

Module 3 : Frequency Control in a Power System

Lecture 16 : Automatic Generation Control (AGC)

Objectives

In this lecture you will learn the following

- What is automatic generation control ?
- In what way is it different from governor action ?

Automatic Generation Control (AGC)

We saw in the previous [example](#) how load sharing in a multi-generator power system can be achieved using droop characteristics of governors. The sharing according to droop is *irrespective of load location*.

However if non-zero governor droops are used (which is necessary for appropriate sharing), a steady state frequency error will remain which needs to be corrected. Moreover, since all the governors respond to the load change irrespective of load location, there may be undesirable exchange of power between different areas of the grid. This is manifested as a change in the flows of lines interconnecting these areas.

To ensure that frequency steady state error is corrected and generators in a particular area take on the burden of their own load, the load reference (P_{m0}) of governors is adjusted *slowly*. This control is also called "secondary control". This correction may be done over several minutes as opposed to 5-10 seconds for initial or "primary" control action of governors.

Thus, while primary control (governor action) ensures that a large and sudden frequency fall or rise is prevented, secondary control or Automatic Generation Control ensures that frequency is brought back to the nominal value and inter-area power flow is regulated.

Automatic Generation Control (AGC) (Contd..)

Any change of reference value will lead to a change in sharing among the generators. Thus by slowly changing the reference of speed governors we can over-ride the sharing which is imposed by the droop characteristics.

The question then arises: which generators should change their governor references and what the exact value of these changes ?

In a 2 - area system, if governors are present on some machines in both areas

and

a) power flow in certain ac line, which connects 2 areas is to be regulated.

and

b) Frequency has to be brought back to its nominal value after any load generation change

then

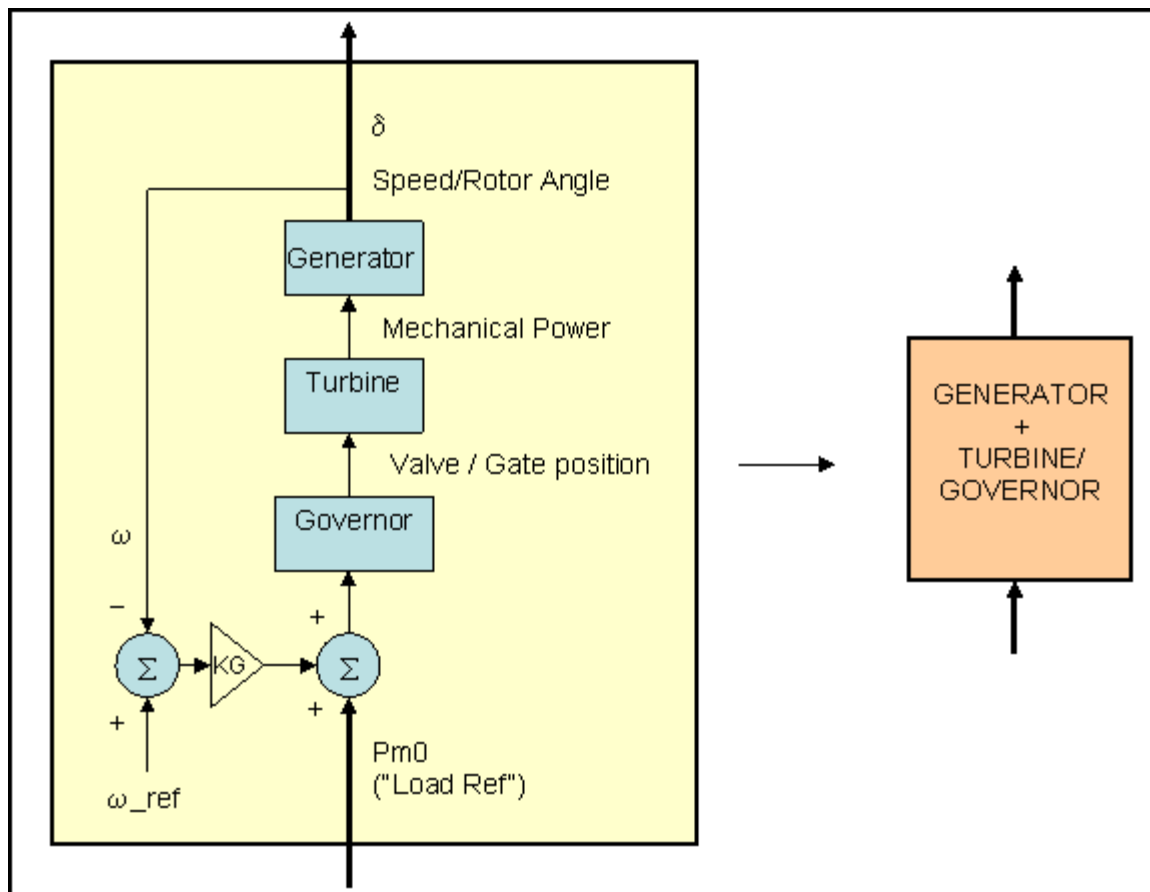
the references of atleast 2 governors (one in each area) in the system should be changed to achieve these objectives.

Note: It is not feasible to *independently* change more than one governor reference in one area, otherwise there is no unique value of reference change for different governors. Thus if more than one governors in an area are "on AGC", then their actions have to be in a pre-decided proportion and not independent of one another.

The AGC concept is illustrated by the following schematic in the next slide.

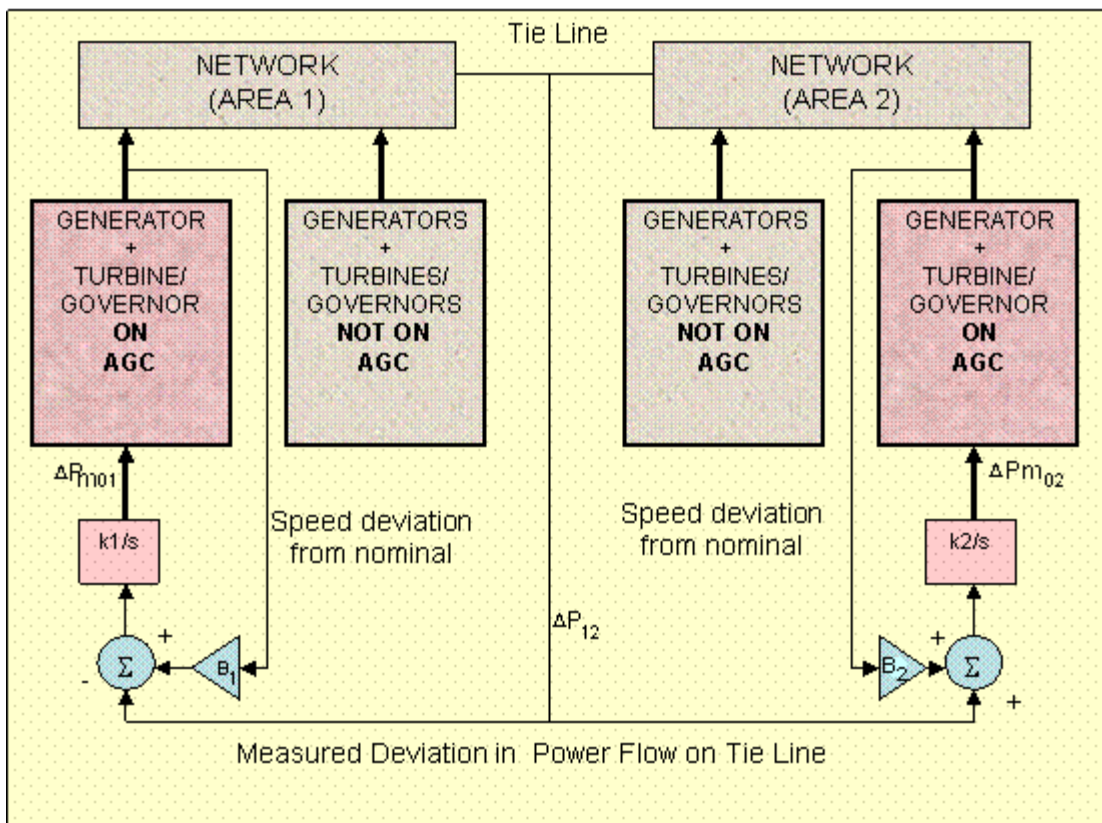
Automatic Generation Control (AGC) (Con td...)

Each generator which has a governor can be represented as follows. Note that the value of the load reference P_{m0} is adjusted by AGC.



Automatic Generation Control (AGC) (Con td...)

The following figure shows how a generator in each area in a 2 area system receives feedback from a tie line (P_{12}). The feedback is combined with the speed deviation signal in a certain proportion (decided by the constant B). It is then fed to an integral controller, the output of which changes P_{m0} .



Automatic Generation Control (AGC) (Con td..)

An integral controller acts on this error to change the load reference of both governors. Since an integral controller drives its input to zero in steady state (**why?**), it follows that in steady state:

$$B_1 \left(\frac{\omega_{REF} - \omega_1}{\omega_0} \right) - \Delta P_{12} = 0$$

$$B_2 \left(\frac{\omega_{REF} - \omega_2}{\omega_0} \right) - \Delta P_{21} = 0$$

$$\Delta P_{21} \simeq -\Delta P_{12} \text{ (losses are assumed to be small), } \omega_1 = \omega_2 \text{ in steady state and typically } \omega_{REF} = \omega_0$$

Then it follows that if B_1 and B_2 are $> \text{zero}$,

$$\omega_1 = \omega_2 = \omega_0$$

and

$$\Delta P_{12} = 0$$

which means that in steady state, both frequency deviation and tie line power flow deviation are made to go to zero by the AGC.

While any value of the weighting factors which are non-zero gives the same result in steady state, they are chosen such that the transient response is good.

We [illustrate this concept](#) on the same system as in the previous example.

Economic Dispatch:

The change in generation in steady state after a load change (due to governor and AGC action), may not be the most optimal one from an economic standpoint. Note that different generators may have different cost of generating power. A power plant or system operator may wish to re-adjust the generated power in various units for maximum economic benefit. This adjustment of generation is generally done manually and is often called "tertiary control".

Of course, how this re-adjustment is done is dependent on generation cost, power -pricing mechanism and the ownership of generation. Interestingly, if power pricing itself is made a function of frequency, then tertiary control also may contribute to (slow) frequency control ! This idea (called **Availability Based Tariff**) is implemented in some regions of our country.

Limitations of prime mover systems:

Generation reserves available for control of frequency are typically only a fraction of the existing generation. Moreover, there are practical constraints like limits on the rate of rise of prime mover power (in a steam turbine) to avoid rapid heating. While an initial sudden change of about 10% can be tolerated, subsequently, rate of rise is limited to 2% (of plant MW rating) per minute. The boiler in a steam prime mover is relatively slow in maintaining the steam pressure by increasing fuel input. Thus as control valves open, restoration of steam pressure is slow. For some types of hydro-turbines, there are forbidden operating zones due to cavitation effects in turbines.

In countries like ours, where substantial generation shortage exists, load shedding may be done to keep frequency within bounds.

Recap

- AGC is control scheme which ensures that frequency deviation from the nominal value is brought to zero, and the power flows between different areas in an interconnected system are regulated.
- While governors act relatively fast to arrest frequency decline, AGC is slow acting. While governors can be present on almost all generators in a system, AGC is present only in selected units.
- Tertiary control involves adjusting generator powers due to economic reasons. This is the slowest generator power control action.

Congratulations, you have finished Lecture 16. Please view the next slide for concluding remarks for this module.