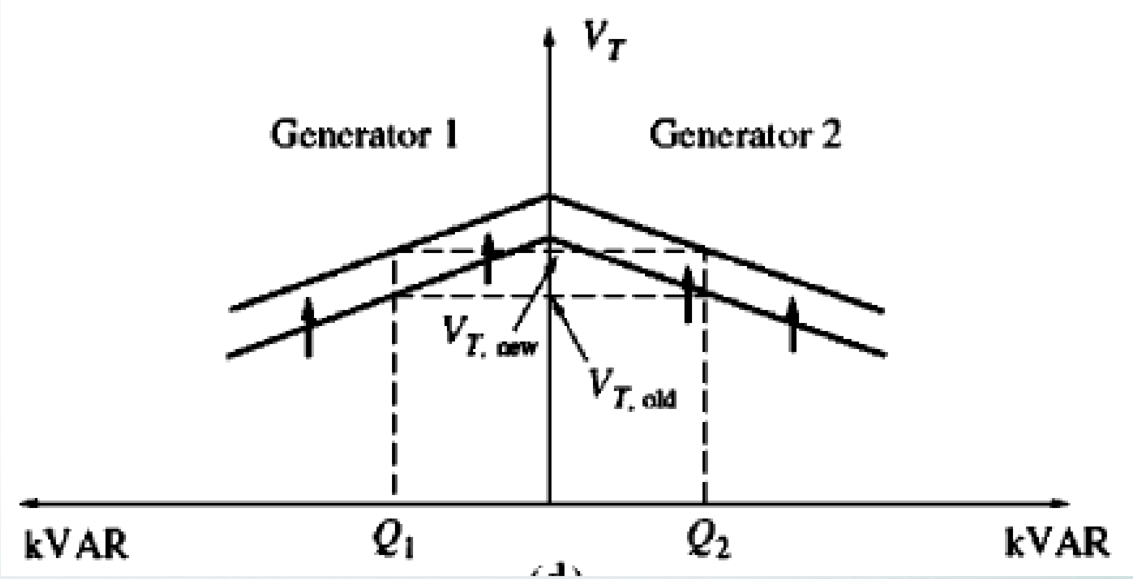
4. To adjust reactive power sharing between generators without changing V_T, simultaneously increase field current on one generator while decreasing field current on the other



The machine whose field current was increased will assume more reactive load

Generators in Parallel with Same Size Units

5. To adjust V_T without changing reactive power sharing, simultaneously increase or decrease both generators' field currents



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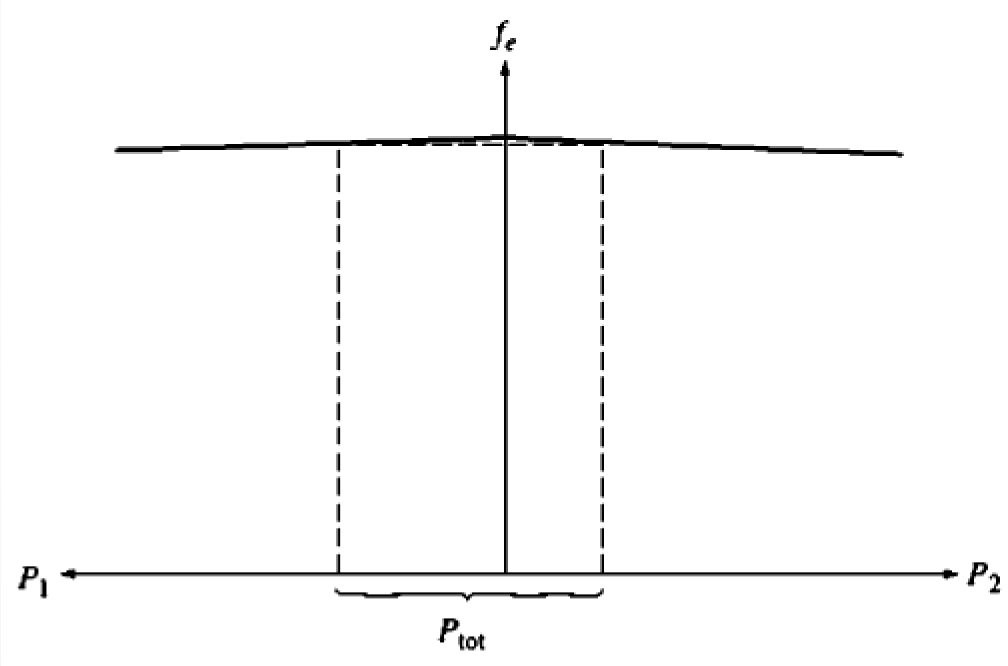
Generators with flat frequency-power characteristics

- A very tiny change in the no-load frequency of either of these machines could cause huge shifts in power sharing
- To ensure good control of power sharing between generators, they should have speed droops in the range of 2 to 5 percent



Synchronous Generator Ratings