International Journal of Enhanced Research in Science Technology & Engineering, ISSN: 2319-7463
Vol. 3 Issue 2, February-2014, pp: (273-278), Impact Factor: 1.252, Available online at: www.erpublications.com

Automatic Generation Control of Hydro-Thermal Plant by Using Thyristor

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Abstract: This paper demonstrates the analysis of AGC of two-area interconnected thyristor controlled phase shifter based hydrothermal system. In this paper the effects of known linearities like dead band & generation rate constraint on the system have also been investigated. The effect of TCPS on the system is demonstrated with the help of computer simulations. Computer simulations reveal that due to presence of TCPS, dynamic performance of the system in terms of settling time is greatly improved. The objectives of load frequency control (LFC) are to minimize the transient deviations in these variables (area frequency and tie-line power interchange) and to ensure their steady state errors to be zeros. The system performance will be checked by integral square error (ISE) parameter. Disturbance in load is checked individually of both plants in MATLAB simulink. State spave equations are developed for plants and TCPS. These equations are then implemented in MATLAB and then results are compared.

Index Terms: AGC, TCPS, LFC, Hydrothermal system

I. INTRODUCTION

Power systems are used to convert natural energy into electric power. They transport electricity to factories and houses to satisfy all kinds of power needs. To optimize the performance of electrical equipment, it is important to ensure the quality of the electric power. It is well known that three-phase alternating current (AC) is generally used to transport the electricity. During the transportation, both the active power balance and the reactive power balance must be maintained between generating and utilizing the AC power. Those two balances correspond to two equilibrium points: frequency and voltage. When either of the two balances is broken and reset at a new level, the equilibrium points will float. A good quality of the electric power system requires both the frequency and voltage to remain at standard values during operation. For North America, the standard values for the frequency and voltage are 60 Hertz and 120 Volts respectively. However, the users of the electric power change the loads randomly and momentarily. It will be impossible to maintain the balances of both the active and reactive powers without control. As a result of the imbalance, the frequency and voltage levels will be varying with the change of the loads. Thus a control system is essential to cancel the effects of the random load changes and to keep the frequency and voltage at the standard values. One is about the active power and frequency control while the other is about the reactive power and voltage control. The active power and frequency control is referred to as load frequency control (LFC).

The foremost task of LFC is to keep the frequency constant against the randomly varying active power loads, which are also referred to as unknown external disturbance. Another task of the LFC is to regulate the tie-line power exchange error. A typical large-scale power system is composed of several areas of generating units. In order to enhance the fault tolerance of the entire power system, these generating units are connected via tie-lines. The usage of tie-line power imports a new error into the control problem, i.e., tie-line power exchange error. When a sudden active power load change occurs to an area, the area will obtain energy via tie-lines from other areas. But eventually, the area that is subject to the load change should balance it without external support. Otherwise there would be economic conflicts between the areas. Hence each area requires a separate load frequency controller to regulate the tie-line power exchange error so that all the areas in an interconnected power system can set their set points differently. In view of this the main

Objectives of the present work are:

- A MATLAB simulink model for hydro & thermal power plant will be used to get optimal controller.
- Thermal & hydro power plant is used to check the stability with deviation in load.
- Integral controller along with thyristor switch is used to stabilise the hydro & thermal power plant.
- ISE optimiser is used to optimise the values of integral controllers.

II. Dynamic Mathematical Model

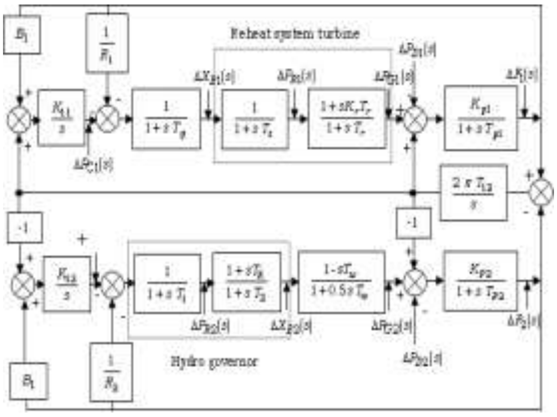

Figure 1: Two area hydrothermal systems.

III. Tie line power flow model considering tcps

Under open market system the power system structure changed in such a way that would allow the evolving of more specialized industries for generation (Genco), transmission (Transco) and distribution (Disco). The recent advances in power electronics have led to the development of the Flexible Alternating Current Transmission Systems (FACTS). FACTS devices are designed to overcome the limitations of the present mechanically controlled power systems and enhance power system stability by using reliable and high-speed electronic devices. One of the promising FACTS devices is the Thyristor Controlled Phase Shifter (TCPS). ATCPS is a device that changes the relative phase angle between the system voltages. Therefore, the real power flow can be regulated to mitigate the frequency oscillations and enhance power system stability. In this study, a two-area hydrothermal power system interconnected by a tie-line under open market scenario is considered.[8]

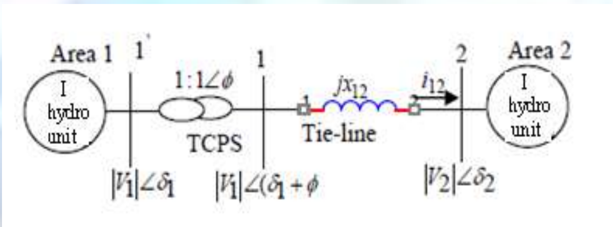

Fig 2: Interconnected hydrothermal two area system with TCPS in series with tie line.

Fig 1 shows the schematic of the two-area interconnected hydrothermal system considering a TCPS in series with the tie-line. TCPS is placed near area 1.Area 1 is the thermal area comprising of three reheat units and area 2 is the hydro area consisting of three hydro units. Without TCPS, the incremental tie-line power flow from area 1 to area 2 under open market system can be expressed as: [9]

$$\Delta P_{tie\,12} = \frac{2\pi T_{12}}{S}(\Delta f_1 - \Delta f_2) \quad (1)$$

When a TCPS is placed in series with the tie line as in a current flowing from area 1 to area 2 can be written as

$$i_{12} = \frac{|V_1|\angle(\delta_1 - \phi) - |V_2|\angle\delta_2}{jX_{12}} \quad (2)$$

From Figure 5.1 it can also be written as

$$P_{tie\,12} - jQ_{tie\,12} = |V_1|\angle - (\delta_1)\left(\frac{|V_1|\angle(\delta_1 + \phi) - |V_2|\angle\delta_2}{jX_{12}}\right) \quad (3)$$

Separating the real part of above equation, we get

$$P_{tie\,12} = \frac{|V_1||V_2|}{X_{12}}\mathrm{Sin}(\delta_1 - \delta_2 + \phi) \quad (4)$$

But in Eqn (4) moving δ_1, δ2 and φ from their nominal values $\delta_1{}^o$,$\delta_2{}^o$and φ^o respectively, $P_{tie\,12} = \frac{|V_1||V_2|}{X_{12}}\cos(\delta_1{}^o - \delta_2{}^o + \phi^o)\sin\left(\Delta\delta_1 - \Delta\delta_2 + \Delta\phi\right)$ (5)

But ($\Delta\delta_1 - \Delta\delta_2 + \Delta\varphi$) is very small and hence, sin($\Delta\delta_1 - \Delta\delta_2 + \Delta\varphi$) ≈ ($\Delta\delta_1 - \Delta\delta_2 + \Delta\varphi$)

So above equation can be written as

$$P_{tie\,12} = \frac{|V_1||V_2|}{X_{12}} \cos(\delta_1{}^{o} - \delta_2{}^{o} + \phi^{o})(\Delta\delta_1 \_ \Delta\delta_2 + \Delta\phi) \quad (6)$$

Let

$$T_{12} = \frac{|V_1||V_2|}{X_{12}} \cos(\delta_2{}^{o} - \delta_2{}^{o} + \phi^{o}) \quad (7)$$

So above equation reduces to

$$P_{tie\,12} = T_{12}(\Delta\delta_1 \_ \Delta\delta_2 + \Delta\phi) \quad (8)$$

Therefore, $\Delta P_{tie\,12} = T_{12}(\Delta\delta_1 - \Delta\delta_2) + T_{12}\Delta\,\Phi$ (9)

We also know that,

From above equations, it can be written as

$$\Delta\delta_1 = 2\pi\delta\Delta f_1 dt\,, \Delta\delta_2 = 2\pi\delta\Delta f_2 dt \quad (10)$$

$$\Delta P_{tie\,12} = 2\pi T_{12}(\delta\Delta f_1 dt - \delta\Delta f_2 dt) + T_{12}\,\Delta\Phi \quad (11)$$

Taking the laplace transform, it can be written as

$$P_{tie\,12} = \frac{2\pi T_{12}}{s}[\Delta F_1(s) - \Delta F_2(s)] + T_{12}\Delta\phi(s) \quad (12)$$

As per above eqn, it can be observed that the tie-line power flow can be controlled by controlling the phase shifter angle $\Delta\varphi$. The phase shifter angle $\Delta\varphi$ (s) can be represented as

$$\Delta\phi_s = \frac{K\phi}{1 + sT_{ps}} \Delta Error_1 \quad (13)$$

Where $K\varphi$and T_{ps} are the gain and time constants of the TCPS. Thus, it can be rewritten as:

$$P_{tie\,12} = \frac{2\pi T_{12}}{s} + T_{12}\frac{K\phi}{1 + sT_{ps}} \Delta Error_1 \quad (14)$$

If the frequency deviation Δf1 is sensed, it can be used as the control signal (i.e., ΔError1 = Δf1) to the TCPS unit to control the TCPS phase shifter angle which in turn, controls the tie-line power flow. Thus,

$$\Delta\phi(s) = \frac{K_\phi}{1 + sT_{ps}} \Delta F_1(s) \quad (15)$$

and the tie-line power flow perturbation becomes

$$P_{tie\,12} = \frac{2\pi T_{12}}{s}[\Delta F_1(s) - \Delta F_2(s)] + T_{12}\frac{K_\phi}{1 + sT_{ps}} \Delta F_1(s) \quad (16)$$

But in the open market system the actual tie-line power flow also includes the demand from Discos in one area to Gencos in another area. It can be represented as follows.$\Delta P_{tie\ 1\text{-}2,\ actual} = \Delta P_{tie12}$ (s) + (demand of Discos in area 2from Gencos in area 1) – (demand of Discos in area 1from Gencos in area2).

IV. RESULTS

In my work two area system of thermal and hydro power plant has been considered. By using the equation developed for TCPS in previous chapter a TCPS with PI controller is place on tie line. The difference between the output of thermal and hydro plant is given to TCPS. When there is no controlling element on the line then disturbance created on the line is shown in figures given below.

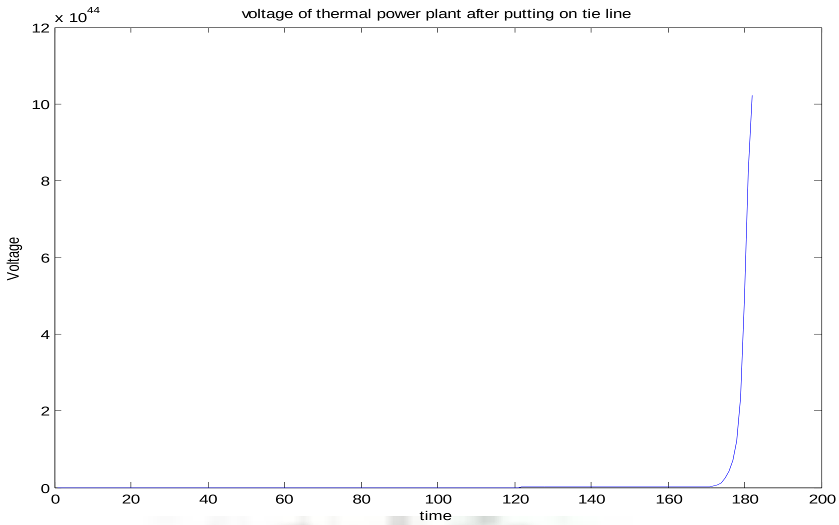

Figure 3: Voltage on the line when no controller to control the load disturbance

The above graph shows the voltage when load disturbance was 0.01 up. This disturbance increases with the increase in load disturbance. Below graph shows for load disturbance 0.07.

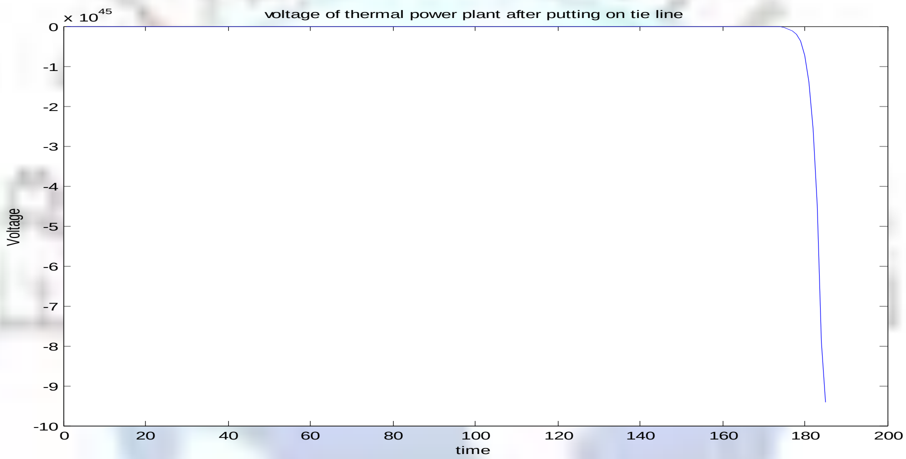

Figure 4: Voltage on tie line when no controller to control the load disturbance

The performance of hydro thermal power plant is measured by ISE graph. Below shown is the ISE graph without any controller.

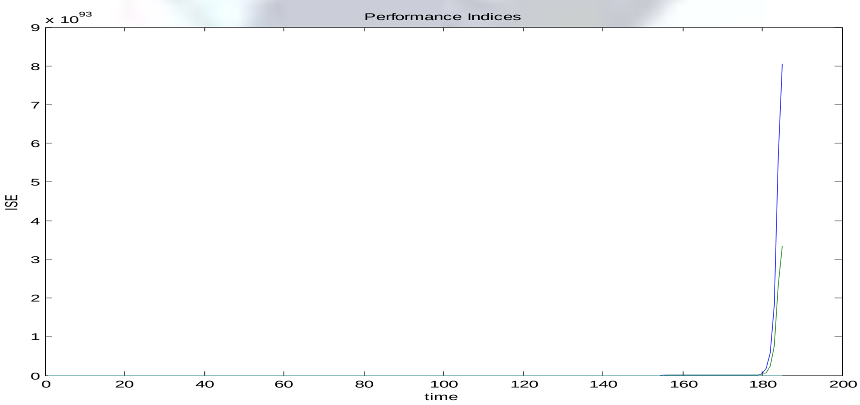

Figure 5: Performance index without any controller.

When TCPS with PI controller is placed on tie line then output before putting on tie line and after putting on tie line for thermal power plant is shown in figure 6.4. The above waveform shown in the graph is after disturbance is created and that disturbed output voltage is put on tie line. The graph shows that even after load disturbance is added the output voltage is same by applying the controllers.

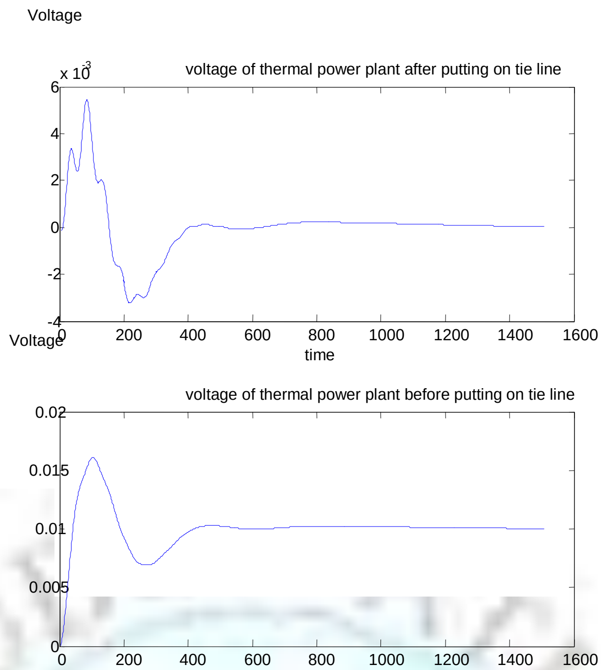

Figure 6.4: Voltage graph for thermal power plant before and after disturbance.

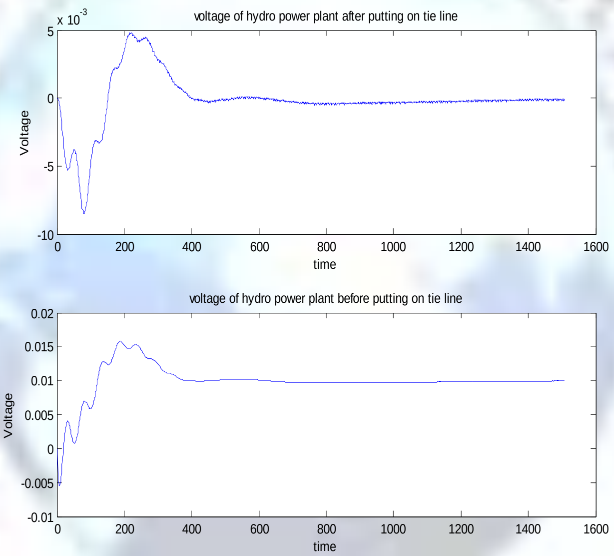

Figure 6: Voltage graph for hydro power plant before and after disturbance. Performance in this case is shown in figure 6.

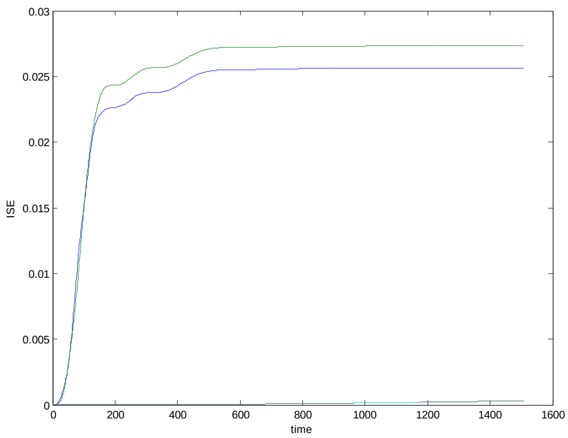

Figure 7: Performance index with TCPS

Above voltage waveforms are for 0.01 p.u. load disturbance. Our controller settled the output to constant value at the same time instant at which the output was before load disturbance.

This thesis work gives an overview of AGC in deregulated environment which acquires a fundamental role to enable power exchanges and to provide better conditions for the electricity trading. The AGC is treated as an ancillary service essential for maintaining the electrical system reliability at an adequate level. The important role of AGC will continue in restructured electricity markets, but with modifications. In my work hydro thermal power plant is controlled by tie line. A small load change, disturb the output distribution of both plants. So TCPS damps out these oscillations along with PI. Our proposed work is more effective in case of thermal power plant as oscillations in this are damped out easily and performance index ISE is also improved more in thermal power plant.

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