Electrical Power Engineering

By

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Lecture (2)

INTERCONNECTIONS OF POWER SYSTEMS

In general, there are three modes in which interconnected operation can be effected. These are:

A. Flat frequency.

B. Flat tie line.

C. Tie line with frequency bias.

A. Flat frequency

- Isolated systems inherently operate in the flat frequency mode because frequency is the only quantity that is affected when load changes.

- When systems are interconnected, they must operate at the same electrical speed, and speed changes in one system appear in all the interconnected systems.

- When one system of an interconnected group senses and responds to frequency changes only, it can exert no control overflow on interconnecting tie lines. This is the condition for flat frequency operation.

B. Flat tie line

- When a system responds to tie-line flow changes only and does not respond to frequency changes, it will maintain the desired tie-line flow but will not respond to changes in frequency. This mode of operation is known as "flat tie line“.

- any flow on tie lines above or below scheduled amounts is called tie-line error, that is, the system (or area) is not producing exactly the amount of power required to satisfy its own load plus the amount it is scheduled to deliver or minus the amount it is scheduled to receive.

Challenge

Neither of the above modes of operation satisfies all the three conditions previously listed as desirable for successful interconnected operation.

Solution

- As a result, it is almost universal for interconnected systems to operate in the tie-line bias mode. When operating with tie-line bias, systems will respond to both frequency changes and tie-line flow changes and will help to maintain desired frequency and tie-line schedules.
- To make it possible for a system to respond to frequency and tie- line changes, it is necessary to provide equipment that will develop error signals proportional to the deviations of these quantities from the desired values, in fig. 1 a method of developing such signals for three interconnected systems is shown.
- In the diagram it can be seen that tie-line flows, and system frequency are made available to the controllers of each system, each of the controllers compares desired total tie-line flow and desired frequency with the actual quantities and develops error signals. The error signals are used to develop control signals to prime-mover governors which restore tie-line flows to schedule and frequency to normal; that is, they reduce the errors to zero.

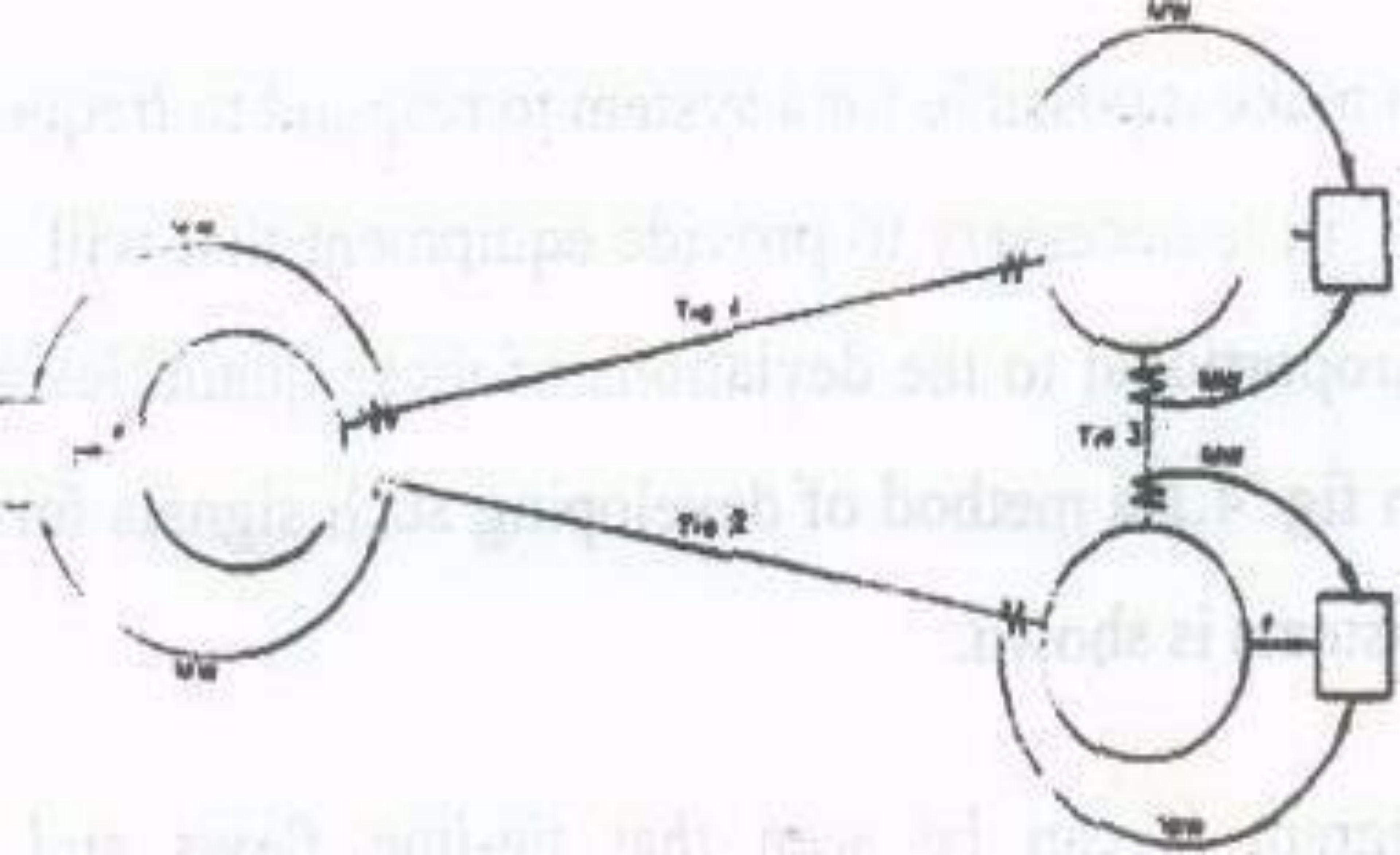

Figure 1: Diagram of three interconnected systems with tie-line flows telemetered and a frequency signal applied to the controller of each system.

C. Tie-Line Bias

- If frequency deviates from desired frequency (50 Hz), the difference between desired frequency and actual frequency is the frequency error.
- A loss of generation or fault will cause the frequency of a system to sag, the amount being dependent on the size of the system (rolling inertia, connected load, etc.).
- The frequency error signal should be adjusted to provide governor control to correct for the frequency swing. This is called frequency bias and is usually designated to megawatts per one-tenth cycle

C. Tie-Line Bias

- The bias is a negative quantity because the slope of the governor characteristic curve is negative; that is, the speed of a generator on governor control decreases as load increases.
- Fig. 2 shows the variation of bias correction versus frequency for 50 and 100 MW/0.1 Hz.
- The sum of tie-line and frequency errors can be expressed mathematically as "area requirement" or "area control error."

C. Tie-Line Bias

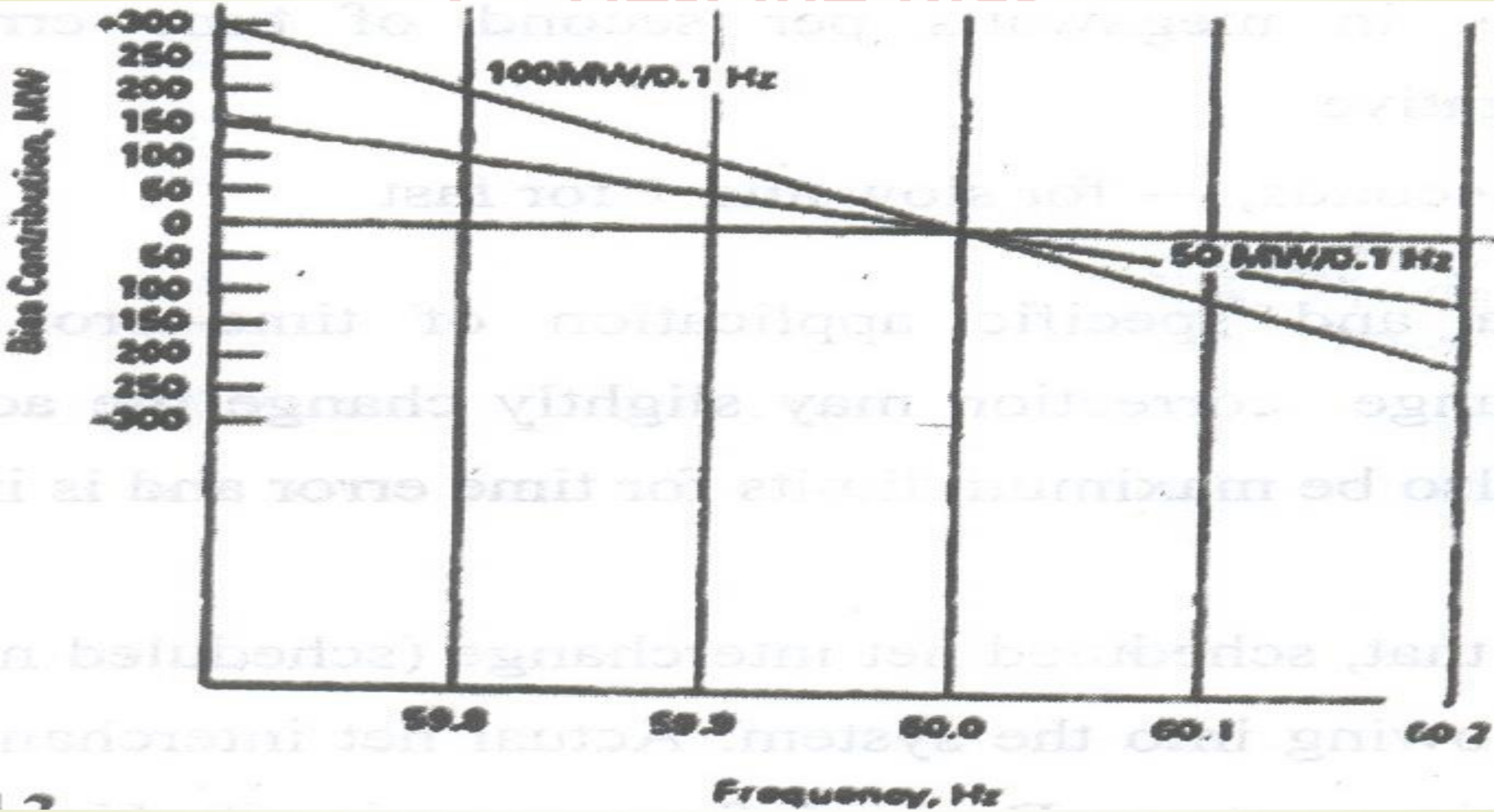

Figure 2: Variation of bias correction versus frequency for 50 and 100 MW/0.1 Hz

C. Tie-Line Bias

- When a system is operating with tie-line bias control, it will respond to both tie-line flow errors and frequency errors and assist in achieving the objective of having each control area match its generation with its load.
- It will also assist in restoring frequency to an interconnected area when an interconnected system suffers loss of generation or transmission.
- The frequency-bias setting must be reviewed from time to time to ensure that it is correct. For example, the addition of a large generating unit on a system would increase the inertia of the system and necessitate an increase in bias setting.

C. Tie-Line Bias

- When the frequency bias is too low, the system will not respond adequately to take its fair share of total interconnected system control during trouble conditions, resulting in a control burden on other systems.
- If bias is set too high, overcontrol will result, also putting an excessive control burden on adjacent systems.

Area Control Error

- The area control error (ACE) of a system or an interconnected group of systems is the resultant error in area interchange compared to the desired or scheduled interchange, including time error. It is the sum of the tie-line and frequency errors, and can be expressed mathematically as follows:

$$ACE = (T_1 - T_0) - 10B_F - (F_1 - F_0) \pm B_t \Delta t$$

Area Control Error

Where ACE = area control error (area requirement)

T_o=scheduled net interchange, which normally has a positive sign for lower flow out (scheduled net tie-line flow, MW at normal frequency)

T_1 = actual net interchange (tie-line flow), MW

Fo = desired frequency, Hz

F_1= actual frequency, Hz

B_f = area bias, megawatts per 0.1 Hz (which has a negative sign due to the negative slope of the bias characteristic curve)

B_t= time error bias in megawatts per second of time error also considered negative

Δt = time error in seconds, — for slow and + for fast

Example: Area Control Error

Assume that scheduled net interchange (scheduled net tie- line flow) is 200 MW flowing into the system. Actual net interchange is 150 MW flowing into the system. Desired frequency is 50 Hz and actual frequency is 50.01 Hz. the frequency bias setting is -50 MW per 0.1 Hz and the time-error bias is 10 MW/s and the time error is 0.5 slow. Determine the area control error.

ACE = [-150 - (-200)] - 10 X (-50) (50.01 - 50) - 10 X 0.5

= 50+ 5 - 5 = 50 MW (over generation)

D. Accumulated frequency error

The frequency- error signal used in system control is developed by comparing system frequency against a frequency standard whose frequency output is not affected by power system operation, sources of standard frequency are quartz crystals (such as are used to control the frequency of radio transmitting stations), precisely controlled tuning forks, and radio signals from standard-frequency radio stations of the Bureau of Standards.

D. Accumulated frequency error

- By accumulating the instantaneous frequency deviations, it is also possible to determine the accumulated time error, which is usually limited to not more than 2 s fast or slow.
- When accumulated time error reaches the limit, or at other convenient times, by agreement, the interconnected systems all offset frequency by a predetermined amount (usually 0.02 Hz), in such a direction that time error will be reduced to zero. By this means the frequency of the interconnected systems is restored to normal.

Modem system-control equipment

- Modem system-control equipment provides control impulses as described above for load-frequency control and for economic allocation of generation, almost all modem AGC systems make use of digital computers

- Analog automatic dispatch systems have become relatively obsolete.
- AGC is combined into supervisory control and data acquisition systems. Objectives of system control are as follows:

1. Each system should provide enough capacity to carry its expected load at the desired frequency with provision for adequate reserve and regulating margin.
2. Each system should operate in such a way that it will not impose a regulating burden on interconnected systems.
3. Each system should continuously balance its generation against its load so that net tie-line loading agrees with its scheduled net interchange plus or minus its frequency-bias obligation.

Thank You For Your Attention

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