School of Electrical, Electronics and Communication Engineering

Course Code : MPSE2502 **Course Name: Power System Dynamics and Stability**

UNIT V

CONTROL OF GENERATING POWER UNIT OUTPUT

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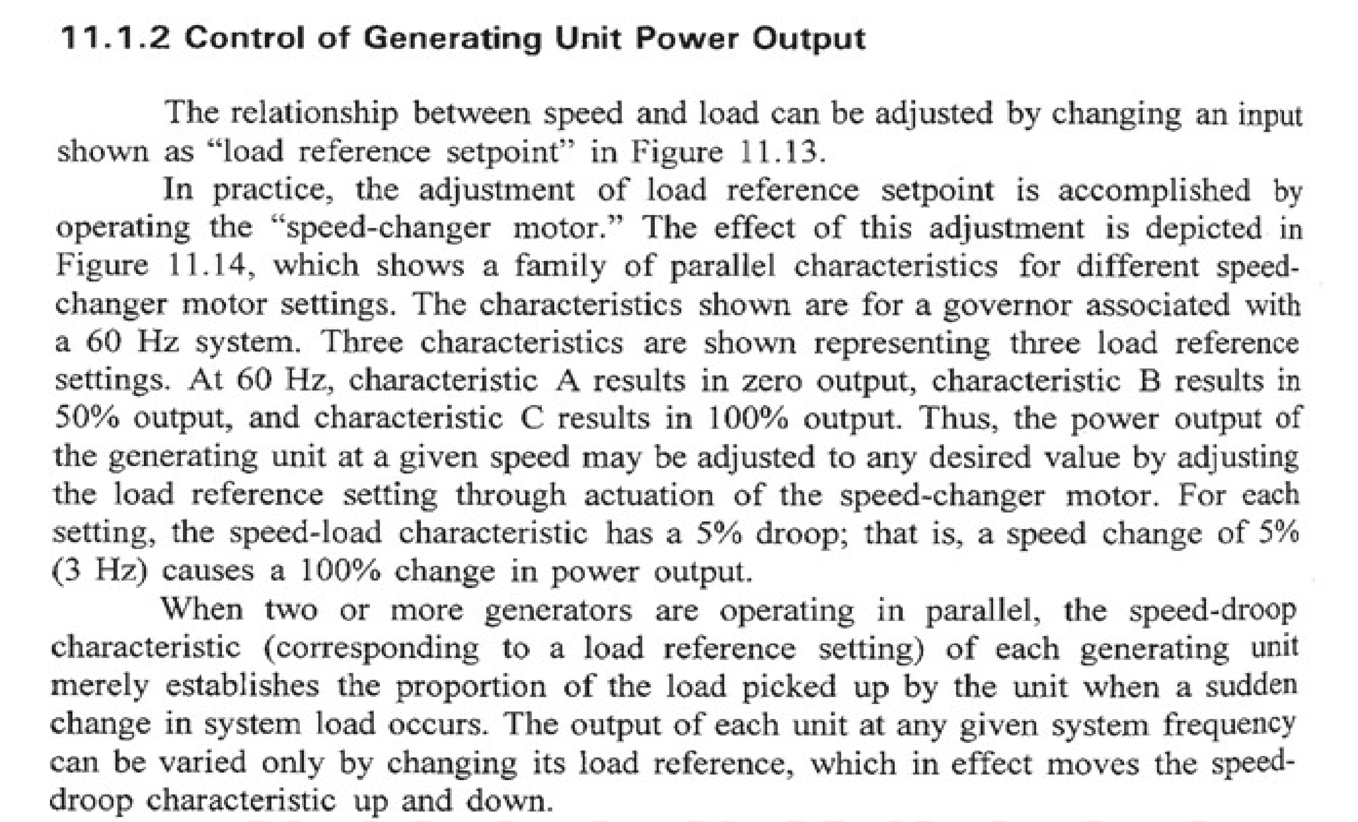
Contents

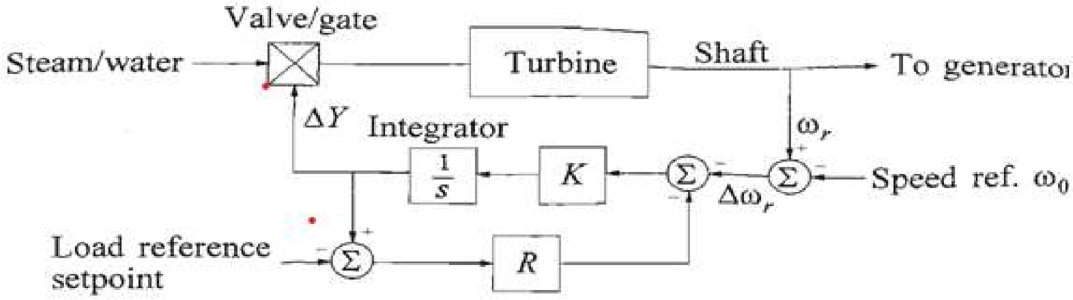


11.1.2 Control of Generating Unit Power Output

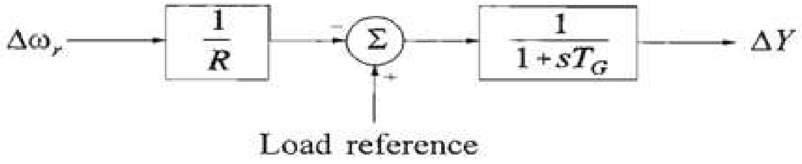
The relationship between speed and load can be adjusted by changing an input shown as "load reference setpoint" in Figure 11.13.

In practice, the adjustment of load reference setpoint is accomplished by operating the "speed-changer motor." The effect of this adjustment is depicted in Figure 11.14, which shows a family of parallel characteristics for different speed-changer motor settings. The characteristics shown are for a governor associated with a 60 Hz system. Three characteristics are shown representing three load reference settings. At 60 Hz, characteristic A results in zero output, characteristic B results in 50% output, and characteristic C results in 100% output. Thus, the power output of the generating unit at a given speed may be adjusted to any desired value by adjusting the load reference setting through actuation of the speed-changer motor. For each setting, the speed-load characteristic has a 5% droop; that is, a speed change of 5% (3 Hz) causes a 100% change in power output.

When two or more generators are operating in parallel, the speed-droop characteristic (corresponding to a load reference setting) of each generating unit merely establishes the proportion of the load picked up by the unit when a sudden change in system load occurs. The output of each unit at any given system frequency can be varied only by changing its load reference, which in effect moves the speed-droop characteristic up and down.

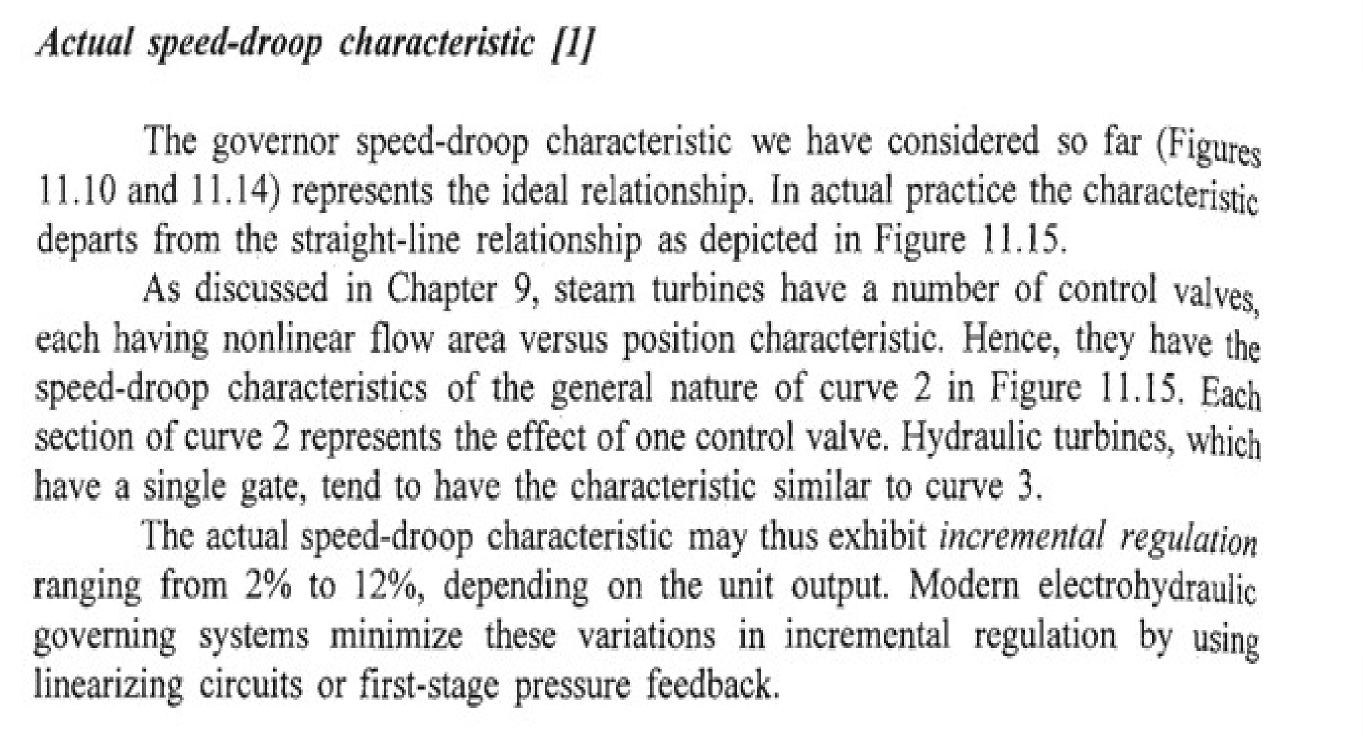


(a) Schematic diagram of governor and turbine



(b) Reduced block diagram of governor

Figure 11.13 Governor with load reference control for adjusting speed-load relationship

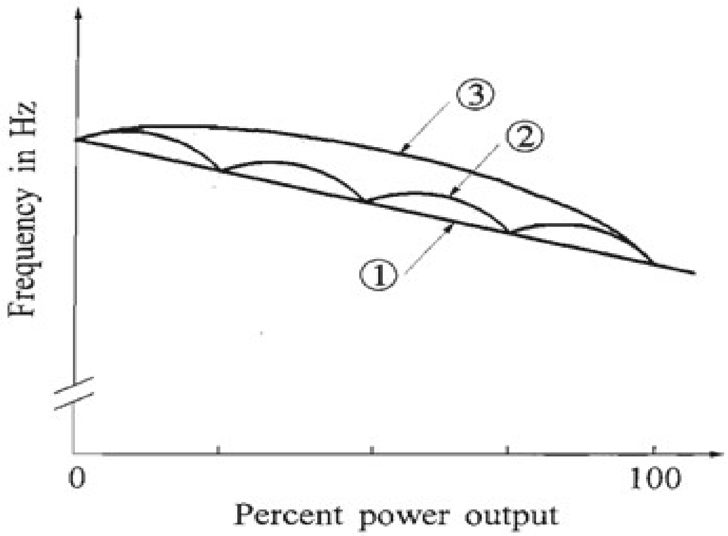


Actual speed-droop characteristic [1]

The governor speed-droop characteristic we have considered so far (Figures 11.10 and 11.14) represents the ideal relationship. In actual practice the characteristic departs from the straight-line relationship as depicted in Figure 11.15.

As discussed in Chapter 9, steam turbines have a number of control valves, each having nonlinear flow area versus position characteristic. Hence, they have the speed-droop characteristics of the general nature of curve 2 in Figure 11.15. Each section of curve 2 represents the effect of one control valve. Hydraulic turbines, which have a single gate, tend to have the characteristic similar to curve 3.

The actual speed-droop characteristic may thus exhibit *incremental regulation* ranging from 2% to 12%, depending on the unit output. Modern electrohydraulic governing systems minimize these variations in incremental regulation by using linearizing circuits or first-stage pressure feedback.



Curve 1: Ideal linear characteristic
Curve 2: Actual characteristic for steam units
Curve 3: Actual characteristic for hydraulic units

Figure 11.15 Actual and ideal governor speed-droop characteristics

11.1.3 Composite Regulating Characteristic of Power Systems

In the analysis of load-frequency controls (LFCs), we are interested in the collective performance of all generators in the system. The intermachine oscillations and transmission system performance are therefore not considered. We tacitly assume the coherent response of all generators to changes in system load and represent them by an equivalent generator. The equivalent generator has an inertia constant M_{eq} equal to the sum of the inertia constants of all the generating units and is driven by the combined mechanical outputs of the individual turbines as illustrated in Figure 11.16. Similarly, the effects of the system loads are lumped into a single damping constant D. The speed of the equivalent generator represents the system frequency, and in per unit the two are equal. We will therefore use rotor speed and frequency interchangeably in our discussion of load-frequency control.

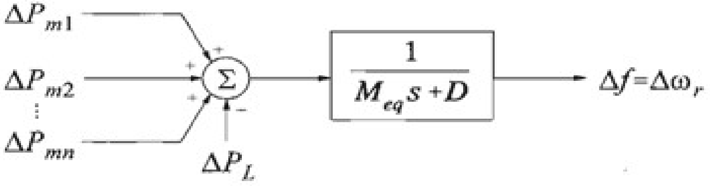
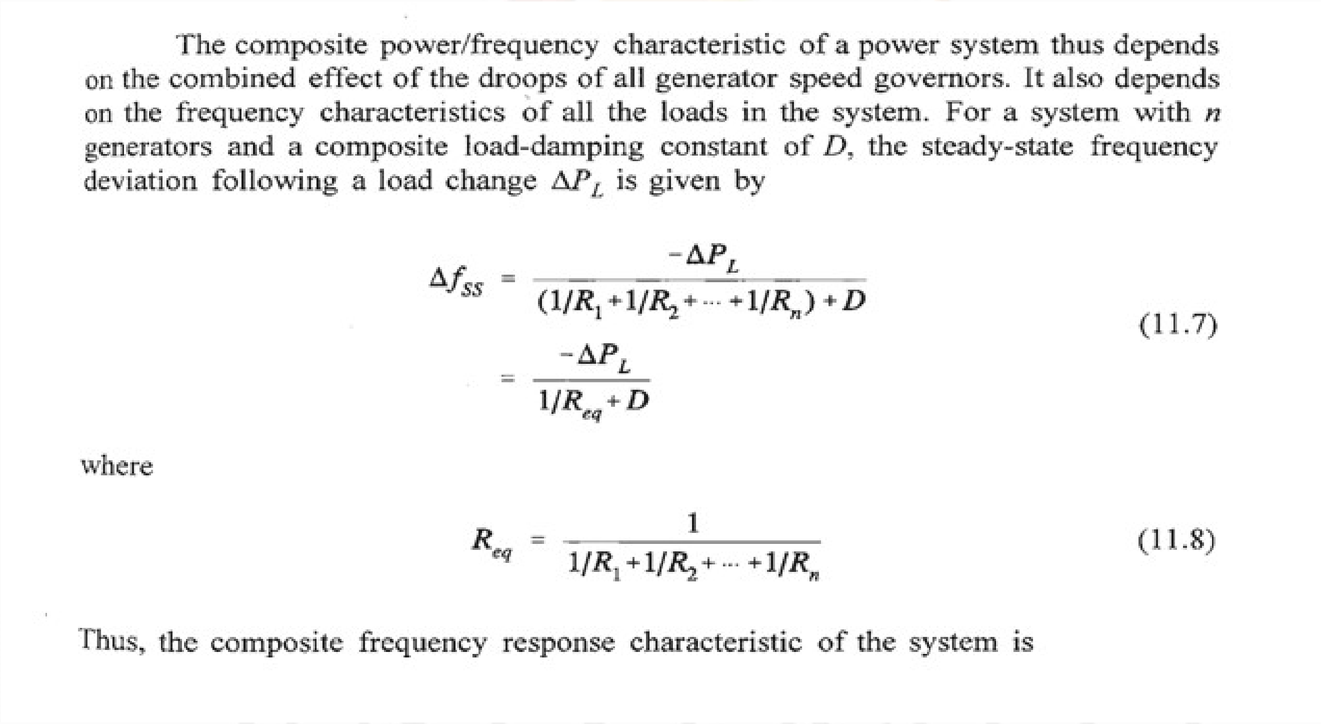


Figure 11.16 System equivalent for LFC analysis



The composite power/frequency characteristic of a power system thus depends on the combined effect of the droops of all generator speed governors. It also depends on the frequency characteristics of all the loads in the system. For a system with n generators and a composite load-damping constant of D, the steady-state frequency deviation following a load change ΔP_L is given by

$$\begin{aligned} \Delta f_{ss} &= \frac{-\Delta P_L}{(1/R_1 + 1/R_2 + \cdots + 1/R_n) + D} \\ &= \frac{-\Delta P_L}{1/R_{eq} + D} \end{aligned} \tag{11.7}$$

where

$$R_{eq} = \frac{1}{1/R_1 + 1/R_2 + \cdots + 1/R_n} \tag{11.8}$$

Thus, the composite frequency response characteristic of the system is

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