Coupling between Automatic Generation Control and Automatic Voltage Regulator While Considering Generation Rate Constraint of Two Areas

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Abstract. This paper describes the implementation of automatic generation control (AGC) and automatic voltage regulator (AVR) under generation rate constraint (GRC) and coupling between automatic generation control and automatic voltage regulator while considering generation rate constrain of two areas for improve and better performance characteristic of load frequency control (LFC) problem. Our control aim has to normalize the area control error (ACE), frequency error and tie-line power error in spite of the presences of system uncertainties and external load disturbance. So that the required frequency and power interchange with adjacent structures are maintained in order to reduce the transient deviations and to provide zero steady state error in proper short time, the behavior of the planned is checked by MATLAB SIMULINK software.

1. Introduction
Automatic generation control maintains a balance between the whole power generation and load demand, to keep the system frequency (normally 50 or 60 Hz) and regular power interchange with neighboring systems [1].

Load frequency control (LFC) performs a vital role for energy stability between load and era sides. In recent years, several robust design strategies have been delivered for LFC [2]–[4] The dynamic behavior of many industrial plants is heavily influenced by disturbances and, in particular, by change. The dynamic conduct of many industrial flowers is closely influenced by disturbances and, in particular, by adjustments in the running point. This is commonly the case for electricity structures [5]. In an electrical grid, many synchronous turbines with different voltage rankings are connected to bus terminals which have the identical frequency and segment sequence as the generators. All generators linked in parallel ought to be run at the suitable capacity to meet the demand. If a generator loses synchrony there’ll be changes within the voltage and frequency offer. It’s essential to synchronize the bus with the generators for the period of transmission for secure operation. also recognized as synchronous balance refers to the capability of a system to return to synchronism after any disturbance such as a sudden exchange in loading conditions offer frequency and voltage should frequently be among a positive prohibit to confirm safe and reliable operation of electrical instrumentation and
equipment every at the client premises and throughout transmission and distribution. So it’s crucial to be in an exceedingly position to screen and hold the voltage and frequency among limits. After an annoyance involving a net exchange in power, the System will enter a transient state which is regularly oscillatory and reflected by means of fluctuations in the energy flow over transmission lines. This is referred to as the dynamic system performance. In a tie-line connecting one team of turbines to another, these oscillation can also construct up and be mirrored via excessive fluctuations in power flow in the tie line. This will motive protective equipment to day trip [6].

The goal of this paper is to sketch a controller to perform LFC. At first an evaluation of one of a kind systems from previous research works was performed. The end result obtained. The Matlap/Simulink platform was used for all simulation outcomes obtained. The balance of the systems used to be investigated and the transient and constant country response of the systems have been simulated before any controller used to be designed. The manipulate goal is to minimize overshoot, settling time and steady state error. In LFC, deviation in frequency and tie line strength must return to zero in the minimal time and with minimal overshoot after a load alternate [7]. Controllers had been designed and tested to obtain this. Different kinds of controllers had been simulated in Simulink for the device specifically the PID, Fuzzy, Neuro-Fuzzy and Fuzzy-PID [8]–[11] to enhance its performance. Finally a comparative evaluation of the consequences from the unique controllers was once achieved and the most appropriate one was once chosen.

2. Two Area Power System

Power systems have complex and multi-variable structures. Also, they consist of many one of a kind control blocks. Most of them are nonlinear and/or non-minimum segment systems [12]. Power systems are divided into manipulate areas related by tie lines. All generators are supposed to represent a coherent crew in every manipulate area. From experiments on electricity systems, it can be viewed that every place wants its gadget frequency and tie line strength go with the flow to be managed [3].

In intention of control at this point is to regulate the frequency of each area and at same time to regulate the tie-line power as per inter area power contract. In case of frequency proportional plus integral control is used to get zero steady state error in tie-line power flow as compared to the contracted power, consider that each control area can be represented by an equivalent turbine, generator and governor system. Consider that case of an isolated control area here the incremental power \( \Delta P_G - \Delta P_D \) was accounted for the rate of rise of kinetic energy stored, and increase in area load caused due to rise in frequency. A tie-line transmits power in or out an area, so this fact must be taken into the incremental power equation of each individual area.

Power transported out of area-1 is given by

\[
P_{tie1} = \frac{\left[ \frac{V_i}{V_2} \right] \sin (\phi_1^0 - \phi_2^0)}{X_{12}}
\]

For incremental change in \( \phi_1^0, \phi_2^0 \) the incremental tie-line power is expressed as follows

\[
\Delta P_{tie1} \quad (pu) = T_{12} \quad (\Delta \phi_1 - \Delta \phi_2)
\]

Where

\[
T_{12} = \left[ \frac{\left[ \frac{V_i}{V_2} \right] \cos (\phi_1^0 - \phi_2^0)}{P_r_{12} X_{12}} \right] = \left[ \frac{P_r_{1}}{P_r_{2}} \right] T_{12} = \phi T_{12}
\]

= Synchronizing coefficient

As the incremental power angel are integral of incremental frequencies the equation is written as

\[
\Delta P_{tie1} = 2\pi T_{12} \left( \int \Delta f_1 dt - \int \Delta f_2 dt \right)
\]

Where \( \Delta f_1 \) and \( \Delta f_2 \) are incremental frequency change in area-1 and area-2 respectively.

In the same way, the incremental tie-line power out of area-2 is given by following equation
\[ \Delta P_{ne1} = 2\pi T_{21} \left( \int \Delta f_1 dt - \int \Delta f_2 dt \right) \]  

(4)

Where

\[ T_{12} = \frac{|V_1| |V_2|}{P_{11}X_{12}} \cos \left( \delta_1^0 - \delta_2^0 \right) = \left[ \begin{array}{c} P_{r1} \\ P_{r2} \end{array} \right] \]

(5)

\[ \Delta f_i(s) = \left[ \Delta P_G(s) - \Delta P_D(s) - \Delta P_{ne1}(s) \right] \times \frac{K_p}{1 + T_{ps} s} \]  

(7)

Where as

\[ K_p = \frac{1}{B_1} \quad T_{ps1} = \frac{2H_1}{B_1 f^0} \]  

(8)

Figure 1. Block diagram of ALFC

Similarly, the incremental power balance equation for area-1 is written as follow

\[ \Delta P_{G1} - \Delta P_{D1} = 2H_1 \frac{d}{f_1^0} \left( \Delta f_1 \right) + B_1 \Delta f_1 + \Delta P_{ne1} \]  

(6)

It may be noted that all quantities other than frequency are in per unit in equation, taking Laplace transform of equation and recognizing, the equation is given as

\[ \Delta F_i(s) = \left[ \Delta P_G(s) - \Delta P_D(s) - \Delta P_{ne1}(s) \right] \times \frac{K_p}{1 + T_{ps} s} \]  

(7)

When compared to the equation of isolated control area case, the only variation in the appearance of the signal \( \Delta P_{ne1}(s) \) is shown in fig (1).

Taking Laplace transform of equation (3) the signal \( \Delta P_{ne1}(s) \) is obtained as

\[ \Delta P_{ne1}(s) = \frac{2\pi T_{12}}{S} \left[ \Delta F_1(s) - \Delta F_2(s) \right] \]  

(9)

From the control area-2, \( \Delta P_{ne2}(s) \) is given by taking the Laplace of the equation (9)

\[ \Delta P_{ne2}(s) = \frac{-2\pi \delta_{12} T_{12}}{S} \left[ \Delta F_1(s) - \Delta F_2(s) \right] \]  

(10)
3. Response Of Two Area System Un Controlled Case

3.1. Static Response

The change or deviation result in the frequency. Tie-line power under steady state conditions flow sudden step changes in load in two area.

Say $\Delta P_{G1}$, $\Delta P_{G2}$ are the incremental changes in the generation in area-1 and area-2 owing to the load changes.

$\Delta f$ is the static change in frequency, which is same for both the areas, $\Delta P_{TL}$ is the static change in the tie-line power that is transmitted from area-1 to area-2.

For the two areas, the dynamics are described by

$$
\left( \Delta P_G - \Delta P_{Di} \right) = \frac{2H_1}{f_0} \frac{d}{dt} (\Delta f) + B_1 \Delta f + \Delta P_{TL1}
$$

(11)

$$
\left( \Delta P_G - \Delta P_{Di} \right) = \frac{2H_2}{f_0} \frac{d}{dt} (\Delta f) + B_2 \Delta f + \Delta P_{TL2}
$$

(12)

3.2. Dynamic Response

A power system of two identical control areas is considered for analysis $\tau_{gt} = \tau_r = 0$ for both the areas.

The damping constants of two areas are neglected $B_1 = B_2 = 0$

By virtue the second assumption equation (11) and (12) become

$$
\left( \Delta P_G - \Delta P_{Di} \right) = \frac{2H_1}{f_0} \frac{d}{dt} (\Delta f) + \Delta P_{TL1}
$$

(13)

$$
\left( \Delta P_G - \Delta P_{Di} \right) = \frac{2H_2}{f_0} \frac{d}{dt} (\Delta f) + \Delta P_{TL2}
$$

(14)

Laplace transformation on both sides of equations (13) and (14)

$$
\Delta F_1 (s) = \frac{f_0}{2H_1} \left[ \left( \Delta P_{G1} (s) - \Delta P_{Di} (s) - P_{TL1} (s) \right) \right]
$$

$$
\Delta F_2 (s) = \frac{f_0}{2H_2} \left[ \left( \Delta P_{G2} (s) - \Delta P_{Di} (s) - P_{TL2} (s) \right) \right]
$$

From the block diagram, the following equations can be obtained

$$
\Delta P_{G1} (s) = \frac{\Delta F_1 (s)}{R}
$$

(15)

$$
\Delta P_{G2} (s) = \frac{\Delta F_2 (s)}{R}
$$

(16)

$$
\Delta P_{TL1} (s) = \frac{-2\alpha_1 T_{12}}{s} \left[ \Delta F_1 (s) - \Delta F_2 (s) \right]
$$

$$
\Delta P_{TL2} (s) = -\Delta P_{TL1} (s)
$$

(17)

From the above equations, the following observations can be made.
4. Simulation Study
The AGC and AVR loop are considered independently, since commotion control of generator have little time fixed contributed by field winding, where AGC loop is slow motion loop be forced major time constant take part by turbine and generator determination of inertia. So that the existing transient in excitation control loop mask many fast or does not influence the AGC loop. Practically these two are not non-interacting, the interaction exists but in opposite direction. Since AVR loop influence the magnitude of generated emf this model located in the magnitude of real power and hence AVR loop felt was existed in AGC loop.

Figure 2. SIMULINK model of two areas of AGC and AVR considering GRC

Figure 3. Comparisons between Dw1 with and without ACE & GRC
In this section develop AGC scheme is employed with AVR and considering generation rate constraint. Here coupling between AGC and AVR scheme is employed. The interaction between frequency domain and voltage cross coupling was exist and can some time disturbing. AVR loop impact the magnitude of generated emf and the internal emf magnitude of the real power. It is complemented that changes in AVR loop is felt in AGC loop. Generation rate constraint is not effect on the terminal voltage because the GRC is applied only from the speed governor system.
In Fig. 5 develop AGC scheme with AVR and considering generation rate constraint of two areas. Here coupling between AGC and AVR scheme is employed. The interaction between frequency and voltage exists and cross coupling does exist and can some time troublesome. AVR loop affect the magnitude of generated emf. The internal emf determines the magnitude of real power. It is concluded that changes in AVR loop is felt in AGC loop.

Fig. 6 represent the change in frequency of area 1 and area 2 the time settling and steady state error is less when coupling. Fig. 7 represent the comparison between frequency of area 1 its clear that the steady state and settling time is less but the over shoot is increase because that the GRC give the real state. Fig. 14 represent the generation rate constraint is not effect on the terminal voltage because the GRC is applied only from the speed governor system.

5. Conclusions
The two major loops that are AVR loop and ALFC loop has been studied for two areas power system. The frequency of the system is dependent on real power output and is taken care of by ALFC. Terminal voltage of the system is dependent on the reactive power of the system and is taken care of by AVR loop. The cross coupling effects between the two loops are studied that are associated with low-frequency oscillations. It has been observed that even with GRCs the system stays stable and that the response are not much different with and without Generation Rate Constraints.

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