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An impact of TCPS with LFC in an multi area power system using conventional controllers

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ABSTRACT

The main objective of Load Frequency Control (LFC) is to regulate the power output of electric generator within an area, in response to the changes in system frequency and tie-line loading. Thus, LFC helps in maintaining the scheduled system frequency and tie-line power interchange with other areas within the prescribed limits. Most LFCs are primarily composed of an integral and PID controller. The integrator gain is set to a level that compromises between fast transient recovery and low overshoot in the dynamic response of the overall system. This type of controller is slow and does not allow the controller designer to consider the possible changes in operating condition and non-linearity in the generator unit. Moreover, it lacks in robustness. FACTS are designed to overcome the limitations of present non-reheat thermal-thermal power systems and enhance the power system stability. One of the promising FACTS devices is the Thyristor controlled phase shifter (TCPS) to alleviate this difficulty. TCPS is connected in the tie-line to self-tune the parameters of integral and PID controller. Two area system, have been considered for simulationof the proposed TCPS connected integral and PID controller .The performance of the Conventional controller, TCPS connected Integral and PID controller have beenCompared through MATLAB Simulation. The qualitative and quantitative comparisonshave been carried out for Integral, PID controllers. The dynamic of performance responses of Integral and PID controller with TCPS shows that in terms of settling .Time, peak overshoot and steady state error are greatly improved than that of without TCPS.

Introduction

Load frequency control (LFC) is a very important issue in power system with an increasing demand for electric power and more complicated. Therefore the objective of LFC of a power system is to maintain the frequency of each area and tie-line power flow (in interconnected system) within specified tolerance by adjusting the new outputs of LFC generators so as to accommodate fluctuating load demand. A number of control schemes have been employed in the design of load frequency controllers [1] in order to achieve better dynamic performance. Among the various types of load frequency controllers the most widely conventional types used are the tie-line bias control and flat frequency control to achieve the above goals of LFC, both schemes are based on the classic controls which work on same function made up of the frequency and tie-line power deviations. Nevertheless these conventional control systems have been successful to some extent only [2]. This suggests the necessity of more advanced control strategies to be incorporated for better control. In this aspect if ensuring a better power quality intelligent controllers [2-8] have been replacing conventional controllers because of their fast and good dynamic response for load frequency control problems. As the load demand increases tremendously, the power transmission over large distances to the remotely located load centres are forces to emerge into new plant for more and more effective and efficient control schemes for a better secured, reliable and stable system operation. This can be achieved by properly designed load-frequency control schemes i.e. either by the proper selection of the controller or by incorporating efficient FACTS devices. [9-12]

A Thyristor Controlled Phase Shifter (TCPS) is expected to be an effective apparatus for the tie-line power flow control of an interconnected power system In the analysis of an interconnected power system. The proposed control strategy will be a new ancillary service for the stabilization of frequency oscillations of an interconnected power system. Literature survey shows ample applications of TCPS for the improvement of dynamic and transient. Stabilities of power systems. With the use of SMES in both theare as, frequency deviations in each area are effectively suppressed. However, it may not be economically feasible to use SMES in every area of a multi-area interconnected power system. Therefore, it is advantageous if an SMES located in an area is available for the control of frequency of other interconnected areas. Further, literature survey shows that, no work has been carried out for the AGC of thermal power system considering an SMES unit. In view of this the main objectives of the present work are:

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1. To develop the two area Simulink model of reheat thermal system
2. To develop the model of TCPS and SMES
3. To compare the improvement of dynamic performance

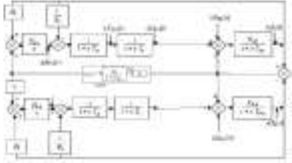

Fig: 1 modeling of TCPS with two area non-reheat thermal system

Tie Line Power Flow With Tcps

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). A TCPS 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 of the system through TCPS and SMES hydrothermal power system interconnected by a tie line is considered.

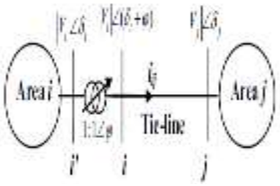

fig:2interconnected two-area system with TCPS in series with tie-line.

Without TCPS, the incremental tie-line power flow from Area 1 to Area 2 in a traditional system can be expressed as

$$\Delta P_{tie12}(s) = \frac{2\pi T_{12}}{s}(\Delta F_1(s) - \Delta F_2(s)) \qquad (1)$$

where*T*12 is the synchronizing constant without TCPS and Δ*F*1(*s*), Δ*F*2 (*s*) are the frequency deviations in area 1 and area 2 respectively. When a TCPS is placed in series with the tie line as in current flowing from Area 1 to Area 2 is

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

And

$$P_{tie12} - jQ_{tie12} = |V_1|\angle-(\delta_1 + \phi)\left(\frac{|V_1|\angle(\delta_1 + \phi) - |V_2|\angle\delta_2}{jX_{12}}\right) \qquad (3)$$

Separating the real part of Eqn. (3)

$$P_{tie12} = \frac{|V_1||V_2|}{X_{12}}\sin(\delta_1 - \delta_2 + \phi) \qquad (4)$$

But in Eqn. (4) perturbing δ1, δ2 and φfrom their nominal values andδ_2^0,φ^0respectively

$$\Delta P_{tie12} = \frac{|V_1||V_2|}{X_{12}}\cos(\delta_1^o - \delta_2^o + \phi^o)\sin(\Delta\delta_1 - \Delta\delta_2 + \Delta\phi) \qquad (5)$$

But for a small change in real power load, the variation of bus voltage angles and also the variation of TCPS phase angle are very small. As a result (Δδ1-Δδ 2+Δφ) is very small and hence,

Sin (Δδ 1- Δδ2 +Δφ)≈(Δδ 1 -Δδ2 +Δφ) . So Eqn. (5) can be written as

$$\Delta P_{tie12} = \frac{|V_1||V_2|}{X_{12}}\cos(\delta_1^o - \delta_2^o + \phi^o)(\Delta\delta_1 - \Delta\delta_2 + \Delta\phi) \qquad (6)$$

$$\Delta P_{tie12} = T_{12}^{'}(\Delta\delta_1 - \Delta\delta_2 + \Delta\phi) \qquad (7)$$

$$\text{where } T_{12}^{'} = \frac{|V_1||V_2|}{X_{12}}\cos(\delta_1^o - \delta_2^o + \phi^o) \qquad (8)$$

$$\Delta P_{tie12} = T_{12}^{'}(\Delta\delta_1 - \Delta\delta_2) + T_{12}^{'}\Delta\phi \qquad (9)$$

$$\text{But } \Delta\delta_1 = 2\pi\int\Delta f_1 dt \text{ and } \Delta\delta_2 = 2\pi\int\Delta f_2 dt \qquad (10)$$

Eqn. (9) can be modified as

$$\Delta P_{tie12} = 2\pi T_{12}^{'}(\int\Delta f_1 dt - \int\Delta f_2 dt) + T_{12}^{'}\Delta\phi \qquad (11)$$

The Laplace transform of Eqn (11) is

$$\Delta P_{tie12}(s) = \frac{2\pi T_{12}^{'}}{s}\left[\Delta F_1(s) - \Delta F_2(s)\right] + T_{12}^{'}\Delta\phi(s) \qquad (12)$$

As per Eqn. (12), it can be observed that the tie-line power flow can be controlled by controlling the phase shifter angle Δφ. Assuming that the control input signal to the TCPS damping controller is Δ*Error*1(*s*) and that the transfer function of the signaling conditioning circuit is $K_\varphi C$ (*s*) , where $K_\varphi$is the gain of the TCPS controller

$$\Delta\phi(s) = K_\phi C(s)\Delta Error_1(s) \qquad (13)$$

$$\text{and } C(s) = \frac{1}{1 + sT_{ps}} \qquad (14)$$

The phase shifter angle Δφ(s) can be written as

$$\Delta\phi(s) = \frac{K_\phi}{1 + sT_{ps}}\Delta Error_1(s) \qquad (15)$$

Where $K_\varphi$and *Tps*are the gain and time constants of the TCPS and Δ*Error*1(*s*) is the control signal which controls the phase angle of the phase shifter.

Logic Oftcps Control, Strategy

Δ*Error*1 can be any signal such as the thermal area frequency deviation Δ*f*1or frequency deviation Δ*f*2 or ACE of the thermal or other area to the TCPS unit to control the TCPS phase shifter angle which in turn controls the tie-line power flow. Thus, with $\Delta Error1=\Delta f1$, Eqn (13) can be written as

$$\Delta\phi(s)=\frac{K_\phi}{1+sT_{ps}}\Delta F_1(s) \qquad (17)$$

The above logic can be demonstrated as follows

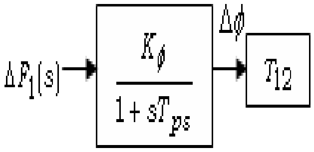

Fig 3.Logic of TCPS in series with tie line

Simulation and Results

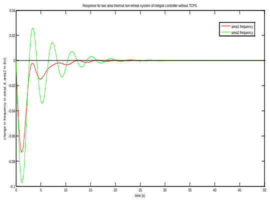

Fig:4Response of integral controllerfrequency without TCPS

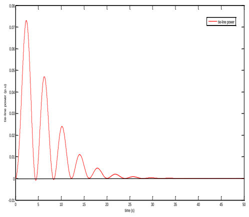

Fig: 5Response of tie-line power without TCPS

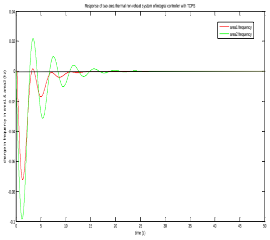

Fig: 6Response of integral controller frequency with TCPS

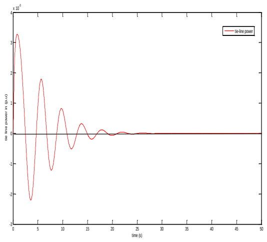

Fig: 7 Response of tie-line power with TCPS

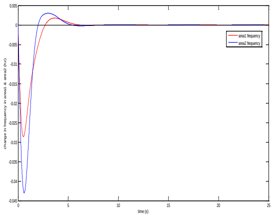

Fig: 8Response of PID controller frequency without TCPS

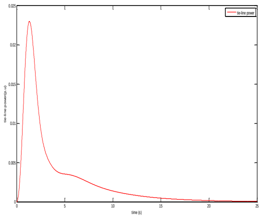

Fig: 9 Response of tie-line power without TCPS

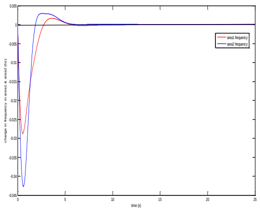

Fig: 10 Response of PID controller frequency with TCPS

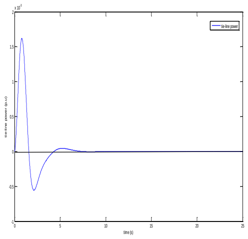

Fig: 11 Response of tie-line power with TCPS

Conclusion

The performance of a two area interconnected thermal non-reheat system is investigated using integral and PID controllers. The integral & PID controller gains with and without operation of TCPS units have been optimized. The dynamic responses of with and without TCPS has been compared as both controllers, we conclude that the TCPS operation is very effective in wiping out oscillatory in area frequencies (i.e. area1 & area2) and tie-line power oscillations following momentary deflections in the load, improving performance of LFC of interconnected power systems. The PID controller responses are superiority performance than the integral cont roller with a operation of TCPS in both areas and tie-line power oscillations. The PID controller gives less overshoot, settling time& tie-line power oscillations than the integral controller for non-reheat thermal turbine in the two area thermal system. The responses are compared both qualitatively and quantitatively with the TCPS operation in both controllers; it effectively reduces the power oscillations and improving the performance of the interconnected area power systems.

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QUANTITATIVE RESULTS

		WITHOUT TCPS			WITH TCPS		
Controller		Area 1 ΔP_{L1}=0.2	Area 2 ΔP_{L2}=0.2	Δp_{tie}	Area 1 ΔP_{L1}=0.2	Area 2 ΔP_{L2}=0.2	Δp_{tie}
Integral Controller	Peak overshot	0.01	0.028	0.074	0.005	0.022	0.0032
	Settling time	32.5	35	32.5	17.5	27	31
	Steady state error	-3.905e^{-7}	8.606e^{-7}	1.802e^{-6}	-2.039e^{-5}	-3.321e^{-8}	-2.733e^{-5}
PID controller	Peak overshot	0.0016	0.0027	0.023	0.0013	0.0023	0.00162
	Settling time	15	14	25	8.25	7.5	9.75
	Steady state error	-2.55e^{-6}	3.137e^{-6}	5.206e^{-5}	1.046e^{-10}	-1.66e^{-11}	1.392e^{-11}