Proposing New Method for Keeping Power Systems in Steady

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Abstract
This paper is an attempt to study the control of active and reactive power to keep the system in the steady state. Also, simple models of the essential components used in control system are analyzed. The objective of the control strategy is to generate and deliver power in an interconnected system as economically and reliably as possible while marinating the voltage and frequency within permissible limits. Changes in real powers affect mainly the system frequency, while reactive power is less sensitive to changes in frequency and is primarily dependent on changes in voltage magnitude. Thus, real and reactive powers are controlled separately. The load frequency control loop controls the real power and frequency, and the automatic voltage regulator loop regulates the reactive and voltage magnitude.
Keywords:
Active power, Reactive power, Steady state of power systems.

1. Introduction

Load frequency control has gained in importance with the growth of interconnected systems and has made the operation of interconnected system possible [1]. There are some methods for control of individual generator and eventually, control of large interconnections play a vital role in modern energy control centers [2]. Modern energy control centers are equipped with online computers performing all signals processing through the remote acquisition system known as supervisory control and data acquisition system.

1.1 Basic Generator Control Loop

In an interconnected power system, load frequency control and automatic voltage regulator equipment are installed for each generator. Here the controller is set for a particular operating condition and take care of small changes in load demand to maintain the frequency and voltage magnitude within the specified limits [5]. Small changes in real power are mainly dependent on changes in rotor angle δ and thus the frequency. The reactive power is mainly dependent on the voltage magnitude. The excitation system time constant is much smaller than the prime mover time constant and its transient decay much faster and does not affect the LFC dynamic [9]. Thus the cross-coupling between the LFC loop and the AVR loop is negligible.

1.2 Load frequency control loop

The operation objectives of the LFC are to maintain reasonably uniform frequency, to divide the load between generators, and to control the tie-line interchange schedules, the changes in frequency and tie-line real power are sensed, which is a measure of the change in rotor angle δ, i.e. the error Δδ to be corrected [12]. The error single, i.e., Δf and ΔPtie are amplified, mixed and transformed into a real power command single ΔPᵛ which is sent to the prime mover to call for an increment in the torque [19]. Prime mover, therefore, brings change in the generator output by an amount ΔPg which will change the value of Δf and ΔPtie within the specific tolerance. The first step in the analysis and design of a control system is mathematical modeling of the system. The two most common methods are the transfer function methods and the state variable approach [17]. The state variable approach can be applied to portray linear as well as a nonlinear system. In order to use the transfer function and linear sate equations, the system must be liberalized.

1.1.1. Generator Model

Applying the swing equation of synchronous machine to small perturbation, we have [14]

$$2Hd^2\Delta\delta / \omega x dt^2 = \Delta \mathrm{Pm} - \Delta Pe$$

With speed expressed in per unit, without explicit per unit notation, we have

$$d\Delta\omega / dt = 1 / 2H(\Delta Pm - \Delta Pe)$$

Taking the Laplace transform of the above equation we have [9]

$$\Delta\Omega(s) = \frac{1}{2Hs}[\Delta Pm(s) - \Delta Pe(s)]$$

The above relation is shown in the figure below

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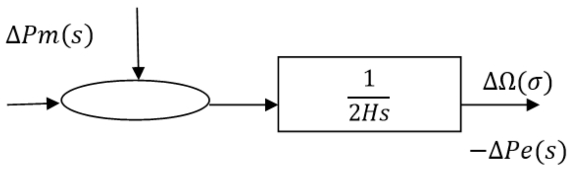

Fig. 1: Block diagram of applying swing formula into the synchronous machine.

Load model: load is very much important in daily usages. Motor loads are very sensitive to change the frequency. The speed load characteristic of a composite load is approximately bt

$$\Delta Pe = \Delta Pl - D\Delta\omega$$

Where $\Delta Pl$the non frequency sensitive load is charge and $D\Delta\omega$ is the frequency sensitive load change. D is expressed as percent change in load divided by percent change in frequency. For example, of the load is changed by 1.6 percent for a 1 percent change in frequency, then d= 1. Including the load model in the generator block diagram, result in the block diagram of figure [21]. Eliminating the simple feedback loop in this result in the block diagram shown the corresponding figure

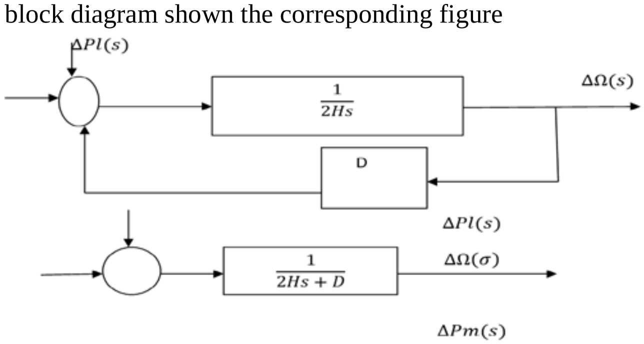

Fig. 2: New system for wiping-out the simple feedback loop.

1.1.2. Prime Mover Model

The source of the mechanical power, commonly known as the prime mover, may be hydraulic turbine at waterfalls, steam turbines whose energy comes from the burning of coal, gas nuclear fuel and gas turbines [25]. The model for the turbines relates changes in mechanical power output ΔPm to changes in steam valve position ΔPv different types of turbines vary widely in characteristics. The simplest prime mover model for the no reheat steam turbine can be approximated with a single time constant τt result in the following transfer function [22]

$$Gt(s) = \frac{\Delta Pm}{\Delta Pv}$$

$$= \frac{1}{1 + \tau tS}$$

Fig. 3: Block diagram of the simplest prime mover model for the no reheat steam turbine.

1.1.3. **Governor Model**:

When the generator electrical load is suddenly increased, the electrical power exceeds the mechanical power input. This power deficiency is supplied by the kinetic energy stored in the rotating system .the reduction of the kinetic energy is causes the turbine speed consequently [23], the generator frequency to fall. The change in speed in sensed by the turbine governor which acts to adjust the turbine input valve to change the mechanical power output to bring the speed to a new steady-state. The earliest governor was the watt governors which sense the speed by means of rotating fly balls and provides mechanical motion in response to speed changes. Such as Speed Governors, linkage Mechanism, hydraulic amplifiers, Speed changers are the main parts [20].

1.3 Automatic generator control:

If the load on the system is increased, the turbine speed drops before the governor can adjust the input of the steam to the new load [19]. As the changes in the value of speed diminished, the error single becomes smaller and the position of the governor fly balls gets closer to the point required to maintain a constant speed. However, the constant speed will not be the set point, and there will be an offset. One way to restore the speed or frequency to its nominal value is to add an integrator [6]. The integral unit monitors the average error over a period of the time and will overcome the offset. Because of the ability to return a system to its set point, integral action is also known as the rest action. Thus, as the system load changes continuously, the generation is adjusted automatically to restore the frequency to the nominal value [4]. This scheme is known as the automatic generator control. In interconnected system consisting of several pools, the role of the AGC is to divide the loads among system, stations, and generators so as to achieve maximum economy and correctly control the scheduled interchange the tie line power while maintaining a reasonably uniform frequency. Of course, it is assumed that the system is stable, so the steady state is achievable [5]. During large transient disturbances and emergencies, AGC is bypassed and other emergencies controls are applied [17].

2. AGC in a single area system

With the main LFC loop, alter in the system load will result in a steady state frequency deviation, depending on the governor speed regulation. In order to decrease the frequency deviation to zero, we must provide a rest action. The rest action can be achieved by introducing an integral controller to act on the load reference setting to modify the speed set point. The integral controller increases the system type by 1 which forces the final frequency deviation to zero [10]. The LFC system, with addition of the secondary loop, is shown in figure.

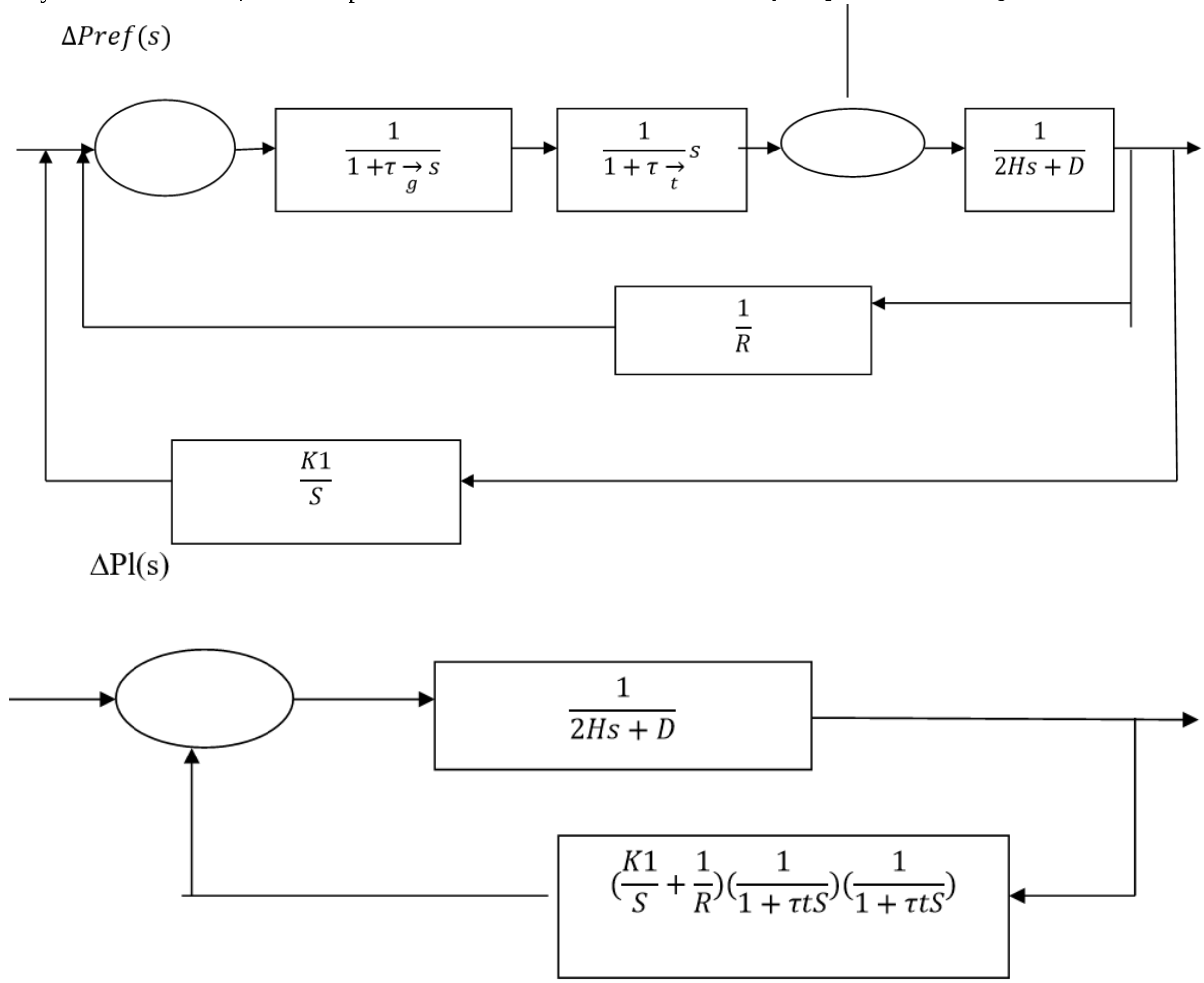

Fig. 4: Block diagram for the proposing system to degrade the frequency deviation.

3. Tie-Line Bias Control

If LFC were operational with only the primary control loop, vary of power in area 1 is met by the augment in generation in both areas associated with a change in the tie-line power, and a reduction in frequency. In the normal operating state, the power system is operated so that the demands of area are satisfied at the nominal frequency [2]. AGC with optimal dispatch of generation: The parameter affecting power generations at minimum cost are operating efficiencies, fuel cost, and transmission losses [11]. The optimal dispatch of generation may be treated within the framework of LFC. In direct digital control system, the digital computer is included in the control loop which scans the unit generation and tie-line flows if the actual setting is off from the optimal values, the computer generates the raise/lower pulses which are sent to the individual units [14]. With the development of modern control theory, several concepts are included in the AGC which go beyond the simple tie-line bias control. The fundamental approach is the use of more extended mathematical models. Other concepts of modern control theory are being employed such as state estimation and optimal control with linear regulator utilization constant feedback gains. In addition to the structures which aim at the control of deterministic signals and disturbances, there are schemes which employ stochastic control concept e.g.

minimizing of some expected values of an integral quadratic error criterion. Frequently, the results in the design of the Kalman filter [15].

3.1 Reactive power and voltage control

The generator excitation system keeps the generator voltage and controls the reactive power flows. A vary in the real power demands affects effectively the frequency and the voltage magnitude. The interaction among the voltage and frequency control is generally weak enough to justify their analysis separately; the sources of reactive power are generator, capacitor and reactors. The generator reactive power is controlled by field excitation. Other supplementary methods of improving the voltage profile on electric transmission system are transformed load-tap changers, switch capacitors, step-voltage regulators and static VAR control apparatus. An augment in the reactive power load of the generator is accompanied by a drop in the terminal voltage magnitude [18].

3.1.1 Amplifier Model

The excitation system amplifier may be a magnetic amplifier, rotating amplifier or modern electronic amplifier, the amplifier is represented by a gain Ka and a time constant τa and the transform function is:

$$\frac{Vr(s)}{Ve(s)} = \frac{Ka}{1 + \tau aS}$$

Typical values of Ka are the variety of 10 to 400. The amplifier constant is very minute in the range of 0.02 to 0.1 second and often is neglected [21].

Exciter Model: there is actuality of diverse excitation type. But, modern excitation system uses AC power sources through solid-state rectifier such as SCR. The output voltages of the exciter are nonlinear function of the field voltages because of the saturation effects in the magnetic circuit. Therefore, there is no simple relationship between the terminal voltage and the field voltage of the exciter. Many models with different degrees of sophistication have been developed. A logical model of a modern exciter is a liberalized model, which takes into account the major time constant and ignores the saturation or the other non-linearity. In the simplest form, the transfer function of a modern exciter may be represented by a single time constantτe and the gain $Ke\ i.e.$

$$\frac{vf(s)}{Vr(s)} = \frac{Ke}{1 + \tau eS}$$

The time constant of modern exciters are very small [13].

3.1.2 Generator model:

The synchronous machine generates emf is a function of the machine magnetization curve and its terminal voltage is reliant on the generator load. In the liberalized model, the transfer fiction relating the generator terminal voltage to its field voltage can be represented by gain$Kg$and the time constantτg, and the transfer function is [15]

$$\frac{Vt(s)}{Vf(s)} = \frac{Kg}{1 + \tau gS}$$

These constant are load reliant, kg may vary from 0.7 to 1 and τg between 1.0 and 2.0 seconds from full load to no load [7].

3.1.3 Sensor Model:

The voltage is sensed through a potential transformer and in one form; it is rectified through a bridge rectifier. The sensor is modeled by a simple order transfer function, given by [8]

$$\frac{Vs(s)}{Vt(s)} = \frac{Kr}{1 + \tau dS}$$

$$Vref(s)$$

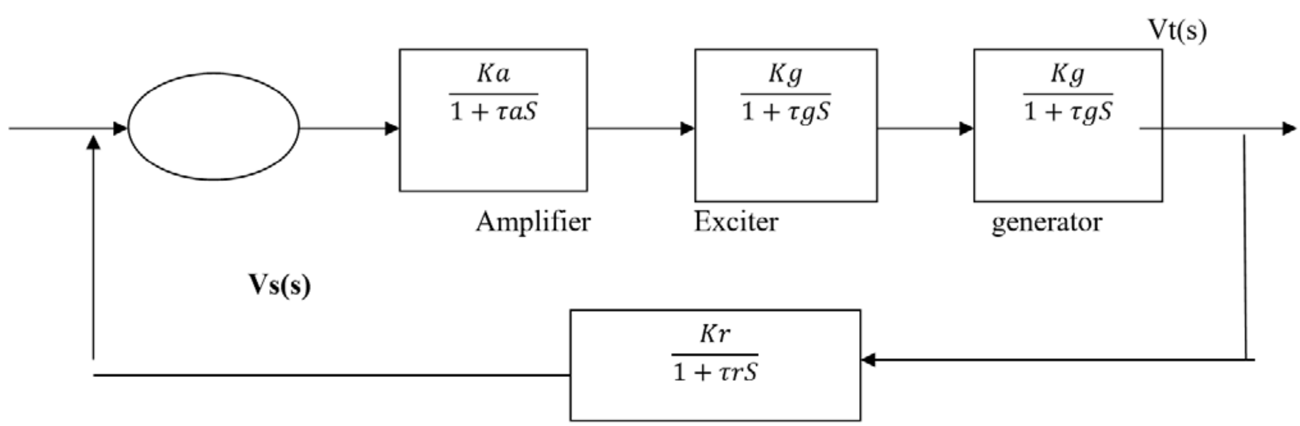

Fig. 5: Block diagram for modeling the sensor function and bridge rectifier.

4. Conclusion:

τrIs very small and we may assume a range of 0.01 to 0.06 second. Utilizing the above models results in AVR block diagram shown in the figure [25]

Technical data: Solution of two area control system using stimulant block diagram

A two area system connected by a tie line has the following parameter on a 1000 MVA common base [13]:

Table 1: Different factors of two area system which connected via a tie line

Area	1	2
Speed Regulation	$R1 = 0.05$	$R2 = 0.0625$
Frequency-sense load coefficient	$D1 = 0.6$	$D2 = 0.9$
Inertia constant	$H1 = 5$	$H2 = 4$
Base power	1000MVA	1000MVA
Governor time constant	$\tau g1 = 0.2sec$	$\tau g2 = 0.3sec$
Turbine time constant	$\tau t1 = 0.5sec$	$\tau t2 = 0.6sec$

The unit is operating in parallel a monomial frequency of 60 HZ. This synchronizing power coefficient is computed from the initial operating condition and is given to be $Ps = 2.0p.u.$a load change of 187.5 MW occurs in area 1.

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