EEE363

Electrical Machines

Lecture # 18

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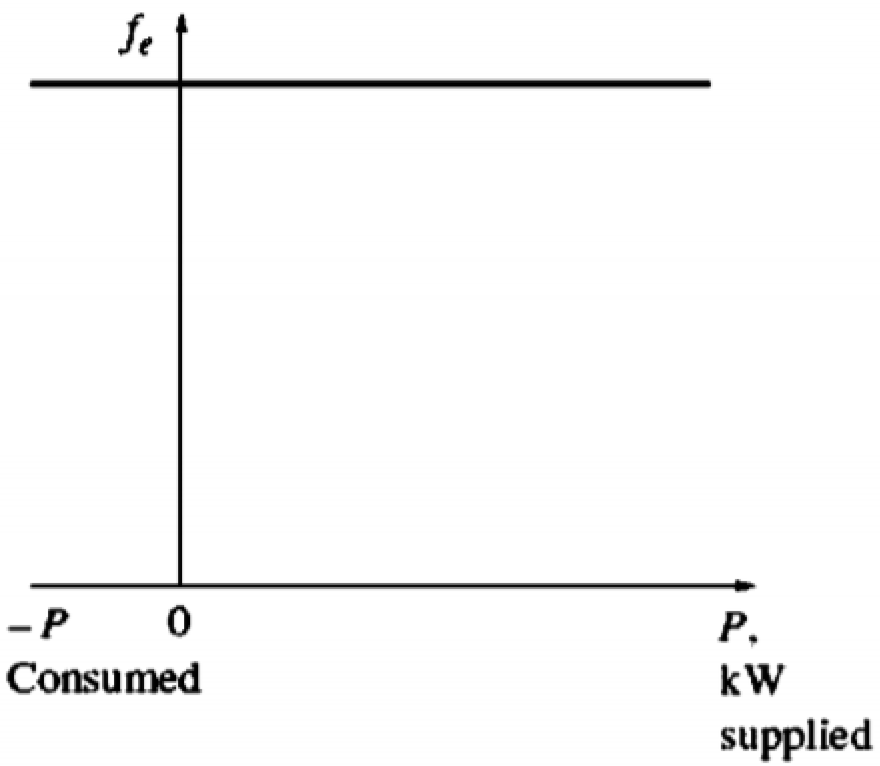
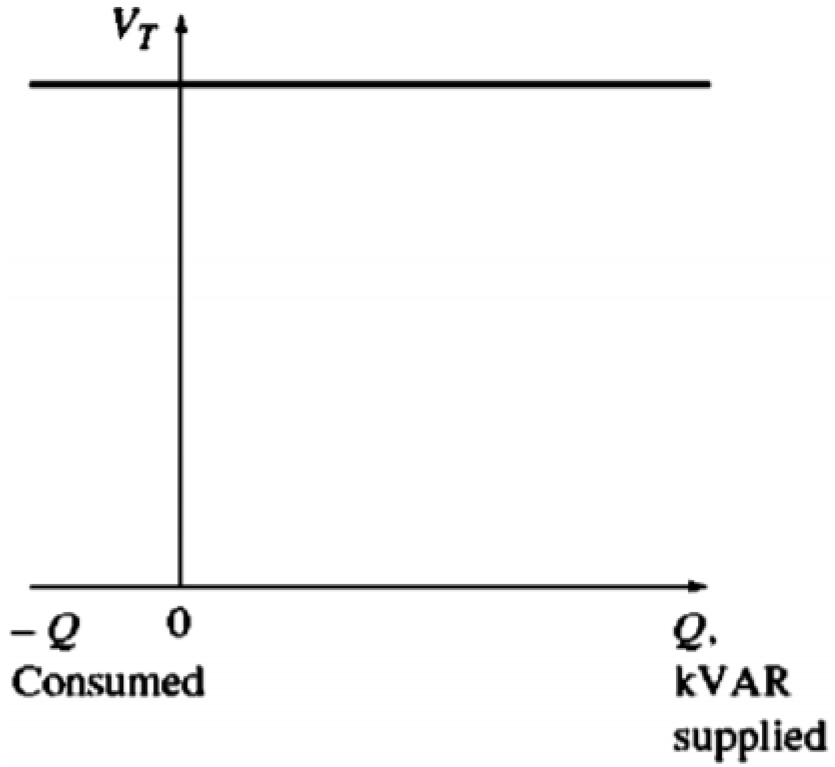
Large power system (Infinite BUS)

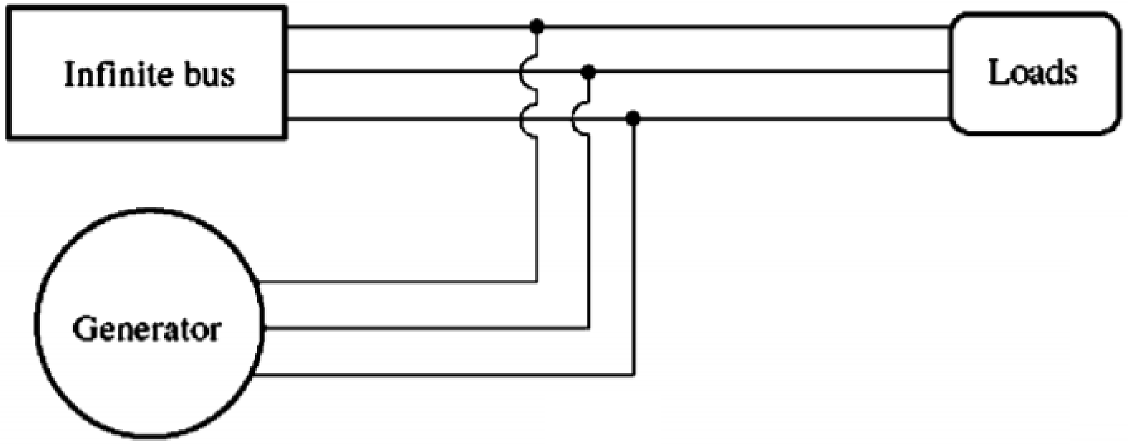
An infinite bus is a power system so large that its voltage and frequency do not vary regardless of how much real and reactive power is drawn from or supplied to it.

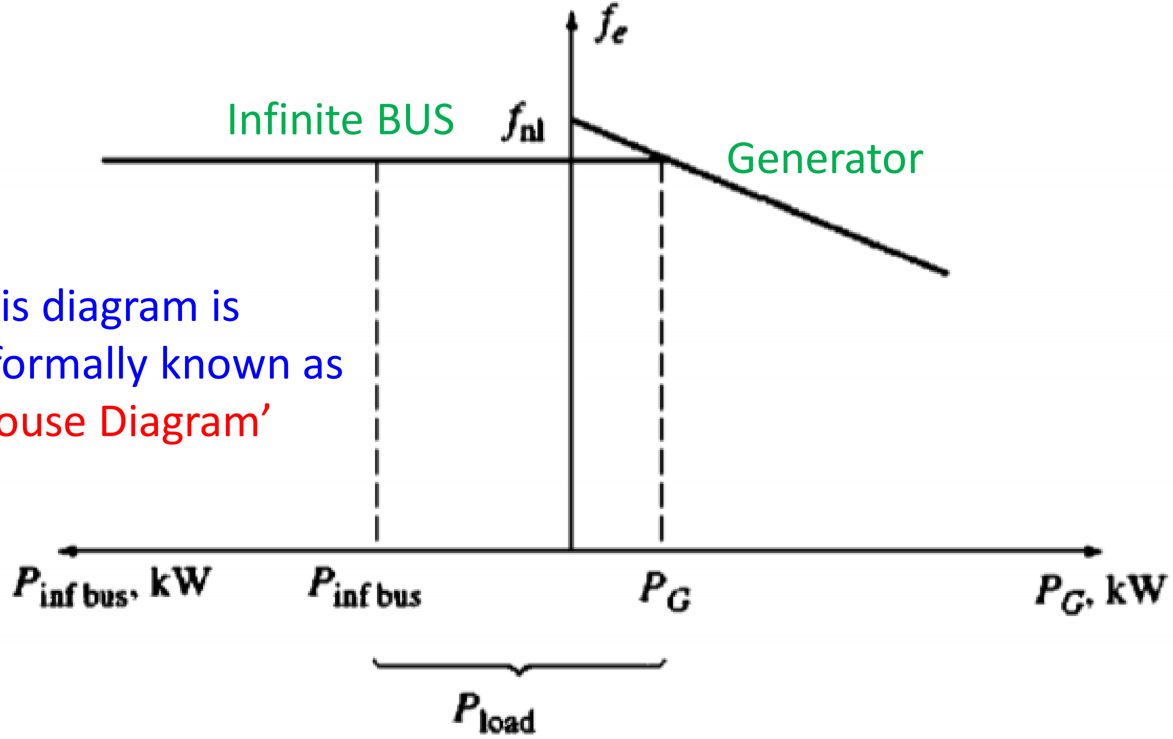




Operation of Generators in Parallel with Large Power Systems

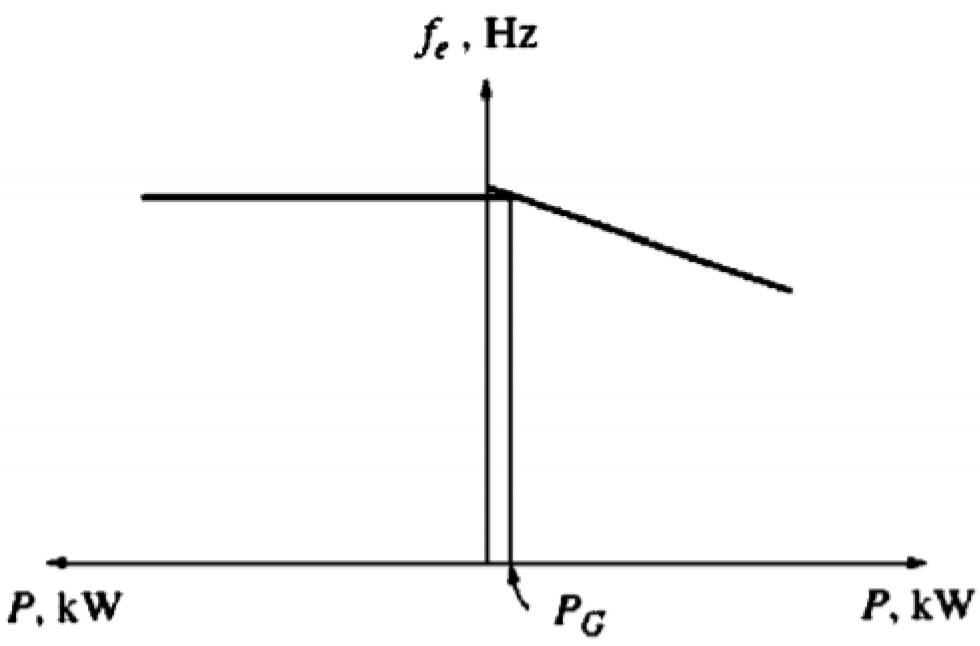
When a generator is connected in parallel with another generator or a large system, the frequency and terminal voltage of all the machines must be the same, since their output conductors are tied together.

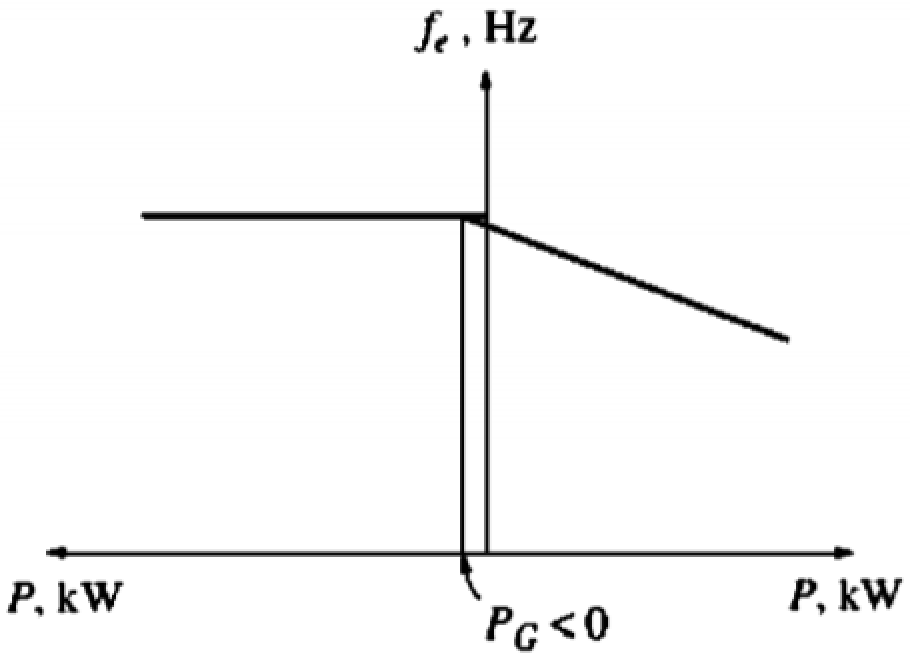




This diagram is informally known as 'House Diagram'

Operation of Generators in Parallel with Large Power Systems



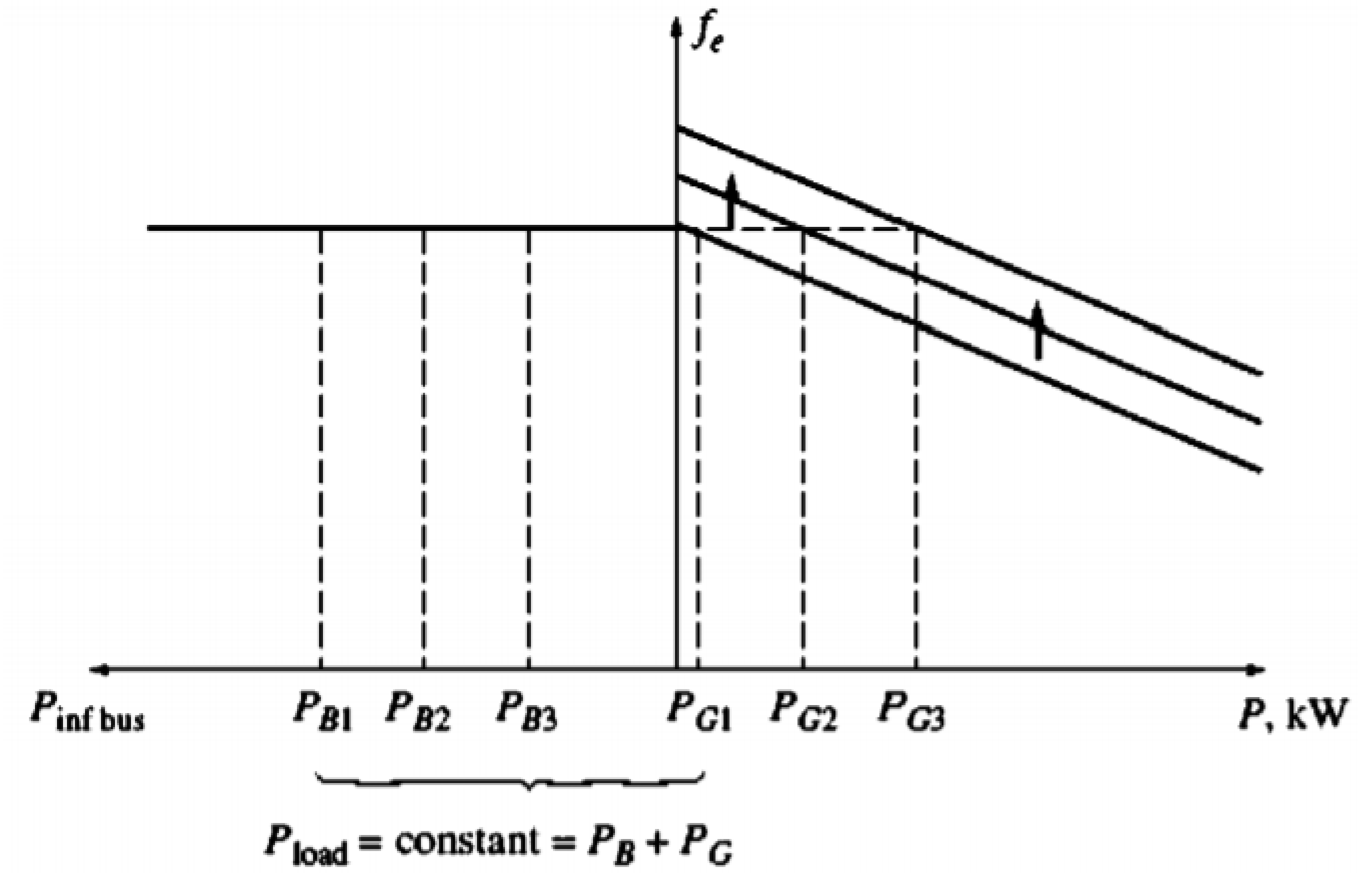


when the generator's no-load frequency is less than the system's operating frequency, the generator actually consumes electric power and runs as a motor.

✓ Many real generators have a reverse-power trip connected to them. If such a generator ever starts to consume power. it will be automatically disconnected from the line.

Impact of governor set points change (House Diagram)

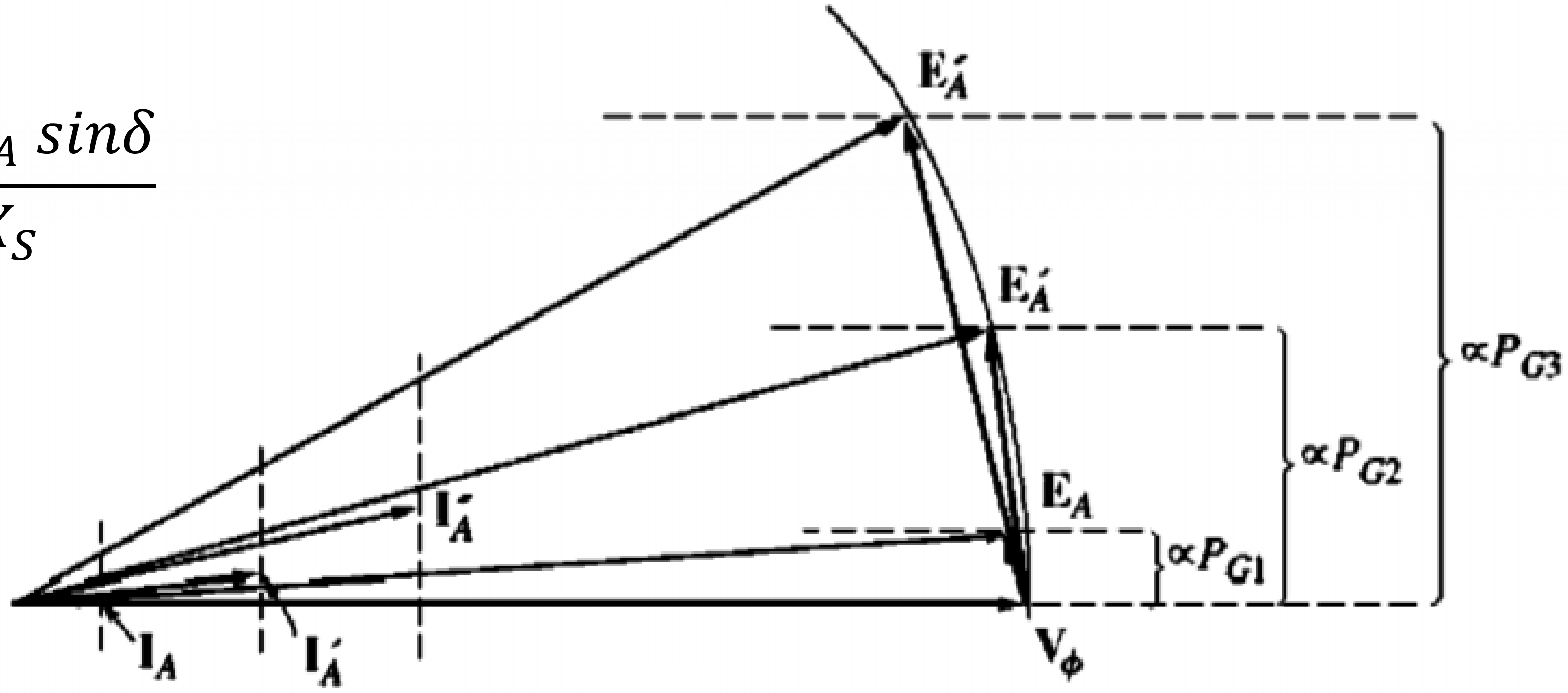
- An increase in governor set points shifts the curve upward.
- Since the frequency of the system is unchanged (the frequency of an infinite bus cannot change), the power supplied by the generator increases.



Impact of governor set points change (Phasor Diagram)

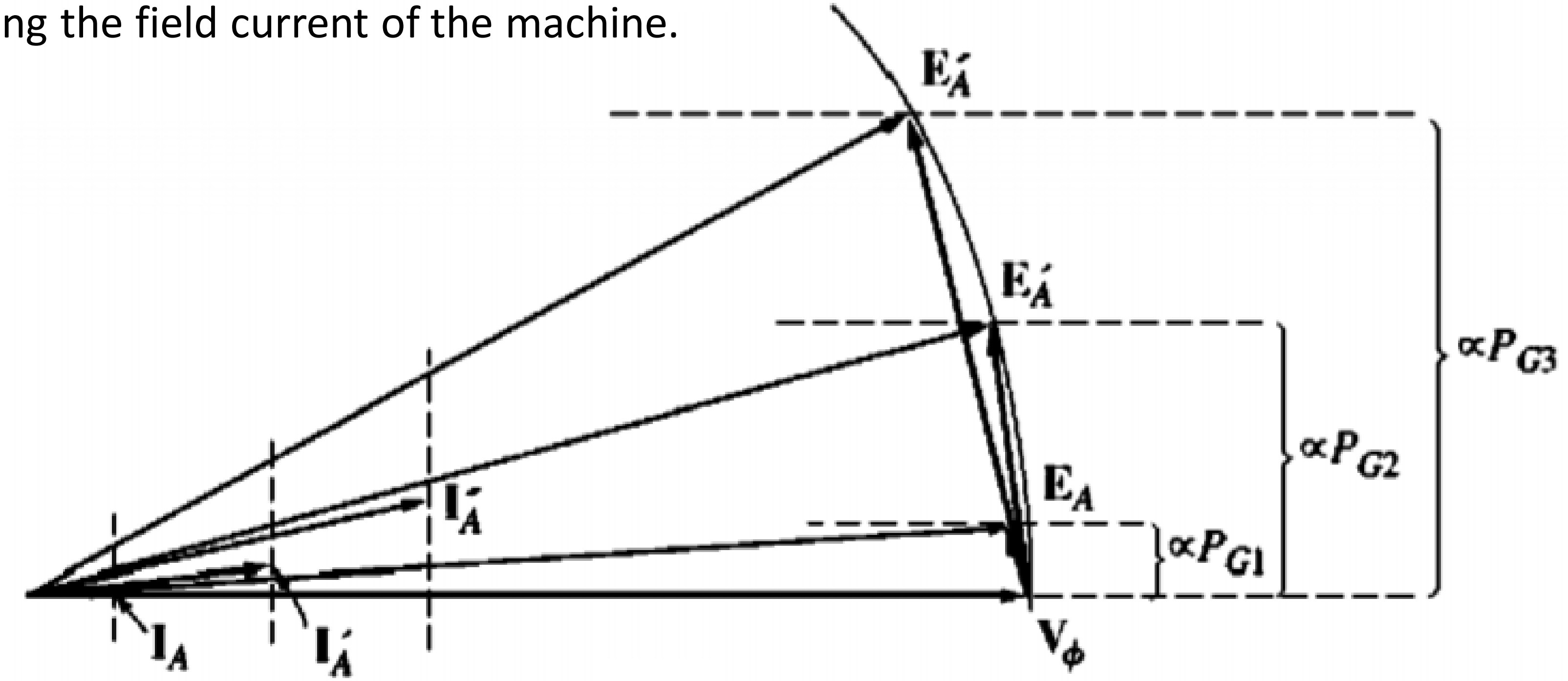
- Power supplied by the generator increases as governor set points creases. Thus $E_A\ sin\delta$ has to increase as shown in the diagram.
- Notice that V_φ remains same. E_A Also remains same as we haven't done anything with excitation.
- Also notice the increase of armature current (I_A) with governor set points.

$$P_{out} = \frac{3V_\varphi E_A\ sin\delta}{X_S}$$



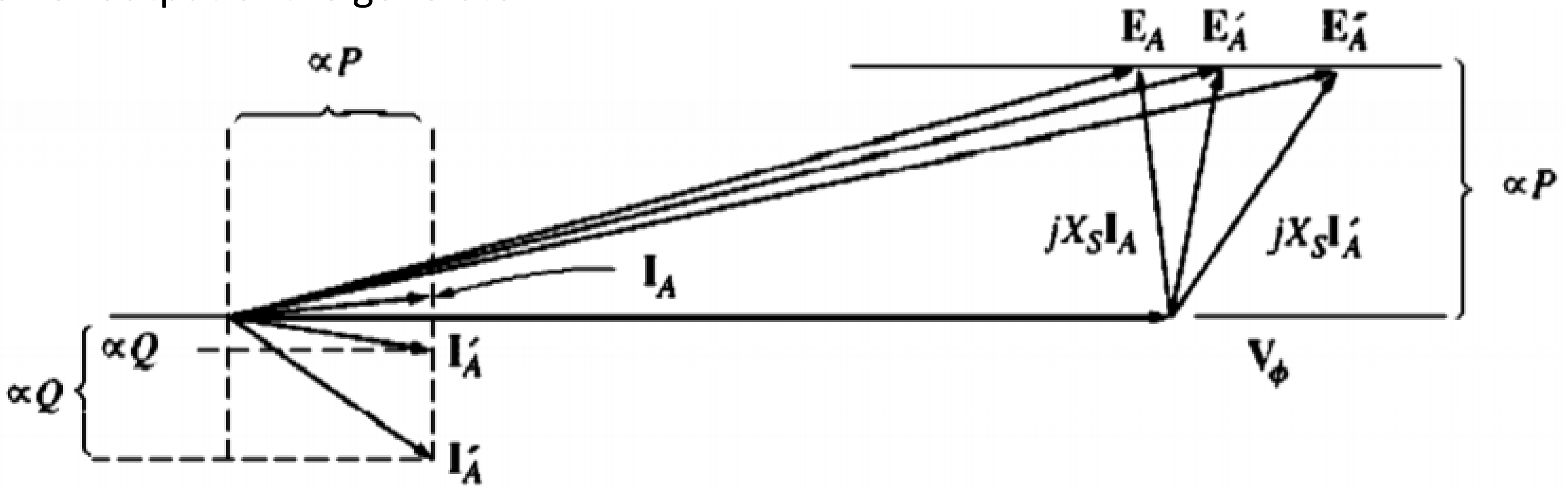
Alternator PF adjustment

- ✓ The vector diagram below suggests that generator is actually operating at a slightly leading power factor, supplying negative reactive power.
- ✓ Alternatively, the generator can be said to be consuming reactive power.
- ✓ How can the generator be adjusted so that it will supply some reactive power Q to the system?
- ✓ This can be done by adjusting the field current of the machine.

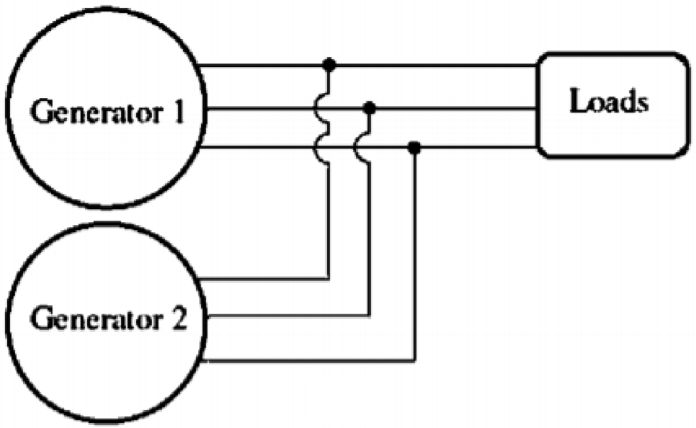


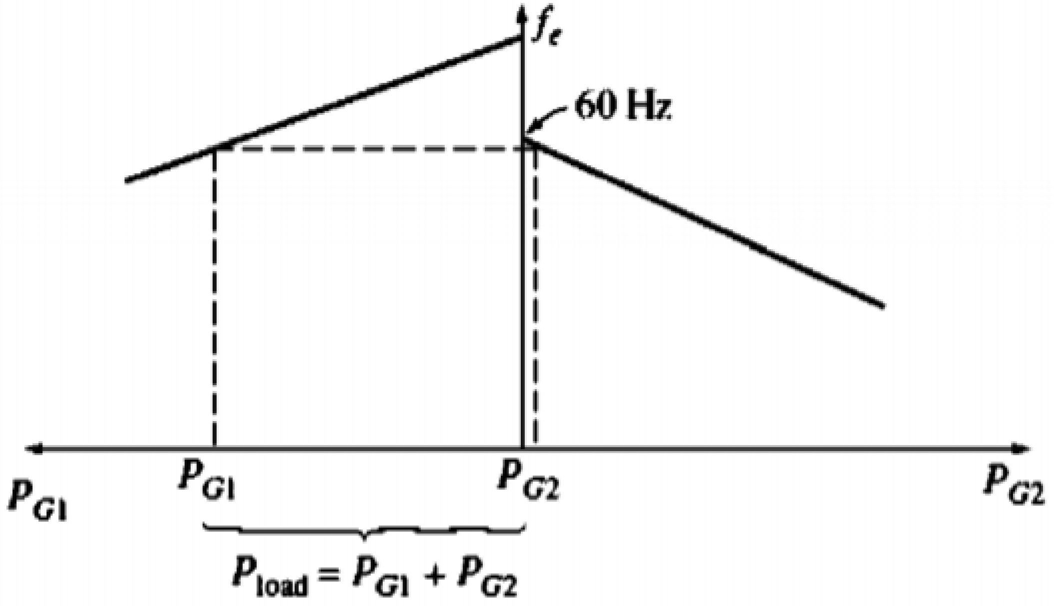
Alternator PF adjustment

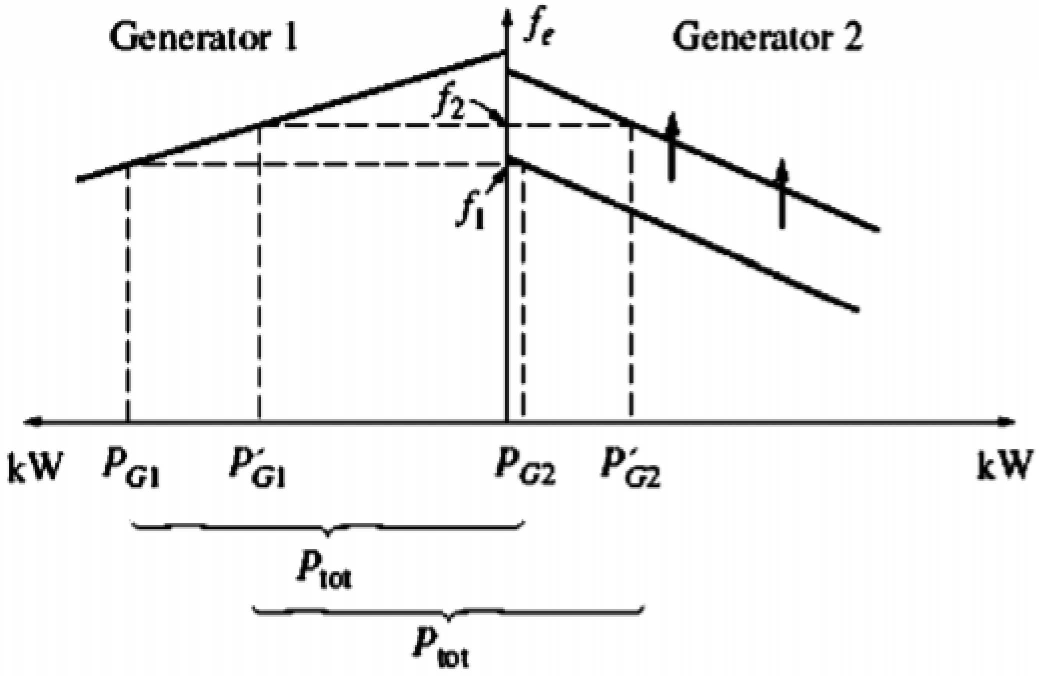
- By increasing the excitation (I_f) , armature current can be made from leading to lagging as shown in the diagram.
- The constraint however is that the power must remain constant when (I_f) is changed. Thus $E_A\ sin\delta$ is same on all three cases.
- The power into a generator is also given by the equation $P_{in} = \tau_{in}\omega_m$. Thus P_{in} changes only when the governor set points are changed.
- Increasing the field current in a synchronous generator operating in parallel with an infinite bus increases the reactive power output of the generator.



Operation of Generators in Parallel with Other Generators of the Same Size



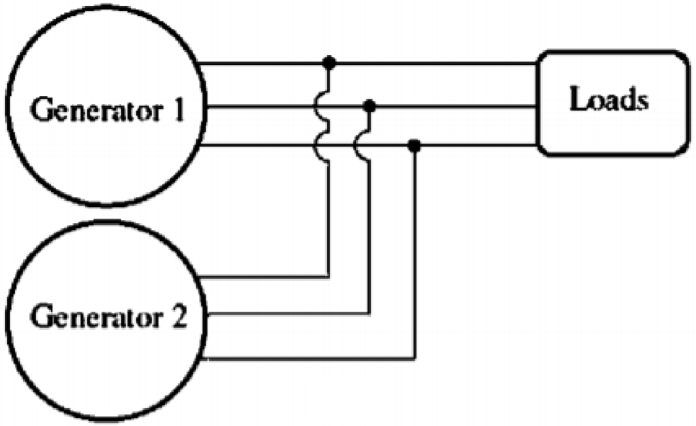




Increasing governor set points increases the power sharing of the generator

Problem # 1

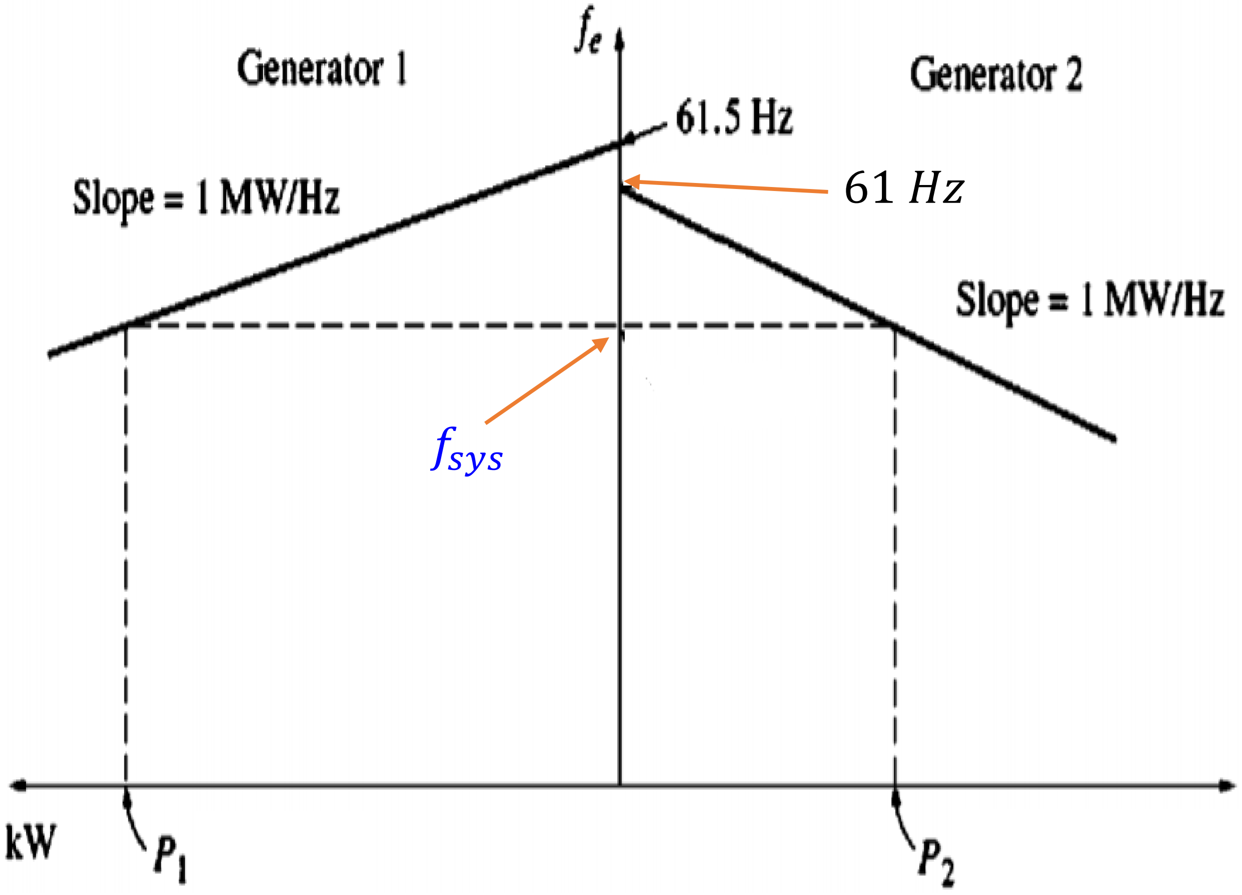
Figure below shows two generators supplying a load. Generator I has a no-load frequency of 61.5 Hz and a slope S_{p1} of 1 MW/Hz. Generator 2 has a no-load frequency of 61.0 Hz and a slope S_{p2} of 1 MW/Hz. The two generators are supplying a real load totalling 2.5 MW at 0.8 PF lagging



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

II. Suppose an additional 1 MW load were attached to this power system. What would the new system frequency be, and how much power would G1 and G2 supply now?

III. With the system in the configuration described in part II, what will the system frequency and generator powers be if the governor set points on G2 are increased by 0.5 Hz?



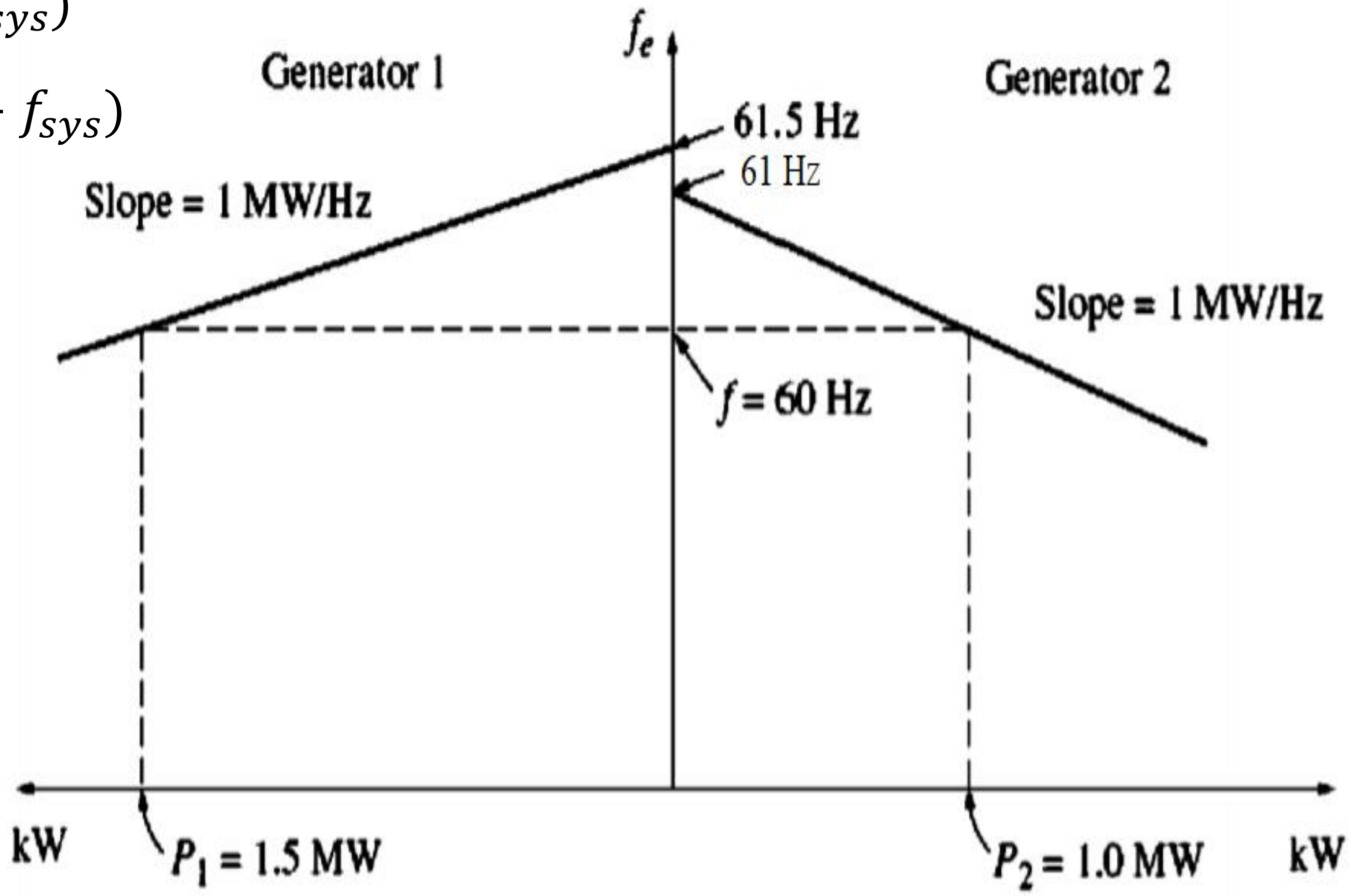
Problem # 1

(a) $P_1 = S_{P1}(f_{nl1} - f_{sys})$ $\qquad$ $P_2 = S_{P2}(f_{nl2} - f_{sys})$

$$P_{load} = P_1 + P_2 = S_{P1}\left(f_{nl1} - f_{sys}\right) + S_{P2}\left(f_{nl2} - f_{sys}\right)$$

$$2.5 = 1.\left(61.5 - f_{sys}\right) + 1.\left(61 - f_{sys}\right)$$

$$f_{sys} = \frac{122.5 - 2.5}{2} = 60 \text{ Hz}$$



Powers supplied by the two generators are

$$P_1 = S_{P1}(f_{nl1} - f_{sys})$$

$$= (1 \text{ MW/Hz})(61.5 \text{ Hz} - 60.0 \text{ Hz}) = 1.5 \text{ MW}$$

$$P_2 = S_{P2}(f_{nl2} - f_{sys})$$

$$= (1 \text{ MW/Hz})(61.0 \text{ Hz} - 60.0 \text{ Hz}) = 1 \text{ MW}$$

Problem # 1

(b) When the load is increased by 1 MW, the total load becomes 3.5 MW.

$$P_{load} = P_1 + P_2 = S_{p1}(f_{nl1} - f_{sys}) + S_{p2}(f_{nl2} - f_{sys})$$

$$3.5 = 1.(61.5 - f_{sys}) + 1.(61 - f_{sys})$$

$$f_{sys} = \frac{123.5 - 2.5}{2} = 59.5 \text{ Hz}$$

The resulting powers are

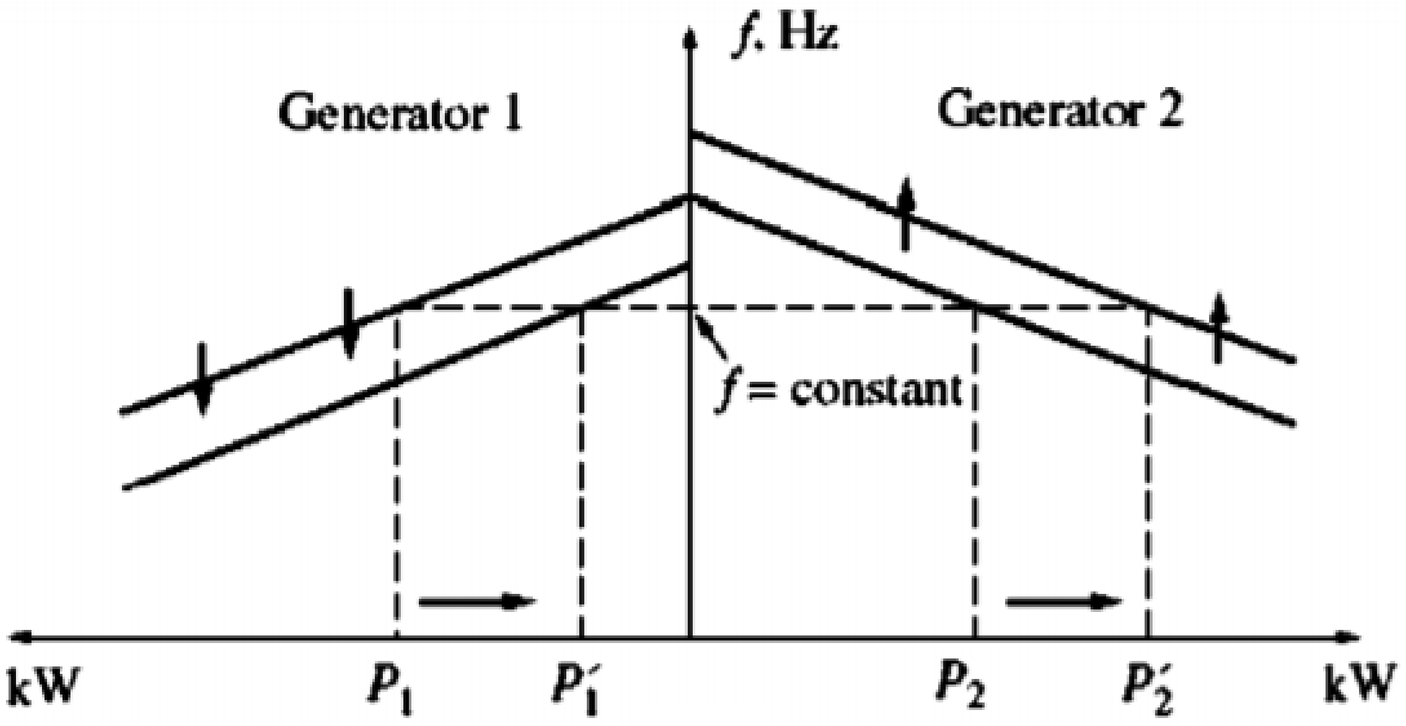
$$P_1 = S_{P1}(f_{nl1} - f_{sys}) = (1\ \text{MW/Hz})(61.5\ \text{Hz} - 59.5\ \text{Hz}) = 2.0\ \text{MW}$$

$$P_2 = S_{P2}(f_{nl2} - f_{sys}) = (1\ \text{MW/Hz})(61.0\ \text{Hz} - 59.5\ \text{Hz}) = 1.5\ \text{MW}$$

(c) Try yourself

Power sharing/Frequency adjustment

How can the power sharing between two generators be adjusted independently of the system frequency and vice versa?



To adjust power sharing without changing the system frequency, Increase the governor set points of one generator and simultaneously decrease the governor set points of the other generator.

Power sharing/Frequency adjustment

To adjust the system frequency without changing the power sharing, simultaneously increase or decrease both governor set points.