Lesson 22: Active Power Division Between Alternators

ET 332b

Ac Motors, Generators and Power Systems

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Learning Objectives

After this presentation you will be able to:

- Explain how active power load divides between parallel alternators with equal governor droop
- Explain how active power load divides between parallel alternators with unequal governor droop
- Define isochronous governor operation
- Compute the load division and system frequency of a load increase on parallel generators.

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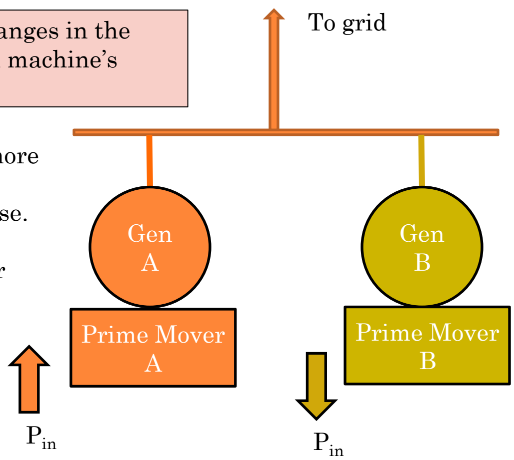
ACTIVE POWER DIVISION BETWEEN ALTERNATORS

Governor droop determines the active power division between parallel alternators

Load shifting requires changes in the mechanical power of each machine's prime-mover

If Gen A wishes to take more active power load, prime-mover power must increase.

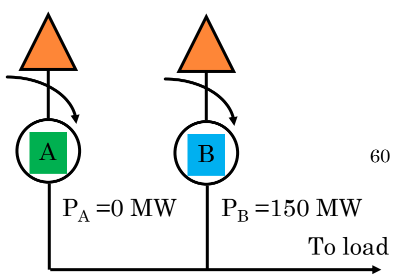
Gen B prime-mover power must decrease or system frequency will increase.

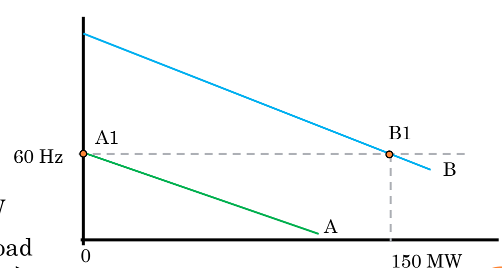


ACTIVE POWER DIVISION BETWEEN ALTERNATORS

Power transfer between alternators accomplished by adjusting their governor's no-load speed settings

Example 22-1: Two alternators serve a 150 MW load in an isolated power system and have identical governor characteristics



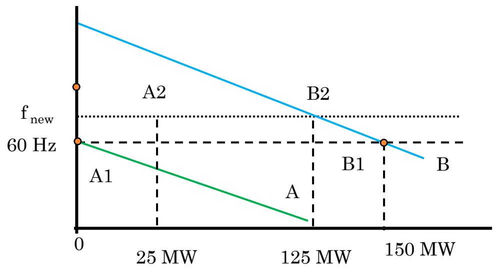


Initial conditions:

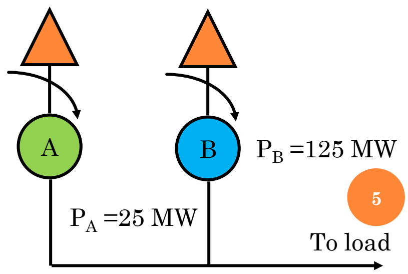
Frequency is constant in power system. Change load by shifting governor characteristics.

Active Power Division Between Alternators

To shift load: raise the no-load speed of Gen A raising the whole characteristic.



If 50 MW change required, pick up 25 MW on Gen A



Speed increases on A because more mechanical power is applied to the prime-mover

Speed increases on B because load transfers to A from B

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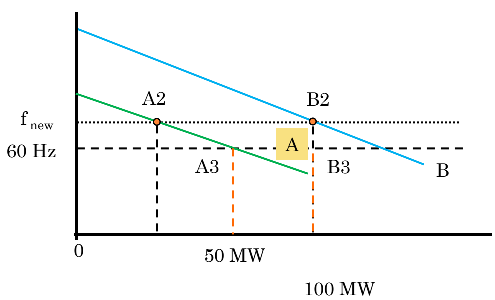
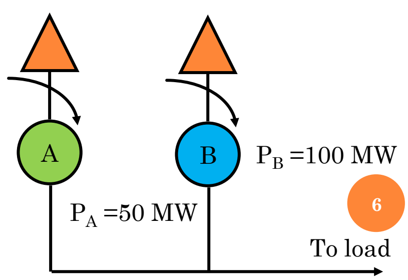
Active Power Division Between Alternators

System frequency must remain at 60 Hz so Gen B must lower its characteristic



Gen B lowers characteristic to reduce load by 25 MW



Machines with identical governor droops divide load increases equally between themselves regardless of machine rating

With dissimilar governor droops machine with least droop assumes most of any load change

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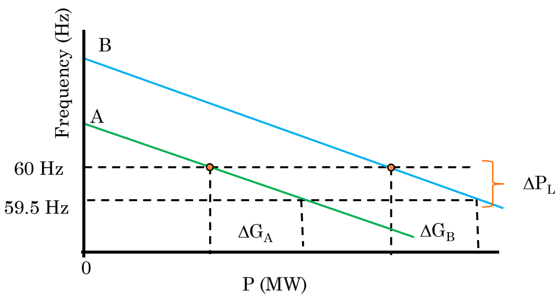
Load Increase and System Frequency

If electrical load on system increases and there is no governor control the system frequency falls



Adding load to a system with similar governor droops

$\Delta G_A = \Delta G_B$

Automatic control of governor no-load speed corrects for change in load by raising or lowering the characteristics of the machines. This causes the development of more or less mechanical power.
Steam Turbines – open turbine control valve more
Diesel Engine – open throttle more
Hydropower – open water control valves

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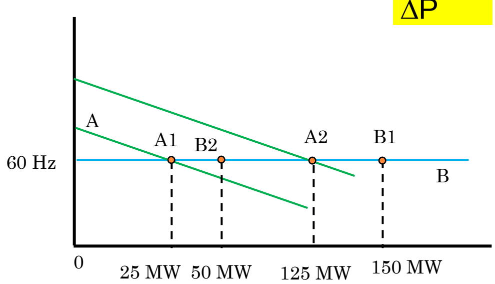
Isochronous Governors and Frequency Control

Isochronous governors - This type of governor can maintain constant speed for any level of output power.

For isochronous governors $\frac{\Delta f}{\Delta P} = 0$



Gen B is isochronous

Can only change loading by changing A's characteristic. Changing B changes system frequency. Isochronous machine takes load changes.

1.) $P_A = 25$ MW, $P_B = 150$ MW $P_T = P_A + P_B = 25+150 = 175$ MW

2.) $P_A = 125$ MW, $P_B = 50$ MW $P_T = P_A + P_B = 125+50 = 175$ MW

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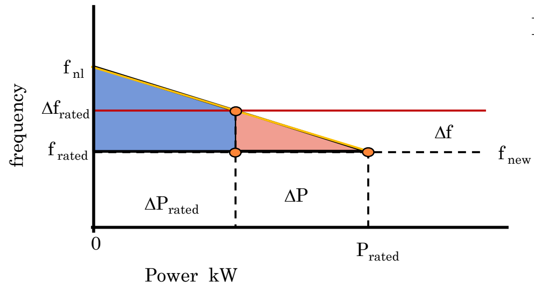
Power Division In Parallel Alternators

Use similar triangle solution to find active power distribution in parallel alternators



From Similar Triangles

$$GD = \frac{f_{nl} - f_{rated}}{P_{rated}}$$

So

$$\frac{f_{nl} - f_{rated}}{P_{rated}} = \frac{\Delta f}{\Delta P}$$

Rearranging the speed regulation equation gives:

$$GD = \frac{GSR \cdot f_{rated}}{P_{rated}} = \frac{\Delta f}{\Delta P}$$

Where: GD = governor droop
GSR = governor speed regulation
Δf = change in f due to change in load
ΔP = change in load

Example 22-1: Parallel generators A and B share a total load of 300 kW at 60 Hz.

Machine	Voltage	Power	GSR	Freq	Load
A	460 V	500 kW	2.0%	60 Hz	100 kW
B	460 V	500 kW	2.0%	60 Hz	200 kW

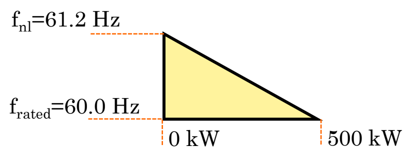
If generator A trips off line determine a.) frequency of generator A b.) frequency of generator B c.) frequency of the system

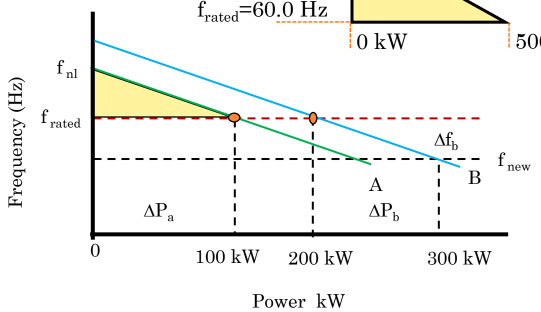
Qualitative analysis: Machine A loses load and should have speed increase. Machine B must take up load lost by A and should decrease speed.

EXAMPLE 22-1 SOLUTION (1)

Show system operation using power/frequency plots

$$f_{nl} = f_{rated} + GSR \cdot f_{rated}$$
$$f_{nl} = 60\ \text{Hz} + 0.02 \cdot 60\ \text{Hz}$$
$$f_{nl} = 61.2\ \text{Hz}$$





After A trips off-line P_A=0 and P_B=300 kW
ΔP_A=ΔP_B=100 kW

EXAMPLE 22-1 SOLUTION (2)

a.) For machine A

$$\frac{GSR \cdot f_{rated}}{P_{rated}} = \frac{\Delta f_a}{\Delta P_a}$$

ΔP_a = 100 kW A tripped off. Now delivers 0 kW

$$\frac{0.02 \cdot 60\ \text{Hz}}{500\ \text{kW}} = \frac{\Delta f_a}{100}$$
$$\Delta f_a = 0.24\ \text{Hz}$$
$$f_a = 60 + 0.24 = 60.24\ \text{Hz}$$

Answer

Loss of electrical load causes speed to increase if mechanical power input is not decreased.

EXAMPLE 22-1 SOLUTION (3)

b.) Since Gen A and B are identical, increasing electrical load causes frequency to drop if mechanical power input is not increased

$$f_b = 60 - 0.24 = 59.76\ \text{Hz}$$ Answer

c.) Only Gen B is on-line, so its frequency is the system frequency

$$f_s = 59.76\ \text{Hz}$$ Answer

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Example 22-2: 500 kW 60 Hz 2300 V alternator is paralleled with a 60 Hz 300 kW machine. Both have governor speed regulation values of 2.43%. Each machine carries 200 kW at a frequency of 60.5 Hz. If total load increases to 500 kW determine:

a.) system frequency
b.) load carries by each machine

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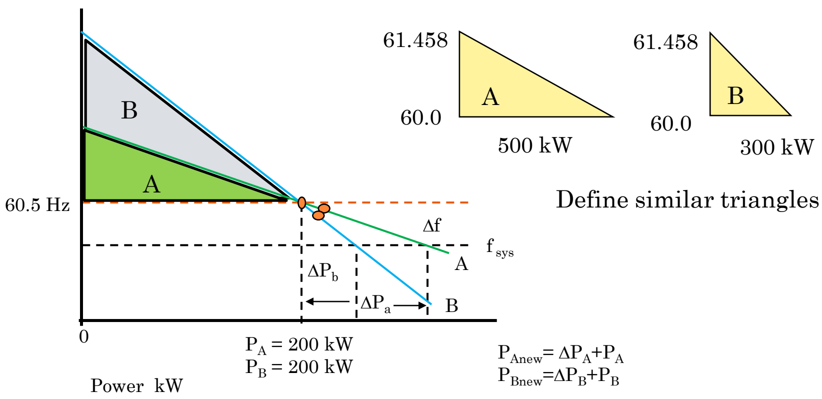
EXAMPLE 22-2 SOLUTION (1)

Machines have unequal governor droops.



Define similar triangles

Increasing load causes machines to follow governor curves

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EXAMPLE 22-2 SOLUTION (2)

FOR EACH MACHINE

$$\frac{GSR \times f_{rated}}{P_{rated}} = \frac{\Delta f}{\Delta P}$$

In this case ΔP & Δf are unkown

$P_{rated\,A} = 500$ kW $\quad f_{rated\,A} = f_{rated\,B} = 60$ Hz

$P_{rated\,B} = 300$ kW $\quad GSR_A = GSR_B = 0.0243$

So for MACHINE A

$$\frac{0.0243(60\,Hz)}{500\,kW} = \frac{\Delta f_s}{\Delta P_A}$$

$$\Delta P_A = 342.936\,\Delta f_s$$

MACHINE B

$$\frac{0.0243(60\,Hz)}{300\,kW} = \frac{\Delta f_s}{\Delta P_B}$$

$$\Delta P_B + 205.761\,\Delta f_s$$

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EXAMPLE 22-2 SOLUTION (3)

$\Delta P_A + \Delta P_B = \Delta P_L$

ΔP_L = change in sysem load

$(500kW - 400kW) = \Delta P_L$

$\Delta P_A + \Delta P_B = 342.936\,\Delta f_s + 205.761\,\Delta f_s = 500 - 400\ kW$

$548.697\ Hz/kW\ \Delta f_s = 100\ kW$

$\Delta f_s = 0.182\ Hz$

Increase in load causes f decrease

$f_s = f_{init} - \Delta f_s \quad f_{init} = 60.5\ Hz$

$f_s = 60.5\ Hz - 0.182\ Hz = \boxed{60.318\ Hz}$

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EXAMPLE 22-2 SOLUTION (4)

ΔP_A and ΔP_B found from original relationships

$\Delta P_A = 342.936\,\Delta f = 342.936(0.182) = 62.414\ kW$

$\Delta P_B = (205.761\ Hz/kW)(0.182\ Hz) = 37.586\ kW$

OR

$\Delta P_L = 100\ kW \quad \Delta P_L = \Delta P_A + \Delta P_B$

so $\Delta P_B = \Delta P_L - \Delta P_A$

$\Delta P_B = 100kW - 62.414\ kW$

$\Delta P_B = 37.586\ kW$

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Example 22-2 Solution (5)

$$P_{A_{new}} = P_A + \Delta P_A = 200\ kW + 62.414\ kW$$

$$\boxed{P_{A_{new}} = 262.414\ kW}$$

$$P_{B_{new}} = P_B + \Delta P_B = 200\ kW + 37.59\ kW$$

$$\boxed{P_{B_{new}} = 237.59\ kW}$$

End Lesson 22: Active Power Division Between Alternators

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