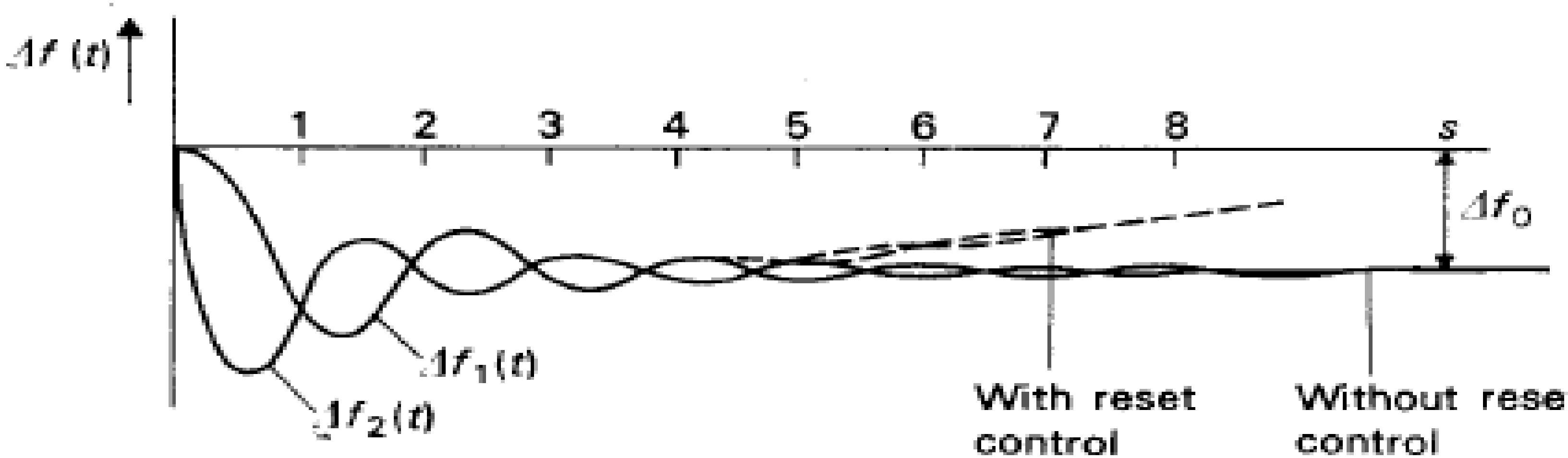
Tie line bias control

- The response curves in Fig. a indicate clearly that some form of reset integral control must be added to the two-area system.



(a). Dynamic response of two-area system subject to a step-load increase in area 2

- The persistent static frequency error is intolerable in tie-line power flow—so-called "inadvertent exchange"—would mean that one area would have to support the other on a steady-state basis. A basic guiding principle in pool operation must be that each area, in normal steady state, absorbs its own load.

- Various methods of reset integral control have over the years been tried out—and abandoned—for multiarea systems. For example, in our two-area system we could conceive of the arrangement that area 1 be responsible for frequency reset and area 2 take care of the tie-line power. We would thus arrange for the following area control errors:

$$\begin{aligned} \mathrm{ACE}_1 &\triangleq \Delta f_1 \\ \mathrm{ACE}_2 &\triangleq \Delta P_{21} \end{aligned} \tag{9-77}$$

- These ACE's would be fed via slow integrators on to the respective speed changers. This arrangement would work—but not too good. Actually in the early days of pool operation one area was designated to reset the system frequency and the others would be responsible for zeroing their own "net interchanges" . The problem with this arrangement proved to be that the central frequency controlling station tended to regulate for everybody trying to absorb everybody else's errors and offsets. As a result it would swing wildly between its generating limits.

- As a result of the original work by Cohn[4] a control standard has developed. The control strategy is termed "tie-line bias control" and is based upon the principle that *all operating pool members must contribute their share to frequency control in addition to taking care of their own net interchange.*

- **Tie-Line Bias Control of Two-Area System**
- In applying this reset control method to our two-area system we would add the dashed loops shown in the next Fig(b). The control error for each area consists of a linear combination of frequency and tie-line error:

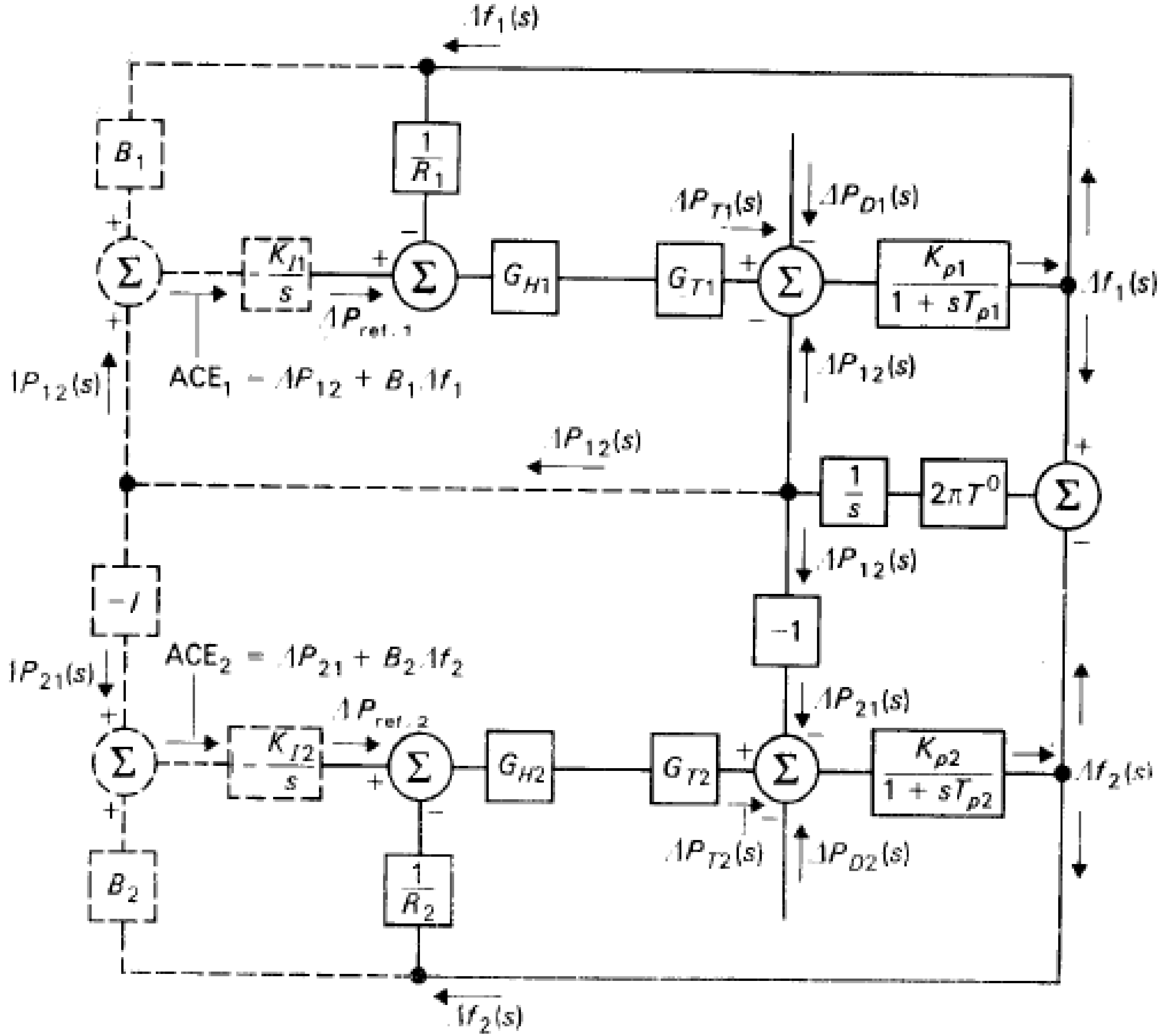
$$\begin{aligned} \mathrm{ACE}_1 &\triangleq \Delta P_{12} + B_1 \Delta f_1 \\ \mathrm{ACE}_2 &\triangleq \Delta P_{21} + B_2 \Delta f_2 \end{aligned} \tag{1}$$

The speed-changer commands will thus be of the form

$$\begin{aligned} \Delta P_{\mathrm{ref},1} &= -K_{I1} \int (\Delta P_{12} + B_1 \Delta f_1)\, dt \\ \Delta P_{\mathrm{ref},2} &= -K_{I2} \int (\Delta P_{21} + B_2 \Delta f_2)\, dt \end{aligned} \tag{2}$$

- The constants K_{I1} and K_{I2} are integrator gains, and the constants B_1 and B_2 are the *frequency bias* parameters. The minus signs must be included since each area should *increase* its generation if *either* its frequency error *or* its tie-line power increment is negative.

(b)



- **Static System Response**
- The chosen strategy will eliminate the steady-state frequency *and* tie-line deviations for the following reasons.
- Following a step load change in either area, a new static equilibrium, *if such an equilibrium exists,* can be achieved only after the speed-changer commands have reached *constant values.* But this evidently requires that both integrands in Eq. (2) be zero; i.e.,

$$\Delta P_{12,0} + B_1 \Delta f_0 = 0 \qquad (3)$$
$$\Delta P_{21,0} + B_2 \Delta f_0 = 0$$

In view of Eq. (9-68), these conditions can be met *only* if

$$\Delta f_0 = \Delta P_{12,0} = \Delta P_{21,0} = 0 \qquad (4)$$

- The question what "best" value to choose for the B parameters has been hotly debated. Cohn has shown that choosing $B = \beta$ (i.e., the AFRC) produces satisfactory over-all performance of the interconnected system. The integrator gain constants K_{I1} and K_{I2} are not critical -but they must be chosen small enough not to stimulate the area generators to " chase " load offsets of short duration.

- The actual effect on the frequency and tie-line power graphs of the added tie-line bias control is shown in Fig, (b) (dashed parts of graphs). Following the immediate excursions which are entirely determined by the primary speed-governor loops of each area, the secondary integrator loops of each area go into action and reset both the frequency and tie-line power back to original values.

- **9-4-10 Tie-Line Bias Control of Multiarea Systems**
- In reality a control area is interconnected not with one tie-line to one neighboring area but with several tie-lines to neighboring control areas, all part of the overall power pool. Consider the ith control area. Its *net interchange* equals the sum of the megawatts on all '*m*' outgoing tie-lines. As the area control error ACEi. ought to be reflective of the *total* exchange of power it should thus be chosen of the form

$$\mathrm{ACE}_i = \sum_{j=1}^{m} \Delta P_{ij} + B_i \, \Delta f_i \qquad (5)$$

- Typically, the reset control is implemented by *sampled-data* technique; At sampling intervals of, say, one second, all tie-line power data are fed into the central energy control center where they are added and compared with predetermined contracted interchange megawatts. In this way is obtained the sum-error of Eq. (5). This error is added to the biased frequency error and the ACE results. The ACE is communicated with all area generators that are participating in the secondary ALFC. If optimum dispatch is employed, a tertiary. slower "OD loop" is added.

where

$$\delta_1^o, \delta_2^o = \text{power angles of equivalent machines of the two areas.}$$

For incremental changes in δ_1 and δ_2, the incremental tie line power can be expressed as

$$\Delta P_{\text{tie},1}(\text{pu}) = T_{12}(\Delta\delta_1 - \Delta\delta_2) \tag{8.27}$$

where

$$T_{12} = \frac{|V_1|\,|V_2|}{P_{r1}X_{12}} \cos(\delta_1^o - \delta_2^o) = \textit{synchronizing coefficient}$$

Since incremental power angles are integrals of incremental frequencies, we can write Eq. (8.27) as

$$\Delta P_{\text{tie},1} = 2\pi T_{12}\left(\int \Delta f_1\,\mathrm{d}t - \int \Delta f_2\,\mathrm{d}t\right) \tag{8.28}$$

where Δf_1 and Δf_2 are incremental frequency changes of areas 1 and 2, respectively.

Similarly the incremental tie line power out of area 2 is given by

$$\Delta P_{\text{tie},2} = 2\pi T_{21}\left(\int \Delta f_2 \, \mathrm{d}t - \int \Delta f_1 \, \mathrm{d}t\right) \tag{8.29}$$

where

$$T_{21} = \frac{|V_2|\,|V_1|}{P_{r2}X_{21}} \cos(\delta_2^\circ - \delta_1^\circ) = \left(\frac{P_{r1}}{P_{r2}}\right) T_{12} = a_{12}T_{12} \tag{8.30}$$

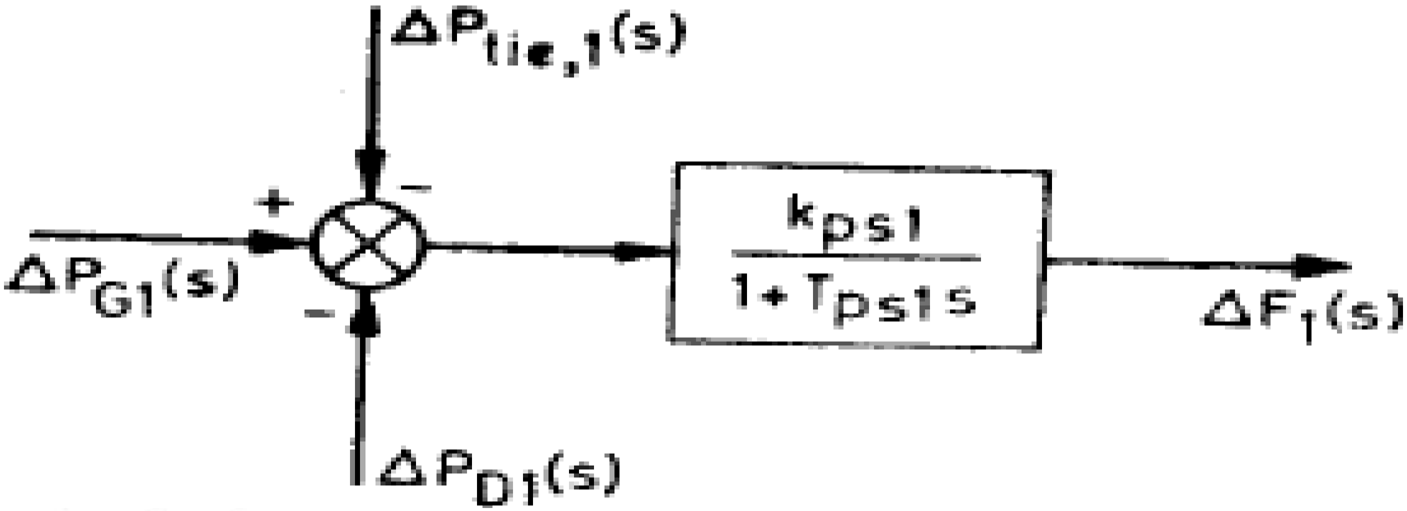
With reference to Eq. (8.12), the incremental power balance equation for area 1 can be written as

$$\Delta P_{G1} - \Delta P_{D1} = \frac{2H_1}{f_1^\circ} \frac{\mathrm{d}}{\mathrm{d}t}(\Delta f_1) + B_1 \, \Delta f_1 + \Delta P_{\text{tie},1} \tag{8.31}$$

It may be noted that all quantities other than frequency are in per unit in Eq. (8.31).

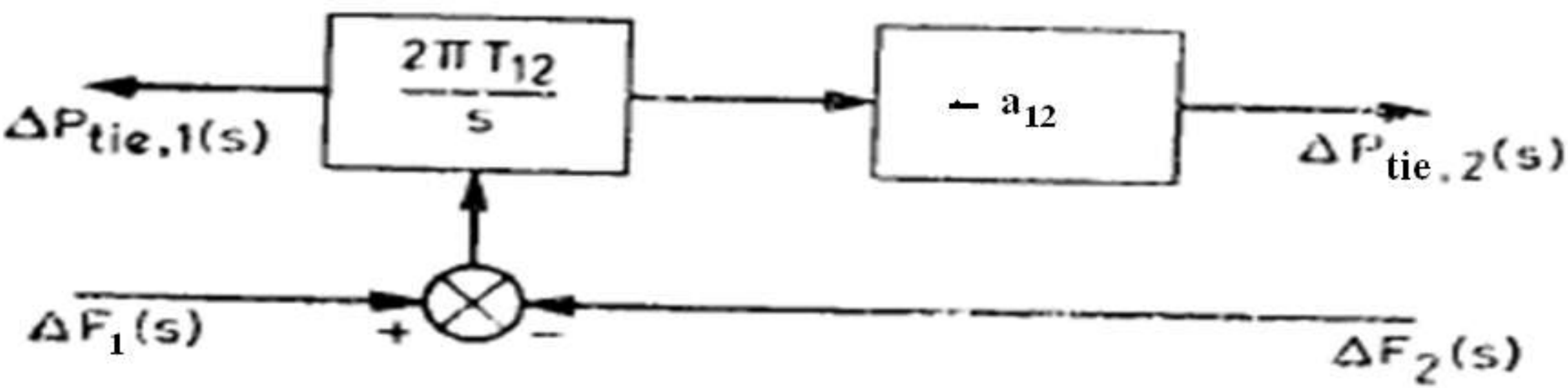
Taking the Laplace transform of Eq. (8.31) and reorganizing, we get

$$\Delta F_1(s) = [\Delta P_{G1}(s) - \Delta P_{D1}(s) - \Delta P_{\text{tie},1}(s)] \times \frac{K_{ps1}}{1 + T_{ps1}s} \tag{8.32}$$



Taking the Laplace transform of Eq. (8.28), the signal $\Delta P_{tie,1}(s)$ is obtained as

$$\Delta P_{tie,1}(s) = \frac{2\pi T_{12}}{s}[\Delta F_1(s) - \Delta F_2(s)] \tag{8.34}$$



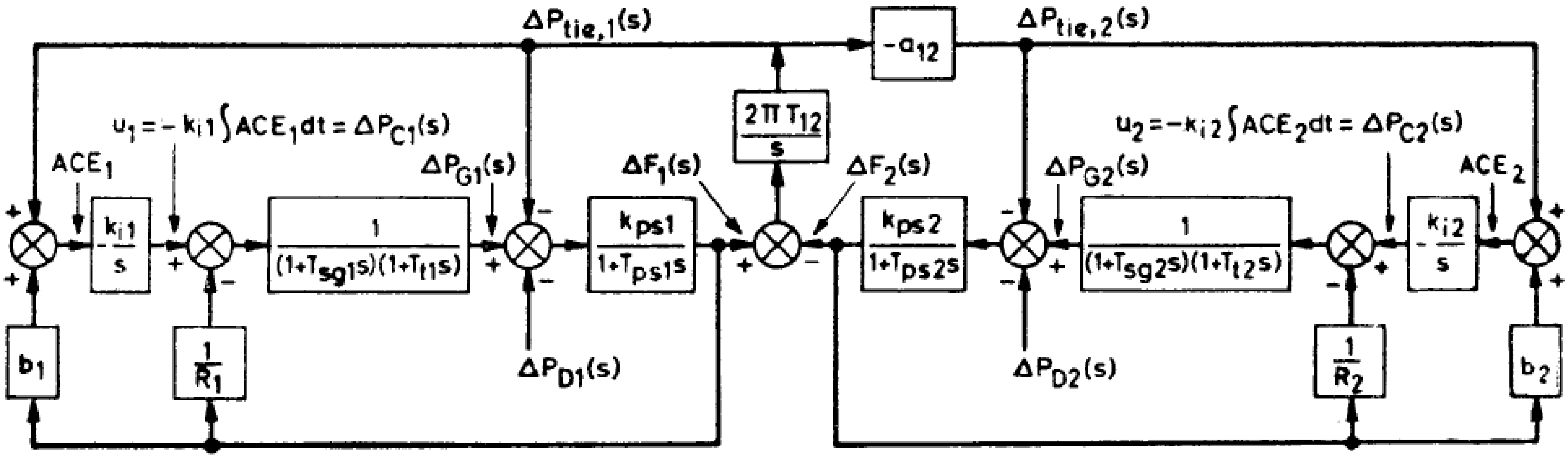
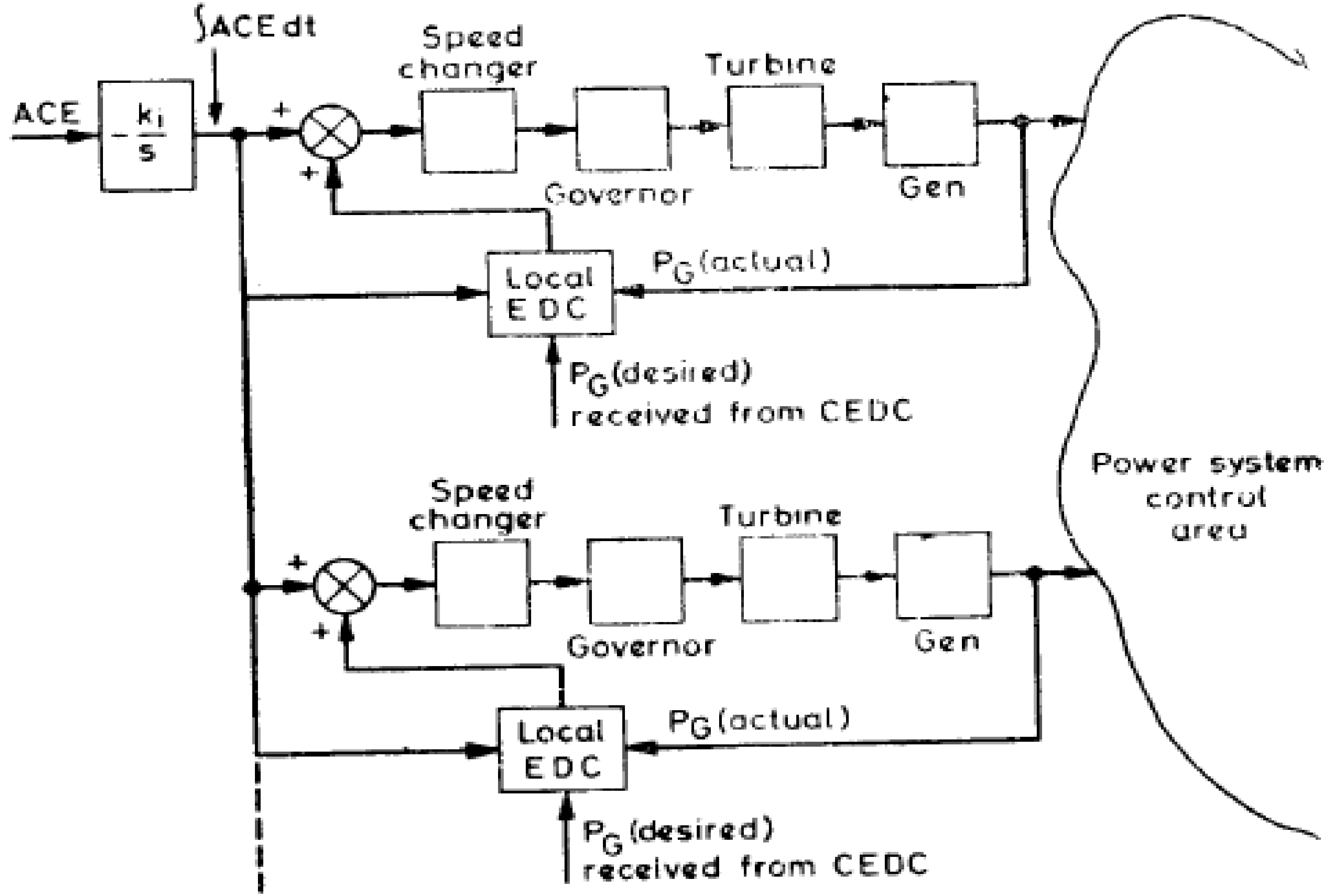
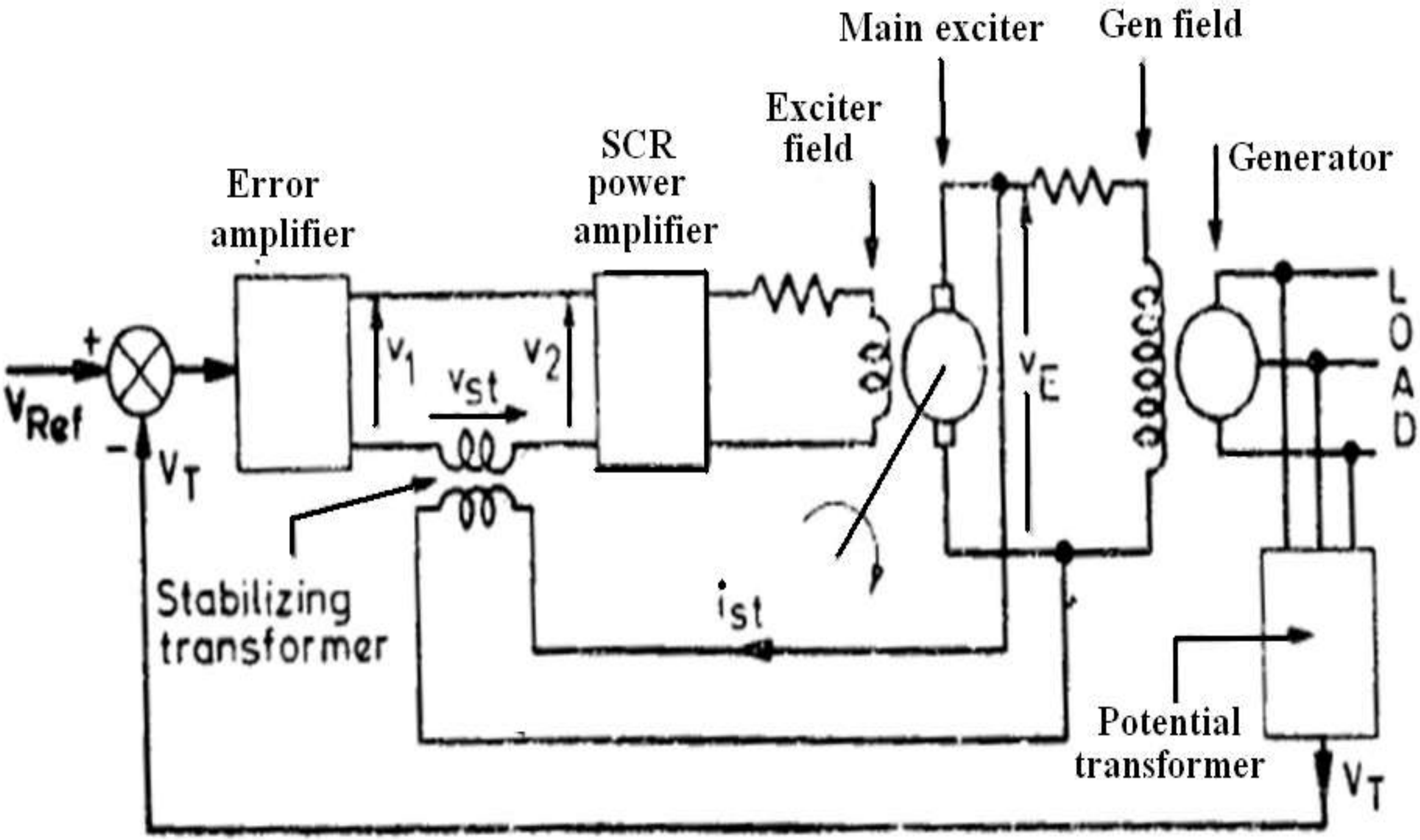


Fig. 8.16 Composite block diagram of two-area load frequency control (feedback loops provided with integral of respective area control errors)

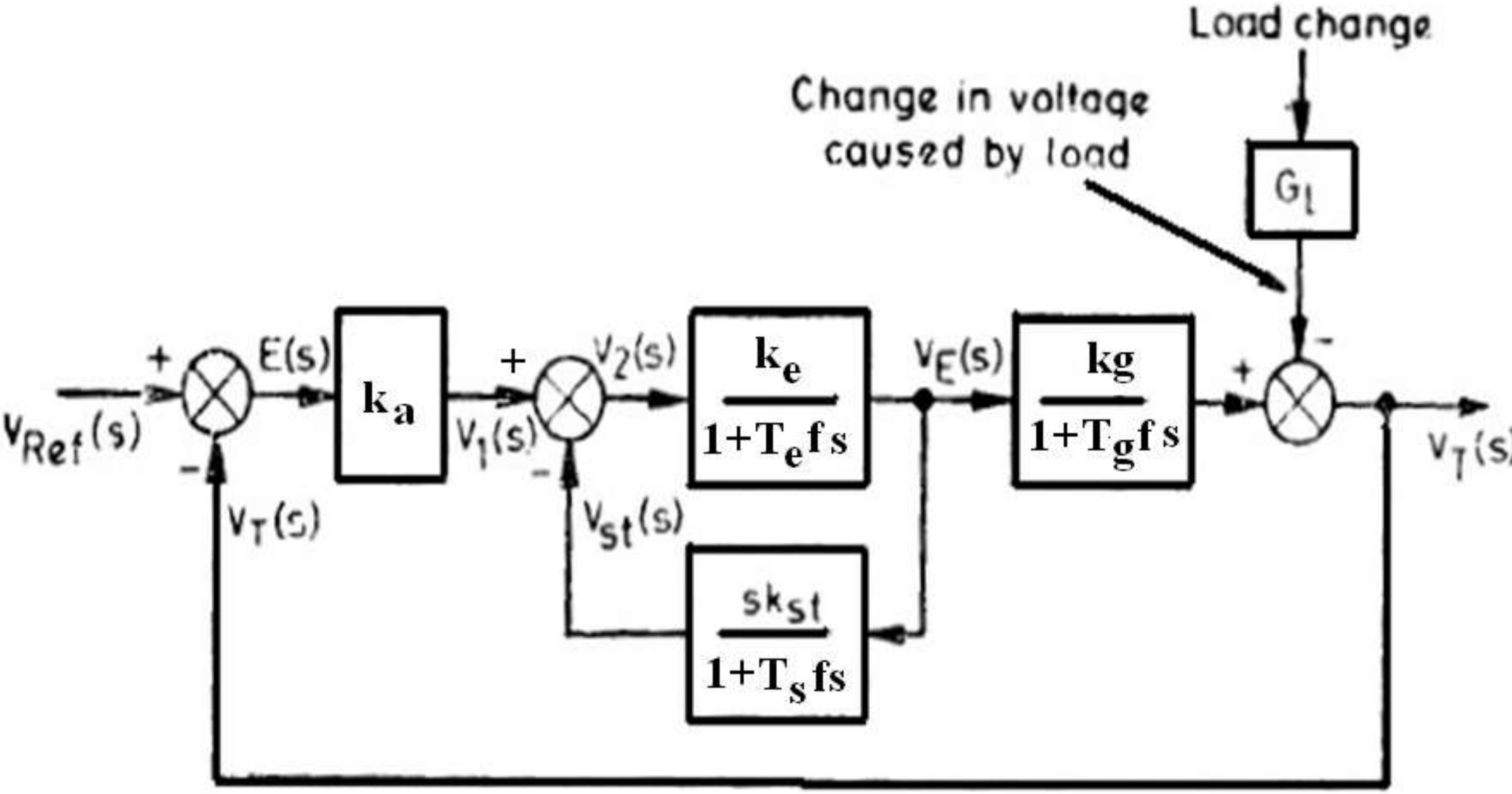


EDC – Economic despatch controller
CEDC – Central economic despatch computer

Automatic voltage regulator of Generator



- It basically consists of a main exciter which excites the alternator field to control the output voltage. The exciter field is automatically controlled through error $e = V_{ref} — V_T$, *suitably amplified through voltage and power amplifiers. It is a type-0 system which requires a constant error 'e' for a specified voltage at generator terminals. The block diagram of the system is given in Fig. below. The function of important components and their transfer functions is given below:*



Load change
Change in voltage
caused by load
G_l
+
-
E(s)
k_a
$v_{Ref}(s)$
$v_T(s)$
$v_1(s)$
$v_2(s)$
$v_{st}(s)$
$\frac{k_e}{1+T_e f s}$
$v_E(s)$
$\frac{kg}{1+T_g f s}$
$\frac{s k_{st}}{1+T_s fs}$
$v_T(s)$

- *Potential transformer: It gives a sample of terminal voltage V_T.*
- *Differencing device: It gives the actuating error*

  $e = V_{ref} - V_T$
- The error initiates the corrective action of adjusting the alternator excitation. Error wave form is suppressed carrier modulated, the carrier frequency being the system frequency of 50 Hz.
- *Error amplifier: It demodulates and amplifies the error signal. Its gain is K_a.*

- *SCR power amplifier and exciter field: It provides the necessary power amplification to the signal for controlling the exciter field. Assuming the amplifier time constant to be small enough to be neglected, the overall transfer function of these two is*

$$\frac{K_e}{1 + T_{ef}s}$$

where T_{ef} *is the exciter field time constant.*

- *Alternator: Its field is excited by the main exciter voltage v_E. Under no load it produces a voltage proportional to field current. The no load transfer function is*

$$\frac{K_g}{1 + T_{gf}s}$$

- where
- T_{gf} *= generator field time constant.*
- The load causes a voltage drop which is a complex function of direct and quadrature axis currents. The effect is only schematically represented by block G_L.

- *Stabilizing transformer: T_{ef} and T_{gf} are large enough time constants to impair the system's dynamic response. It is well known that the dynamic response of a control system can be improved by the internal derivative feedback loop. The derivative feedback in this system is provided by means of a stabilizing transformer excited by the exciter output voltage v_E. The output of the stabilizing transformer is fed negatively at the input terminals of the SCR power amplifier. The transfer function of the stabilizing transformer is derived below.*

- Since the secondary is connected at the input terminals of an amplifier, it can be assumed to draw zero current. Now

$$v_L = R_1 i_{st} + L_1 \frac{di_{st}}{dt}$$

$$v_{st} = M \frac{di_{st}}{dt}$$

Taking the Laplace transform, we get

$$\frac{V_{st}(s)}{V_E(s)} = \frac{sM}{R_1 + sL_1} = \frac{sM/R_1}{1 + T_{st}s}$$

$$= \frac{sK_{st}}{1 + T_{st}s}$$