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Load Frequency Control in Tie-Line in a Deregulated Power system

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Abstract: In practice, the design of a linear model for Load Frequency Control (LFC) in Tie-Line using proportional Integral (PI) controllers in a deregulated competitive market. The controller improves the steady state error. This gives rise to the complexity of the structure as the order of the system increases, towards which some industry show reluctance. There is disturbances among some areas which are interconnected, Thyristor Controlled Phase Shifter (TCPS) controls the power flow in the tie-line connecting the these areas, makes the oscillating load frequency stabilized through interconnection and governor system coordinates for the suppression of these disturbances. Such scheme provides the ancillary service for the further power systems. It is seen from the Analysis that the thyristor controlled phase shifter is quite capable of suppressing the frequency and tie-line power oscillations effectively for the wide range of plant parameter changes, even disturbances and area load demands presents system nonlinearities.

Keywords: Load Frequency control, Thyristor Control Phase Shifter, Deregulated Power System.

Introduction

Day by day the development is going to increase with which the demand of electricity is also increased. There is a need of the supply of more power to fulfill the requirement of the consumer. Thus the interconnection of power system is important, the size and complexity of the system increases, the system ensures reliable power supply by sharing the spinning reserve capacities even under the emergencies. In the load frequency control (LFC) and areas connected by tie-line power flow control, decentralized control scheme is important. Thus stabilization and solution of Load Frequency Control (LFC) in an interconnected power system becomes more tedious when implemented in the competitive environment. For improvement in the control of power system operation an advanced control of frequency stabilization services which are pressed in used with economics, reliability and efficiency. Conventionally, the load frequency control is accomplished by the governor system, but this system no longer attains the satisfactory operation. To minimize the unscheduled tie-line power flows between the neighboring control areas and return the frequency to its normal value, the reestablishment of the governor system is required.

In the recent post there is fast development in the field of power electronic which led to the development of Flexible Alternating Current Transmission System (FACTS) which enhances the stability, power transfer limits and power system operation controllability. The independent adjustment in the certain system variables such as power flows is due to the advances in the power electronic devices. One of the best devices in the Flexible Alternating Current Transmission (FACTS) device family is the Thyristor Controlled Phase Shifter (TCPS) which is considered to be an effective component for controlling the power flow through a tie-line of an interconnected areas. It is a device that relatively changes the phase angle between the system voltages. The active power flow can be regulated at the suitable frequency oscillations and the system stability can be enhanced. The TCPS will have a high speed control for the tie-line power flow when connected in series with the interconnected tie-line in between the two areas. This new technique provides the better solution for frequency oscillation of the load frequency control problem in the deregulated environment and also improves the dynamic and transient of the power system. The study reveals that some of the areas are the major source of the disturbances in the interconnected power system and it is to be designed to regulate the area control errors to zeros positively. The deviation of power through tie-line and frequency exist for long time. However, due to slow governor response it may no longer be able to accommodate the change in load frequency. On the other hand with the development of thyristor control phase shifter, the control of power flow through the tie-line is possible if the TCPS are installed in series with tie-line between two areas and effectively controls the system frequency through interconnections. Thus the suppression of the transition of disturbances of active power by thyristor control phase shifter is achieved in faster way. This scheme has the ability to get the contribution of the frequency control capabilities of other interconnected areas to stabilized the frequency oscillation of an area which has insufficient control capability. It is a new ancillary service for the solution of load frequency control problem in a deregulated power system. The TCPS provides the technical and economical feasibility for frequency oscillation control in deregulated power system application. For small load variation, frequency oscillation control is required for the active power transmission. Thus a small time is desired for the transfer of active power. With the application of TCPS to the power system, transients in frequency and tie-line power deviation improves significantly with the small variation in the load.

Model Of A Tie-Line Power Flow For A Two – Area Interconnected System

The study reveals that the high speed performance TCPS is superior than the governor system. The peak value of the transient frequency which is due to the sudden change of load in a power system can be suppressed more quickly by the use of TCPS. The figure shows the schematic diagram of a two-area interconnected power system with TCPS connected in series with Tie-Line. The TCPS is placed near area 1. The resistance of the tie-line is very small. A TCPS is capable of changing 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. From the power control characteristics of the TCPS, mathematical model can be derived for stabilization of frequency oscillations.

Since the incremental frequency Δf is related to the phase angle deviation, i.e. $\Delta f=\frac{1}{2\pi}\frac{d}{dt}\Delta\delta$

Without TCPS, the power flowing through the interconnected tie-line from area 1 to area 2 can be expressed as

$$\Delta P_{tie12} = 2\pi T_{12}^{o}[\int \Delta f_1 dt - \int \Delta f_2\, dt]\ p.u.MW \quad (1)$$

Taking the Laplace Transform of equation (1)

$\Delta P_{tie12}(s) = \frac{2\pi T_{12}^{o}}{S}\left[\Delta f_{1(S)} - \Delta f_{2(S)}\right]$ (2)

With the TCPS is placed in series with the tie-line near area 1 as shown in figure.

$i_{12} = \frac{|V_1|<(\delta_{1+\Phi}) - |V_2|<\delta_2}{j X_{12}}$ (3)

where, $X_{12}$is the tie-line reactance, V_1 and V_2 are the bus voltages. The active and reactive power flows at bus 1 are:

$P_{12} + jQ_{12} = V_1 I_{12}^{*}$ (4)

Where, I_{12}^{*} is the complex conjugate of I_{12}. Substituting eq. (3) into (4) gives

$P_{12} - jQ_{12} = |V_1| < -(\delta_1 + \Phi)\left(\frac{|V_2|<(\delta_1+\Phi) - |V_2|<\delta_2}{jX_{12}}\right)$ (5)

Separating the real part of the tie-line power

$P_{12} = \frac{|V_1||V_2|}{X_{12}} \sin(\delta_1 - \delta_2 + \Phi)$ (6)

With TCPS, the power flowing through the interconnected tie-line from area 1 to area 2 can be expressed as

$\therefore \Delta P_{tie12} = T_{12}(\Delta\delta_1 - \Delta\delta_2) + T_{12}\Delta\Phi$ (7)

Where $\Delta\delta_{1} = 2\pi\int \Delta f_1\, dt$ and $\Delta\delta_{2} = 2\pi\int \Delta f_2\, dt$ (8)

From the equation (7) and (8) $\Delta P_{tie12} = 2\pi T_{12}[\int \Delta f_1\, dt - \int \Delta f_2 dt] + T_{12}\Delta\Phi$ (9)

Apply Laplace Transform to equation (9), it can be written as

$\Delta P_{tie12}(s) = \frac{2\pi T_{12}}{s}[\Delta F_1(s) - \Delta F_2(s)] + T_{12}\Delta\Phi(s)$ (10)

From equation (10) it is seen that the tie-line power flow can be controlled by controlling the phase shifter angle $\Delta\Phi$. The phase shifter angle $\Delta\Phi$ can be written as

$\Delta\Phi(s) = \frac{K_{TCPS}}{1+sT_{TCPS}}\Delta Error_{TCPS}(s)$ (11)

Where, K_{TCPS} and T_{TCPS} are the gain and time constant of TCPS. Substitute the value of $\Delta\Phi(s)$ from equation (11) to equation (10), gives

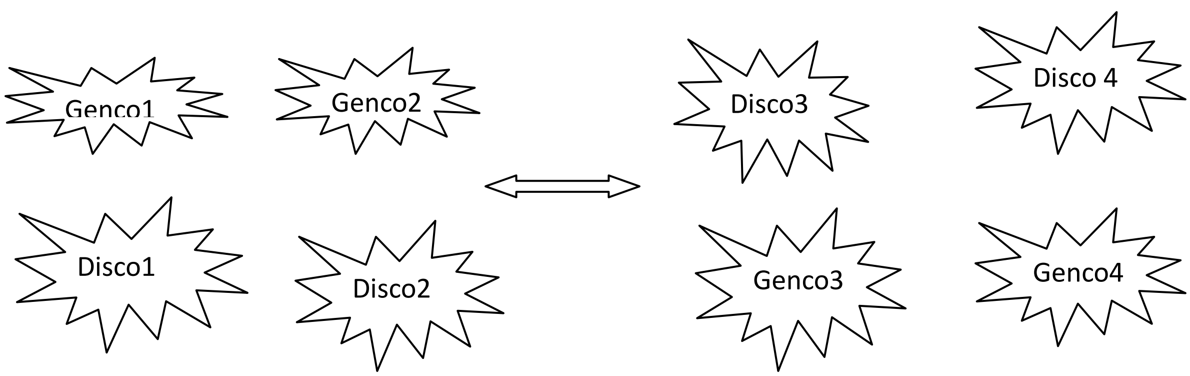
$\Delta P_{tie12}(s) = \frac{2\pi T_{12}}{s}[\Delta F_1(s) - \Delta F_2(s)] + T_{12}\frac{K_{TCPS}}{1+sT_{TCPS}}\Delta Error_{TCPS}(s)$ (12)

However, in the deregulated power systems the actual tie-line power flow also includes the demand from DISCOs in one area to GENCOs in another areas.

LFC Model IN TWO AREAS

The vertically integrated utility is not attracted by the market as it supplies power to customer at regulated rate. For existing into the competitive environment the vertically integrated utility needs to restructured. The restructured system consists of Generating companies (GENCOs), Distribution companies (DESCOs), Transmission companies (TRANSCOs) and Independent System Operator (ISO). The ISO has to control a number of "ancillary services". Automatic Generation Control is one such service. The goal is to control the load frequency in the power system i.e. restoring the frequency and the net interchanges to their desired values for each control area, still remain. For the load frequency control, a flexible method is required which should be suitable for the simulation of the operation of the system.

In a restructure environment, GENCOs sell power to various DISCOs at competitive prices. DISCO participation matrix (DPM) is used for easy visualization of contracts. Figure shows a restructured two area power system. Each area having two GENCOs and two DISCOs in it . In a DPM matrix, GENCOs represents the number rows in a matrix and DISCOs represents the number of columns in a matrix. Let $GENCO_1$, $GENCO_2$, $DISCO_1$ and $DISCO_2$ are in area 1 and $GENCO_3$, $GENCO_4$, $DISCO_3$ and $DISCO_4$ are in area 2.



AREA1 AREA2

The DPM structure is given by

		$DISCO_1$	$DISCO_2$	$DISCO_3$	$DISCO_4$
	$GENCO_1$	dpm_{11}	dpm_{12}	dpm_{13}	dpm_{14}
DPM =	$GENCO_2$	dpm_{21}	dpm_{22}	dpm_{23}	dpm_{24}
	$GENCO_3$	dpm_{31}	dpm_{32}	dpm_{33}	dpm_{34}
	$GENCO_4$	dpm_{41}	dpm_{42}	dpm_{43}	dpm_{44}

For the purpose of explanation, suppose that $DISCO_3$ demands 1 pu KW power, out of which 0.3 pu KW is demanded from $GENCO_1$, 0.25 pu KW from $GENCO_2$, 0.2 pu KW from $GENCO_3$ and 0.25 pu KW is demanded from $GENCO_4$.

The column 3 entries are defined as

DPM_{13}+DPM_{23}+DPM_{33}+DPM34=1

The other DPMs can be defined easily. In general

$$\sum 1 = DPM_{12} = 1$$

Conclusion

This paper presents a design of load frequency control of interconnected power systems with TCPS in series with the tie-line. The main aim in introducing TCPS in the interconnected power system is to enhance the reduced ACE in the interconnected areas and regulates the power flow through the tie-line. The proposed controller design is found to be simple. With its implementation, contracted load is fed forward through the DPM matrix to GENCO set points. The dynamic system is affected by the actual loads.

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