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MULTI AREA FREQUENCY AND TIE LINE POWER FLOW CONTROL WITH TCPS

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Abstract – In an electric power system, *Load Frequency Control (LFC) is a system to maintain reasonably uniform frequency, to divide the load between the generators, and to control the tie line interchange schedules. Analysis of load frequency control models of interconnected power system representation with TCPS is series with tie line provide more detailed information about the system. Interconnected Power systems have advantage to maintain stability, ensure continuity of supply and maintain the frequency to its nominal value. The control of interconnected system is done by Automatic Generation Control which compose of Automatic Voltage Regulator and Load Frequency Control. In this paper PI and FLC and TCPS in two area power system is carried out and results are obtained. MATLAB software was used to carry out the implementation.*

Keywords: **AUTOMATIC GENERATION CONTROL, FUZZY LOGIC CONTROLLER, LOAD FREQUENCY CONTROL, PROPORTIONAL INTEGRAL CONTROLLER, THYRISTOR CONTROL PHASE SHIFTER.**

1. INTRODUCTION

The system we used is two area interconnected system. In this two areas are connected through a tie line, which allows the flow of electric flow among the interconnected areas. The control unit monitors the system frequency and tie line power derivation and tries to restore the normal operating state of the system during unfavourable conditions such as load perturbations.There is an oscillation in the frequency till the steady state condition is achieved. To damp-out these oscillations TCPS device can be included [4] in the system and the same can meet the sudden change in load.

Load Frequency Control (LFC) is a very important issue power system operation and control for supplying sufficient and both good quality and reliable power. [5] As the Samah A. Rahim proposed integral and FLC controllers, the frequency deviation response exhibited a drop in the frequency of both systems for a few seconds before the deviation was recovered to exactly zero error [1]. After introducing FLC to the system, steady state was reached in a less time range and oscillations were eliminated. Yet, the steady state error was not completely eliminated.

To increase the performance, we introduce the TCPS to the system. By the TCPS, the settling time is reached in seconds and the system performance is improved.

The section 2 deals with methodology of a LFC. Section 3 deals with AGC in single and Multi-area system. Section 4 deals with the implementation of controllers in two area system. Controllers we used are Proportional Integral, Fuzzy Logic Controller and Fuzzy with TCPS and we have explained about construction and rules of FLC. Block Diagrams and Results are also shown. Section 5 deals with conclusion which includes the comparison of the PI, FLC and Fuzzy with TCPS are tabulated and along with references.

2. METHODOLOGY

2.1 Turbine speed governing system

When the generator electrical load is suddenly increased, the generated power also increases to satisfy the load demand, which in turns exceeds the mechanical power input. This mechanical power deficiency is supplied by the kinetic energy stored in the rotating system. The reduction in kinetic energy causes the reduction in turbine speed and consequently, the generator frequency falls. The change in speed is sensed by the turbine governor which acts to adjust the turbine input by adjusting valve position to change the mechanical power output to bring the speed to a new steady-state. The earliest governors were the Watt governors which sense the speed by means of rotating fly-balls and provide mechanical motion in response to speed changes. There are some inherent drawbacks and limitations of Watt type governor such as problem of backlash, dead band and other nonlinearities etc. These governors are mechanical type and hence slow in their operation. However, most modern governors use electronic means to sense speed changes and its control. Figure 1 shows schematically the essential elements of a conventional Watt governor which consists of the following major parts:

Speed governor: this is heart of the system which senses the change in speed (frequency). As the speed increases the fly balls move outwards and the point B on linkage mechanism moves downwards. The reverse happens when the speed decreases.

Linkage Mechanism: These are links for transforming the fly-balls movement to the turbine valve through a hydraulic amplifier and providing a feedback from the turbine valve movement.

Hydraulic Amplifier: It comprises a pilot valve and main piston arrangement. Low power level pilot valve movement is converted into high power level piston valve movement. This is necessary in order to open or close the steam valve against high pressure steam.

Speed changer: It provides steady state power output setting for the turbine. Its downward movement opens the upper pilot valve so that more steam is admitted to the turbine under steady conditions. The reverse happens for upward movement of speed changer.

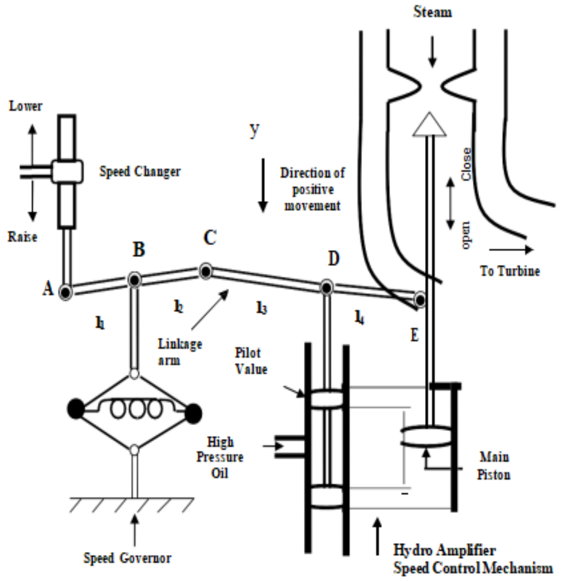

FIG 1 Turbine Speed Governing System

3. AUTOMATIC GENERATION CONTROL:

If the load on the system is increased suddenly then the turbine speed drops before the governor can adjust the input of the steam to the new load. As the change in the value of speed diminishes the error signal becomes smaller and the position of the governor and not of the fly balls gets closer to the point required to maintain the constant speed. One way to restore the speed or frequency to its nominal value is to add an integrator on the way. The integrator will unit shall monitor the average error over a period of time and will overcome the offset. Thus as the load of the system changes continuously the generation is adjusted automatically to restore the frequency to the nominal value. This scheme is known as automatic generation control. In an interconnected system consisting of several pools, the role of the AGC is to divide the load among the system, stations and generators so as to achieve maximum economy and reasonably uniform frequency.

3.1 AGC IN A SINGLE AREA:

With the primary LFC loop a change in the system load will result in a steady state frequency deviation, depending on the governor speed regulation. In order to reduce the frequency deviation to zero we must provide a reset action by introducing an integral controller to act on the load reference setting to change the speed set point. The integral controller increases the system type by 1 which force the final frequency deviation to zero. The integral controller gain must be adjusted for a satisfactory transient response.[1]

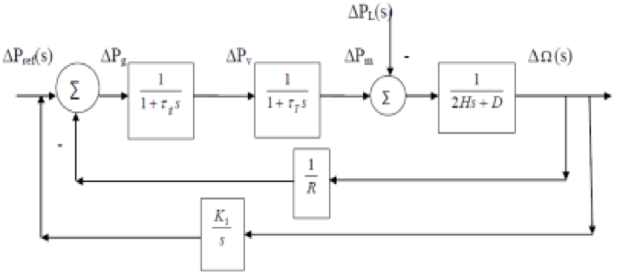

FIG 2 Mathematical modeling of AGC for an isolated power system.

The closed loop transfer function of the control system is given by:

$$\frac{\Delta\Omega(s)}{-\Delta P_L(s)} = \frac{s(1+\tau_g s)(1+\tau_T s)}{s(2Hs+D)(1+\tau_g s)(1+\tau_T s)+K_1+{}^{s}\!/\!_{R}} \quad \text{Eq-1}$$

3.2 AGC IN THE MULTIAREA SYSTEM:

In many cases a group of generators are closely coupled internally and swing in unison. Furthermore, the generator turbines tend to have the same response characteristics. Such a group of generators are said to be coherent. It is possible to let the LFC loop represent the whole system and the group is called the control group. For a two area system, during normal operation the real power transferred over the tie line is given by

$$P_{12}=\frac{|E_1||E_2|}{X_{12}}\sin\delta_{12} \quad \text{----- Eq-2}$$

Where $X_{12}= X_1+X_{tie}+X_2$

4. IMPLEMENTATION

4.1 Conventional PI Controller

The combination of proportional and integral terms is important to increase the speed of the response and also to eliminate the steady state error. In practical examples, use PI controller for the system ability to reduce the error up to maximum value. K_p and K_i are the tuning knobs, are adjusted to obtain the desired output. When there is load perturbation in the LFC it will result to a steady state frequency deviation. The essence of the supplementary control action is to reduce the frequency deviation to zero. The integral controller applied at the load reference setting, changes the speed set point. The controller actually increases the system type by 1 which forces the final frequency deviation to zero. The integral controller is adjusted for a satisfactory of system response.

The PI controller is characterized by the transfer function

$$G_c(s) = K_p(1+\frac{1}{sT_i})$$

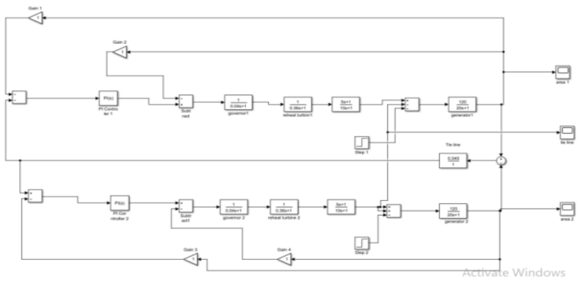

FIG 3 Simulation diagram of two area system with Proportional Integral Controller

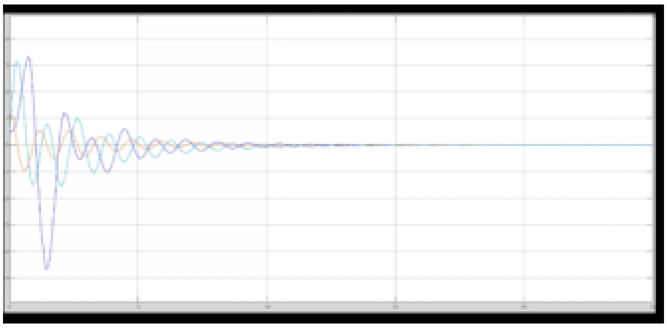

Fig 4 Dynamic responses of the tie line power deviatin considering a step load disturbance of 0.01p.u.Mw in all areas

Area 1

Area2

Tie line

4.2 Development of Fuzzy logic Controller

Fuzzy logic is a mathematical system that analyzes analog input values in terms of logical variables that take on continuous values between 0 and 1, in contrast to classical or digital logic which operates on discrete values of either 0 or 1. [2]

4.2.1Basic construction of the fuzzy logic controller

In control engineering, fuzzy controllers are extensively studied. Case studies present their application in various process- control systems previously controlled manually. One has to understand clearly the notation of "fuzziness" in technical systems(electrical, mechanical, chemical, etc.) and its role in information processing. At first glance, it may seem artificial to apply fuzzy sets in such systems. But such a judgment is not valid. In control strategy applied by the operator, we can recognize some concepts that are evidently fuzzy in their nature, for instance the goals of the control (e.g. 'keep close to the desired trajectory with a quite low control effort' contains the vague expressions close, quite low)[2].

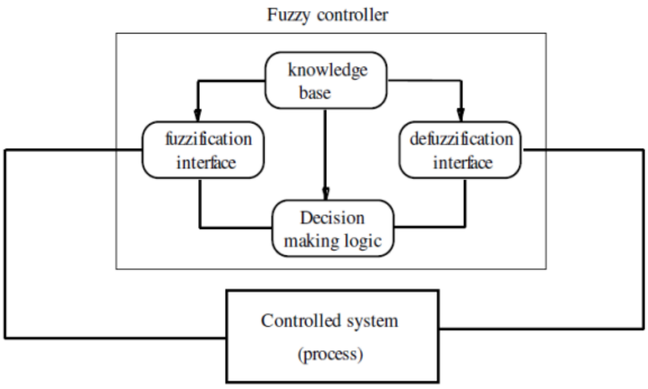

FIG 5 Basic configuration of fuzzy logic controller

- Fuzzification strategies: the process of converting numeric values into fuzzy sets.
- Knowledge base: Choice of the membership function, normalization of the universe of discourse and fuzzy partitions of input and output space.
- Rule-based: Containing a number of fuzzy IF-

THEN rules.

- Fuzzy Inference: is the decision-making logic unit which performs the inference operations on the rules.
- Defuzzification strategies: Transformation of the fuzzy sets based output into a numeric value.

4.2.2FUZZY LOGIC CONTROLLER RULE BASED

In this study ACE and its derivative (DACE) were used as inputs to the proposed controller. Seven linguistic variables: NL, NM, NS, Z, PS, PM and PL represented by triangular membership function that have been chosen to represent the two inputs with universe of discourse between -1 and 1 [3]

TABLE 1: FUZZY LOGIC CONTROLLER RULES

ACE/ DACE	NL	NM	NS	Z	PS	PM	PL
NL	NL	NL	NL	NL	NM	NS	Z
NM	NL	NL	NM	NM	NS	Z	PS
NS	NL	NM	NS	NS	Z	PS	PM
Z	NL	NM	NS	Z	PS	PM	PL
PS	NM	NS	Z	PS	PS	PM	PL
PM	NS	Z	PS	PM	PL	PL	PL
PL	Z	PS	PM	PL	PL	PL	PL

4.2.3 Limitations of Fuzzy Logic Controller

1. The tuning of FLC is quite difficult due to large number of parameters such as number of linguistic terms, number of membership functions, shape of membership functions, their range etc.
2. The appropriate number of rules of FLC is not an easy task.
3. The selection of conjunctive, disjunctive and implication operators used are problem dependent.
4. The appropriate size of rule base of FLC is not known.

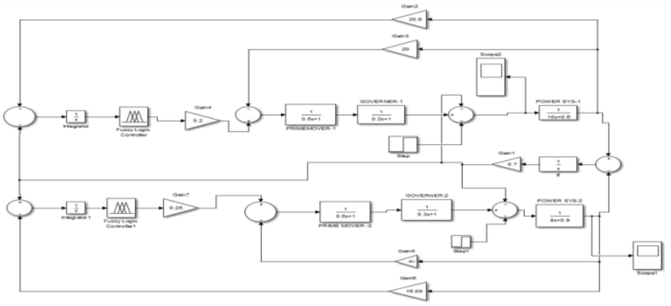

FIG 6 Simulation diagram of Fuzzy Logic controller in two area system

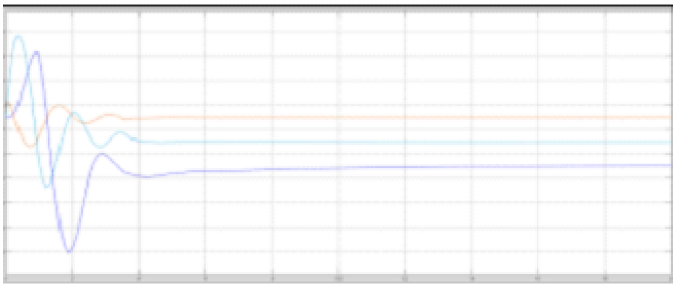

FIG 7 Dynamic response of fuzzy controller in area 1, area 2, tie line

4.3 Implementation of TCPS

The automatic generation control (AGC) of an interconnected power system has two principal aspects: maintenance of frequency and exchange of power over inter-area tie-lines on their respective scheduled values. It has been a topic of concern, right from the beginning of interconnected power system operation. Considerable work has been carried out for the AGC of interconnected power systems as reported in the literature. Transformed AGC eliminates the need for bias settings, directly controlling the nominal frequency set point of each unit. Now proposed a new method of designing control systems in the area of power systems which relies on a combination of advanced system simulations and genetic computations. An approach for designing decentralized load frequency controllers for interconnected power systems has been presented in. While designing supplementary controller for any area, has represented the rest of the system by its external equivalent. Have presented an extended integral control to load frequency control scheme in the presence of generation rate constraints in order to get rid of overshoot of the conventional proportional– integral control. Previous works show that attempts were made to design different types of AGC controllers but no efforts were made to attenuate the oscillations in system frequency and tie-line power interchange. In fact, attenuating those oscillations is not among AGC objectives. In the analysis of an interconnected power system, some areas are considered as the channels of disturbances and in this situation, the conventional frequency control, that is, the governor may no longer be able to attenuate the oscillations in frequency and tie-power fluctuations because of its slow response. Therefore it is important to minimize these oscillations by other means and it should not dynamically interact with AGC response.

On the other hand, the concept of utilizing power electronic devices for power system control has been widely accepted in the form of flexible AC transmission system (FACTS) devices which provide more flexibility in power system operation and control. This extra flexibility permits the independent adjustment of certain system variables such as power flows, which are not normally controllable. Thyristor controlled phase shifter (TCPS) is a device that allows dispatchers to change the relative phase angle between two system voltages, thereby helping them to control real power transfers between the two interconnected power systems. It attenuates the frequency of oscillations of power flow following a load disturbance in either of the areas, as well. Phase shifters also provide series compensation to augment stability. The high-speed responses of phase shifters make them attractive for use in improving stability. A TCPS is expected to be an effective apparatus for the tie-line power flow control of an interconnected power system.

Literature survey shows ample applications of TCPS for the improvement of dynamic and transient stabilities of power system. However, no attempt has been made to attenuate the oscillations in system frequency and tie-line power between the control areas after sudden load disturbances considering TCPS in series with the tie-line. On the other hand, tie-line power flow control by a TCPS installed in series with the tie-line in between two areas of an interconnected power system has the possibility to control the system frequency positively. The proposed control strategy will be very useful for the stabilization of frequency oscillations of an interconnected power system.

In the view of above the present objective of the work are:

1. To develop a linearised model of a two-area interconnected hydro thermal system considering a TCPS in series with the tie-line.
2. To minimize the oscillations in the system frequency and tie-line power considering a TCPS in series with the tie-line of a two-area interconnected hydro thermal power system.
3. To optimize the gain settings of the integral controllers with and without considering TCPS.
4. To compare the dynamic responses with and without considering the TCPS.

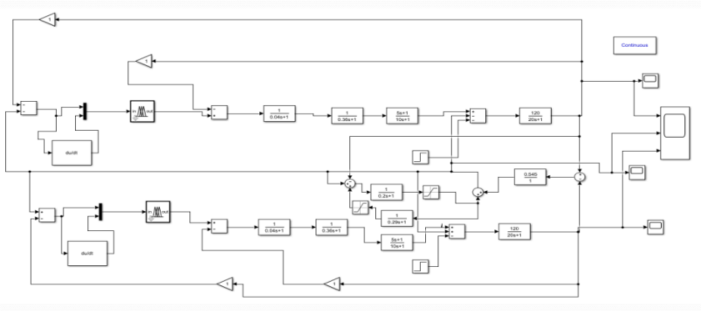

FIG 8 Simulation diagram of two area system with TCPS

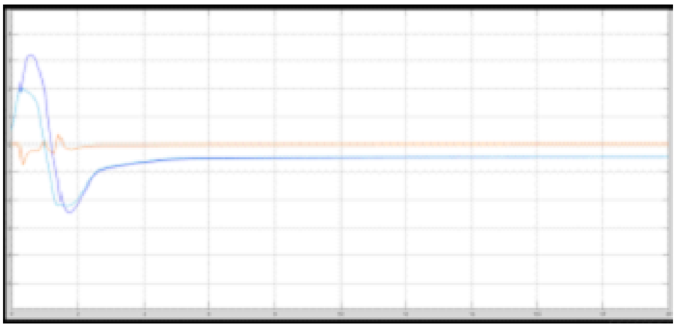

FIG 9 Dynamic response of fuzzy controller in two area system with TCPS in area 1, area 2, tie line

5. CONCLUSIONS

In this page, two very advanced methods along with TCPS were used instead of the governor control system which made the load frequency control. The methods used are PID and fuzzy logic which are widely used in control. PID and fuzzy logic are commonly used methods in control systems. In practice, the performance of these controls was compared with the in the two area interconnected systems are as follows:

TABLE 2 DIFFERENT CONTROLLERS RESULTS

Type of controller	Area 1	Area 2	Tie line
Proportional Integral	The system reaches a steady state of zero, within a settling time of 15 seconds	The system reaches a steady state of zero, within a settling time of 13 seconds	The system reaches a steady state of zero, within a settling time of 12 seconds
Fuzzy Logic Controller	The system reaches a steady state of -	The system reaches a steady state of	The system reaches a steady state of

	0.005, within a settling time of 4.1 seconds	-0.18, within a settling time of 5.8 seconds	-0.1, within a settling time of 2.8 seconds
Fuzzy with TCPS	The system reaches a steady state of 0.6, within a settling time of 2.5 seconds	The system reaches a steady state of 1, within a settling time of 2.5seconds	The system reaches a steady state of -0.1, within a settling time of 1.7 seconds

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