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TCPS-SMES Based Multi Area Thermal System with AGC Control

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Abstract

Automatic generation control has been used for several years to maintain the system frequency at nominal value and the net tie line power interchange from different areas at their scheduled values. The concept of Automatic Generation Control is discussed. Controlling the deviations in frequency has always been a major problem in electrical power system and is becoming much more significant recently with increasing size, complexity and changing structure in interconnected power systems. The power systems are interconnected for its applicability all over the world. Interconnection not only enhance the system efficiency but also improves reliability of the system. Since due to such interconnections the system becomes more complex and the analysis of the system has more importance. The proposed TCPS-SMES system can improve the dynamic performance of interconnected system after the sudden load disturbance with automatic generation control. The integral gains of AGC are determined by tuning the quadratic performance index using Integral Squared Error (ISE) technique. The system is modelled using MATLAB SIMULINK.

Keywords: Integral Squared Error (ISE), Thyristor Controlled Phase Shifter (TCPS), Flexible AC Transmission System (FACTS).

I. INTRODUCTION

The ultimate objective of automatic generation control (AGC) is to maintain the balance between power output of the electrical generator and load demand so as to keep the frequency within the acceptable limits, in response to the changes in the system and tie-line loading. This function is normally termed as load frequency control (LFC) [1]. The power systems are interconnected for its applicability all over the globe. Interconnection not only enhances system efficiency but also improves the reliability system. Since the system is wide and complex, for the faithful operation, the analysis of the system is of greater importance. Currently system became too complex with addition of more utilities, which may leads to a condition where supply and demand has got a wide gap [2]. Due to heavy load condition in tie-lines by electric power exchange results in poor damping which may leads to inter-area oscillation. Since the loading conditions are unpredictable, this makes the operation more complex. It has been a topic of concern, right from the beginning of interconnected power system operation. In this context, Automatic Generation Control plays a vital role in the power system operation. Several works have been carried out for the AGC of interconnected power systems from past few decades [3][6]. Earlier works in this field proposed many ideas to improve system stability when there is sudden drift in the demand. However thermal power plants consist its own associated operational constraints, most of the solutions proposed so far for AGC have not been carried out properly [7]. But a few efforts were made to attenuate the oscillations in system frequency and tie-line power interchange.

The use of power electronic devices for power system control has been accepted widely in the form of flexible AC transmission system (FACTS) devices which provides more flexibility in power system operation and control [1]. This extra flexibility permits the independent adjustment of certain system variables such as power flows, which are not normally controllable [7]. 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 after a sudden load disturbance in both the areas, as well. Phase shifters also provide series compensation to improve the stability by reducing the effective resistance of the tie line. The high-speed responses of these shifters also 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. A usually sudden change in power requirement is met by kinetic energy of generator rotor, which effectively damp electromechanical oscillations in power system [2].The transient performance of the system is improved by using fast acting storage devices, by supplying stored energy after the sudden load disturbance. [8] Has proposed a control strategy for TCPS to providing active control of system frequency and there by to damp out the system frequency and tie-power oscillations by controlling the phase angle of TCPS.

Authors of [10] have made an attempt to improve the transient performance analysis in hydro-hydro system with SMES, TCPS controllers. This work gives an insight into application of FACT devices especially series connected, to damp out inter area oscillations. A maiden attempt to use energy storage to enhance the system performance appeared in [10], also considered an interconnected hydro-thermal system with capacitive storage devices and TCPS to stabilize low frequency oscillation so as to improve the transient performance of the system. With advent of FACTs devices and energy storage devices many research work are made to damp out the tie line oscillation with some of them like TCPS, SSSC etc. Literature survey reveals that the most of the work in relation with application of FACTS devices and storage systems in AGC problems were considered separately in frequency control and tie-line power control [10-12]. But the there are less work devoted to coordinated action of FACTS devices and storage systems. Thus this paper deals with an attempt to connect thermal-thermal interconnected system with Thyristor Controlled Phase Shifter (TCPS) in tie-line and in coordination with Superconducting Magnetic Energy Storage (SMES) system. The effect of TCPS and SMES in coordinated with two area thermal system were investigated and controllers were designed.

II. THYRISTOR CONTROLLED PHASE SHIFTER (TCPS)

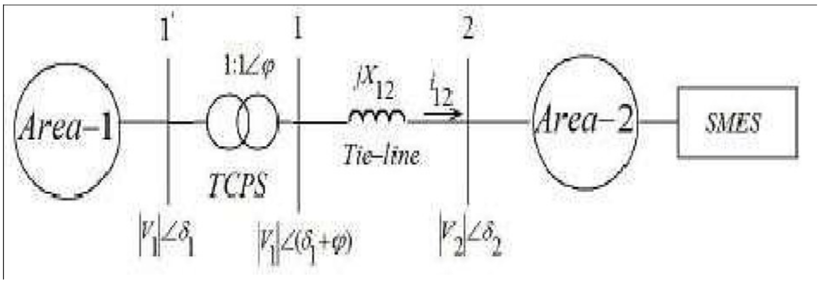

Fig. 1. Schematic diagram of two area system with TCPS & SMES.

TCPS is a device that regulates the relative phase angle between the system voltages. Therefore the mitigate the frequency oscillations and enhance real power flow as well as power system stability [7]. In this study, a two-area multi-unit thermal power system interconnected by a tie-line is considered. Fig. 1 shows the schematic representation of the two-area interconnected power system considering a TCPS in series with the tie-line. TCPS is placed near Area 1. Practically, in an interconnected power system, the reactance to-resistance ratio of a tie-line is quite high and the effect of resistance on the dynamic performance is not that significant. Because of this, the resistance of the tie-line is neglected.

A. Superconducting Magnetic Energy Storage (SMES)

The SMES unit contains a 12-pulse converter and DC superconducting coil, these are connected to grid through a YΔ/Y-Y transformer. During the study state operation of power system the super conducting coil is in charging condition and will be discharged when sag condition occurs. The DC magnetic coil is connected to grid via inverter/ rectifier arrangement. The magnetic coil conducts current which is immersed in a tank containing helium and the entire arrangement is kept in super cooled envelop so the dc magnetic coil acts as super conducting coil. The energy exchange between the superconducting coil and the electric power system is controlled by using a line commutated converter. When there is a sudden increase in the load demand, the stored energy is released to the power system as alternating current through the converter. As the governor and other control mechanisms start working to set the power system to the new equilibrium condition, the coil current changes back to its initial value and are similar for sudden release of load

III. SYSTEMS INVESTIGATED

Fig.2 shows liberalized model of an interconnected power system with AGC comprises two control areas. The two areas are connected through a tie-line which allows the power exchange between the control areas. Area 1 consists of two reheat thermal power generation units and Area 2 comprises two non reheat thermal generation units. The frequency in the power system is being maintained by controlling the driving torques of the thermal turbine. The reheat turbine gives a fast response component due to the High Pressure (HP) stage and a much slower Low Pressure (LP) due to reheat delay. A Generation Rate Constraint (GRC) of 10 % p.u. MW/min and 3% p.u. MW/min for non reheat and reheat thermal systems respectively [9,13]. GRCs are taken into account since the rapid power increase would draw out excessive steam from boiler system to cause steam condensation due to adiabatic expansion. Are the integral gain settings in area 1 and area 2 respectively? The nominal parameters of the system are giveninAppendix-1.

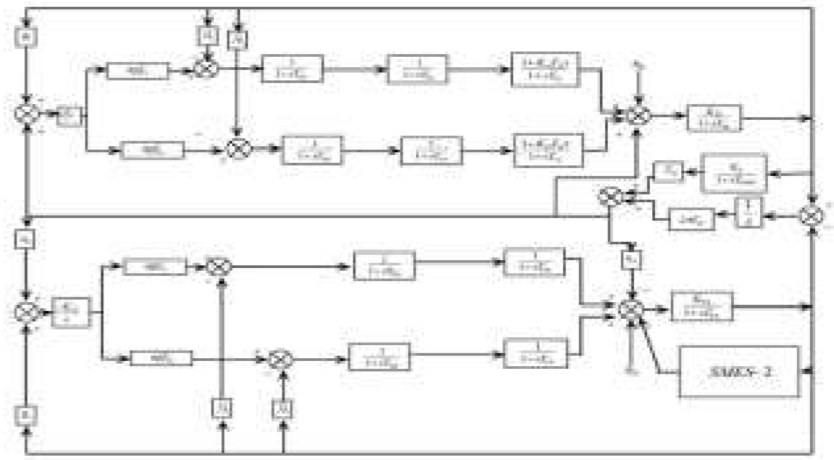

Fig.2. Linear zed model of an interconnected thermal system.

A. State Spacer Presentation

The power system model considered being a linear continuous-time dynamic system can be represented by the standard state space model. The standard state space form of the system can be expressed as

$$\dot{x} = Ax + B\,u + \tau p \quad \textbf{(1)}$$

Where x, u and p are the states, control input, and load disturbance input vectors and A, B and ˜ are the respective matrices of appropriate dimensions associated with them. The dynamic state variables are chosen from the liberalized power system model as shown in Fig.2.

B. Mathematical Problem Formulation

The automatic generation control is incorporated in the interconnected power system is to meet the frequency regulation, i.e. to restore the frequency to its scheduled value as quickly as possible and minimize the oscillations in the tieline power flow between the control areas. To the above requirements, integral controller gains of the control areas (Kl1 &Kl2) are optimized to have better dynamic response. Integral Squared Error (ISE) technique is used for formulating the objective function to obtain the optimum integral gain settings. The quadratic performance index defined by

$$J = \int (\Delta f_1^2 + \Delta f_2^2 + \Delta P_{tie12}^2)\, dt \quad \textbf{(2)}$$

Where, Δ_f is the incremental change in frequency, Δ_p is the incremental change in tie-line power. The objective function is minimized for 1% step load disturbance in either of the areas in the presence of GRCs. The ISE criterion is used because it weighs large errors heavily and small errors lightly.

Table I: Optimum Values of Integral Gain Settings without and with TCPS and SMES for 1% Step Load Disturbance

	K_{I1}	K_{I2}
Without TCPS and SMES	0.065	0.06
With TCPS and SMES	0.13	0.34

IV. FUZZY LOGIC CONTROL

In 1965 L.A.zadeh presented the first paper on fuzzy sets Since then, a new language was developed to describe the fuzzy properties, which are very difficult and sometimes even impossible to be described using conventional methods. Fuzzy set theory has been widely used in the control area with some application to power system [5]. A fuzzy logic control is built up by a group of rules which are based on the human knowledge of system behaviour. Matlab/Simulink simulation model is built to study the dynamic behavior of controller furthermore design of fuzzy logic controller provide small signal as well as large signal at same time, which is not possible with linear control technique. Thus, fuzzy logic controller has been potential ability to improve the robustness of compensator. Fig.3 shows the basic circuit diagram of fuzzy logic controller and consists of four components such as: a fuzzy fication interface, it converts input data into suitable linguistic values; a knowledge base, it consists of a data base with necessary linguistic definitions and the control rule set; a decision-making logic which, simulates a human decision making process, infer the fuzzy control action from the knowledge of the linguistic variable definitions and control rules; a defuzzification interface which yields non fuzzy control action from an inferred fuzzy control action [10].

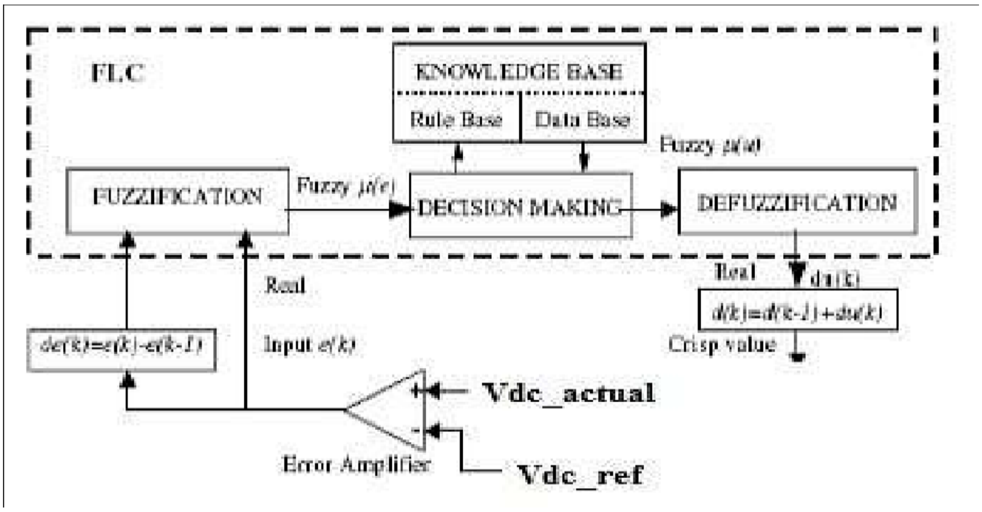

Fig.3. Block diagram of the Fuzzy Logic Controller (FLC) for Proposed Converter.

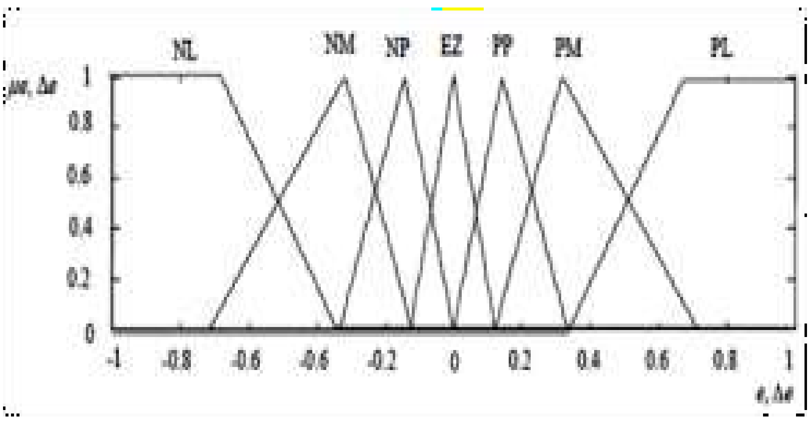

Fig.4. Membership functions for Input, Change in input, Output.

Rule Base: the elements of this rule base table are designed based on the theory, In the steady state form small errors needs fine control, which requires fine input/output variables. In transient state form large errors needs coarse control, which requires coarse input/output variables similar to fine control as shown in Fig.4. Based on this the elements of the rule table are obtained as shown in Table, with „V_{dc}" and „V_{dc-ref}" as inputs.

TABLE II:

Δe \ e	NL	NM	NS	EZ	PS	PM	PL
NL	NL	NL	NL	NL	NM	NS	EZ
NM	NL	NL	NL	NM	NS	EZ	PS
NS	NL	NL	NM	NS	EZ	PS	PM
EZ	NL	NM	NS	EZ	PS	PM	PL
PS	NM	NS	EZ	PS	PM	PL	PL
PM	NS	EZ	PS	PM	PL	PL	PL
PL	NL	NM	NS	EZ	PS	PM	PL

IV. RESULTS AND DISCUSSIONS

Results of this paper is shown in bellow Figs.5 to 12.

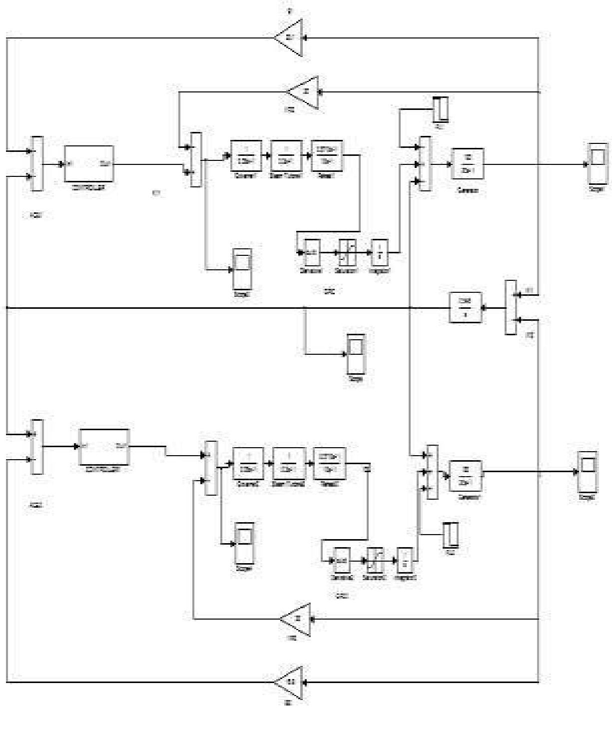

Fig.5. Matlab/Simulink circuit for proposed system in linear zed model of an inter connected with fuzzy controller.

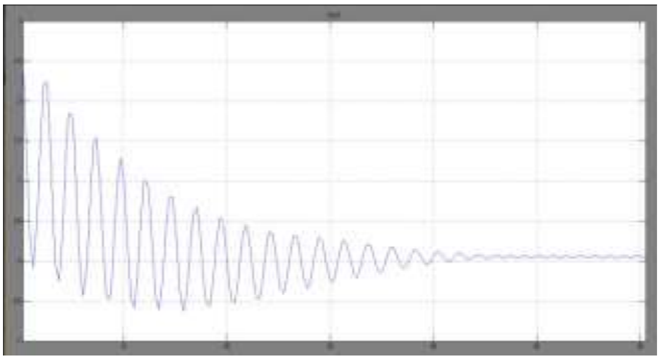

Fig.6. Matlab/Simulink circuit for changing Deviation in frequency of area-1 in conventional method.

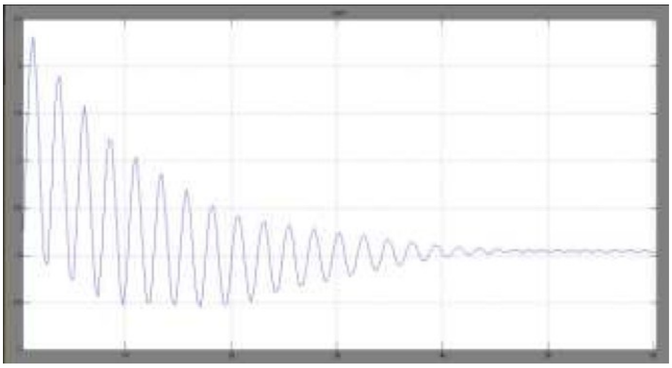

Fig.7. Matlab/Simulink circuit for changing Deviation in frequency of area-2 in conventional method.

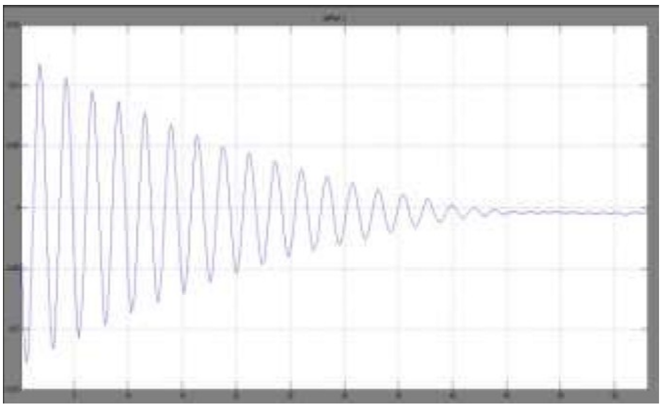

Fig.8. Matlab/Simulink circuit for changing Deviation in tie-line power flow in conventional method.

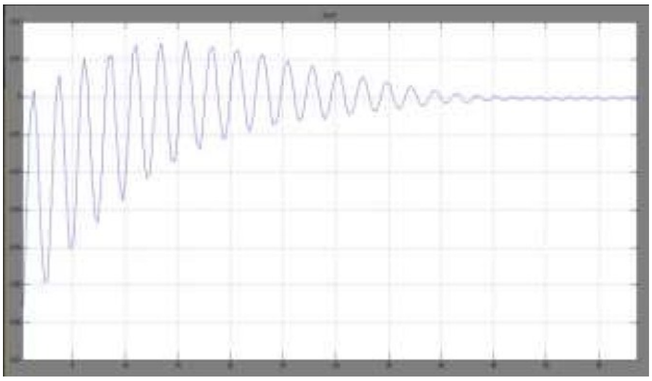

Fig.9. Matlab/Simulink circuit for changing in power output of Generator in area-1 when load is change.

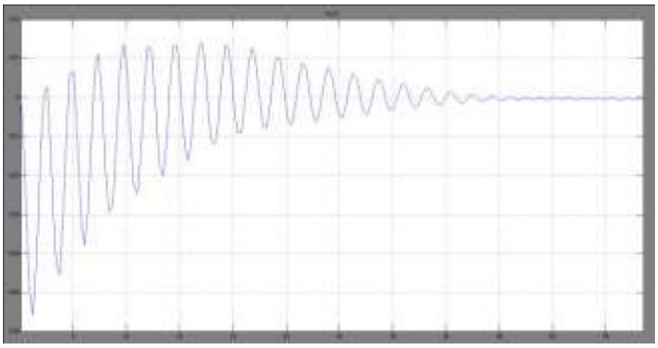

Fig.10. Matlab/Simulink circuit for changing in power output of Generator in area-2 when load is change.

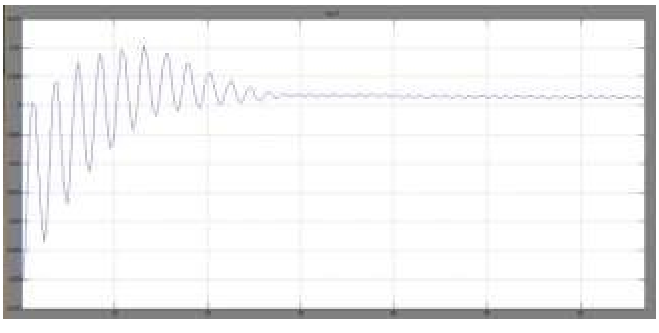

Fig.11. Matlab/Simulink circuit for changing in power output of Generator in area-1 when load is change with fuzzy controller.

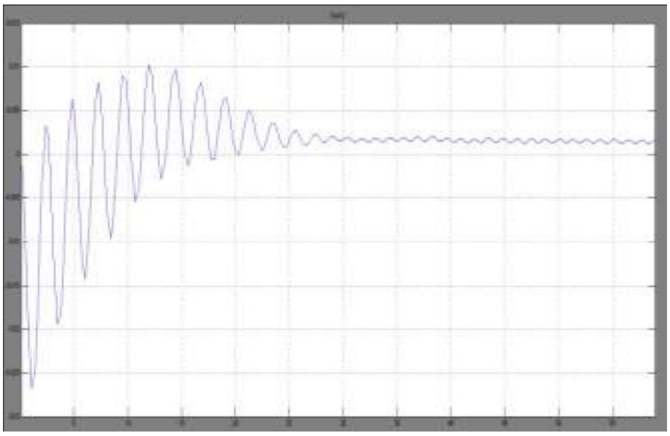

Fig.12. Matlab/Simulink circuit for changing in power output of Generator in area-2 when load is change with fuzzy controller.

CONCLUSION

In this paper, a coordinated control of SMES and TCPS has been proposed for a two-area multi-unit interconnected with fuzzy controller. Gain settings of the integral controllers without and with SMES-TCPS combinations are optimized using fuzzy controller technique in the presence of GRCs by minimizing a quadratic performance index. A control strategy has been proposed to control the SMES-TCPS combination with fuzzy controller is controls the frequency deviation in the control areas and inter-area tie-line power flow. From the simulation studies it is revealed that the SMES-TCPS combination of fuzzy controller can be effectively controlled frequency deviation and minimizing a quadratic performance index.

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