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Stability Enhancement of Interconnected Power System under Small Disturbance

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ABSTRACT: In this paper, design a Wide-area Power System Stabilizer (WPSS) to damp-out the inter-area oscillations in a large scale power system by using Static Synchronous Series Compensator (SSSC) based on fuzzy logic system. In this paper, tie line active power deviation conjunction with speed deviation are used as a input stabilizing signals and the designed methods are illustrated on Kundur two area four machine system. Simulation results revealed that the proposed controller able to damp out the inter-area oscillations in terms of settling time, peak overshoot and number of oscillations.

Keywords: Inter-area Oscillations, Power System Stabilizer, Fuzzy Logic, SSSC

I. INTRODUCTION

Now-a-days, power system is a large interconnected electrical network. The main reason for interconnection of electric grids is that it can efficiently utilize various power resources distributed in different areas and achieve the optimal allocation of energy resources. These also optimize the economic dispatch of power and get relatively cheaper power, which implies that decrease of system installed capacity and the investment. Moreover, in case of fault or disturbance in operating condition, it can also provide additional supporting power of each area of interconnected grids which can increase the reliability of generation, transmission and distribution system.

With the growing electricity demand and the aging utility infrastructure, the present-day power systems are operating close to their maximum transmission capacity and stability limit. Due to large mechanical time constant of machine's rotating members, any change appearing in line power flow, either due to occurrence of fault in the transmission line or due to sudden changes in load or in input mechanical power, the input-output power balance gets upset. This generates low frequency mechanical oscillation of the rotating part of the generator, in range of 0.2 to 3.0 Hz with consequent occurrence of oscillations in power flow through the lines. The oscillation, once started, continues to exist a short time, at that time either disappears or continues to grow causing system separation. Such oscillation deteriorates power transmission capability, hampers efficient operation and threatens power system security even may cause a black out of the whole power system. This is referred to as the power system dynamic stability.

The classical approach to damp out the inter-area oscillations by using Power System Stabilizer (PSS). The basic function of PSS is to add damping to the generator rotor oscillation by controlling its excitation using auxiliary stabilizing signal Series compensator, parallel compensator and phase shifter are used in order to boost the power transmission capacity of lines. It was observed that by operating these compensators using solid state power electronic devices; system security might be extensively enhanced, allowing complete utilization of system capability. This concept is called Flexible AC Transmission Systems (FACTS) [1-8]

These controllers use local signals as an input signal and may not always be able to damp out inert-area oscillations, main cause behind this, the design of PSS based on system components linearization around one operating point. Also local controller have not global observation and may does not be effectively damped out the inter-area oscillation. The loads are varies in infinite way so in each condition operating point also changes hence it is not possible to design a controller at one particular operating condition. In resent year nonlinear control techniques gain more attention and it is applied to the power system.

To design PSS, there are several linear and non-linear methods are reported in [9]. Different types of intelligent technique are used as PSSs and successfully applied in improving the power system stability like Neural Network [10-12], Fuzzy login controllers [13-16] and hybrid neuro-fuzzy controllers. Many researcher have applied different types of optimization technique like Genetic Algorithm (GA), Particle Swarm Optimization to find out the optimal value of tuning parameters of the Lead-Lag Compensator (LLC), Proportional-Integral-Derivative (PID controller and fuzzy logic controller to obtain improve results. It is well known fact that the LLC is the main component of CPSS and generally used to compensate the phase lag between the excitation voltage and electrical torque of the synchronous machine [15]. Selection of parameters for the compensator at different operating point is a challenging task. Some researchers proposed a simple PID controller in place of LLC to perform the same task. Also tuning of PID parameters for different condition is difficult.

Fuzzy controllers are mostly used for the system which are complex and mathematically ill define. It is applied almost all areas of power system problem. Development of fuzzy logic based power system stabilizer to assure system stability and enhance the performance of a power system is described in this paper. Generally the fuzzy logic based PSS used speed deviation and its derivative i.e. acceleration as their input signals.

This paper is structured as follows: Section II presents the brief review study power system. Section III describes the brief review on fuzzy logic system. Section IV discussed the proposed controlled method. Simulation results of the proposed controller & comparison are briefed in section V and finally the conclusion is presented in section VI.

II. STUDY POWER SYSTEM

Figure 1 shows the configuration of the study power system. This system consists of two areas connected by a weak tie-line. The 6[th] order generator model is used for each generator and is equipped with a 1st order AVR without PSS. The governor is a simple 1st order model.

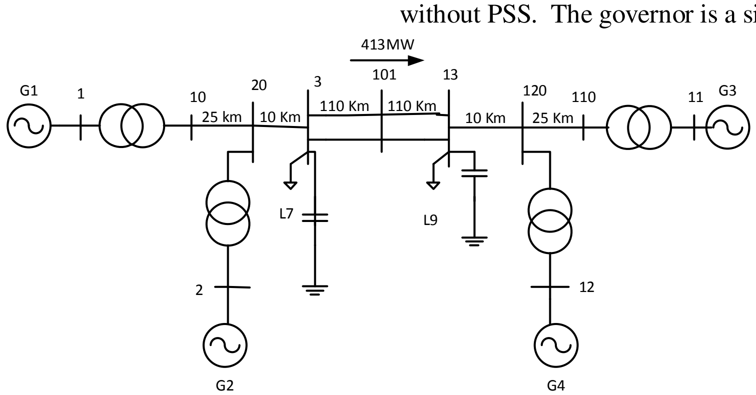

Fig. 1. Kundur two-area four-machine system.

III. BRIEF REVIEW ON FUZZY LOGIC SYSTEM

Fuzzy control systems are rule-based systems in which a set of 'fuzzy' rules represents a control decision mechanism to adjust the effects of certain system disturbances. Figure 2 illustrates the basic structure of a fuzzy logic controller with a fuzzification, inference mechanism, rule base & defuzzification [13]. The knowledge-based module contains knowledge about all the input and output fuzzy partitions [13].

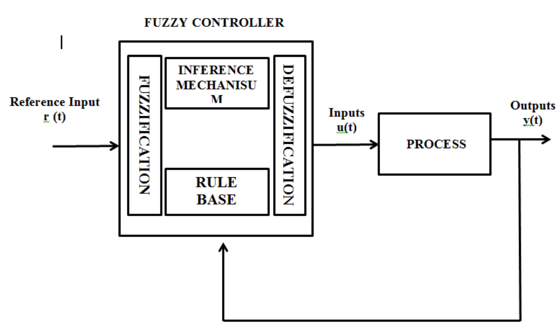

Fig. 2. Basic Structure of a Fuzzy Logic Controller.

The aim of fuzzy control systems is to replace a skilled human operator with a fuzzy rule based system. The fuzzy logic controller provides an algorithm to convert the linguistic control scheme (which is based on expert knowledge) into an automatic control scheme.

The fuzzy controller has following main components:
Fuzzification: The fuzzification is a process by which the crisp input control variables are transformed into fuzzy linguistic variables using normalized membership function.
Knowledge Base and Inference Mechanism: The fuzzy logic inference mechanism is the part responsible for deducing the proper control action based on available rule base. The knowledge base includes the definition of the fuzzy membership function defined for each control variable and the required rules that determine the control action using linguistic variables. It enables the controller to map the input fuzzy sets to the output fuzzy sets through control rules in the form of IF-THEN statements. This part of control design allows for incorporating the human experience in the design process as some of these rules can be derived based on past experience, knowledge acquired through off-line simulation, understanding of dynamics of the involved system and common sense engineering judgment. The required number of control rules depends on the number of linguistic variables being assigned to each input variables.
Defuzzification: The defuzzification is a process by which the fuzzy linguistics output control action is transformed into proper crisp values using normalized membership function.

IV. PROPOSED CONTROL METHOD

Figure-3 shows a damping controller structure which is basically used to control the voltage injected (V_q) of SSSC by fuzzy controller. The change in speed deviation of G-2 w.r.t G-4 and tie-line active power are considered to be the input of the fuzzy controllers. The output of the fuzzy controller will be supplementary stabilizing signal applied to V_{qref} of SSSC which is connected with main tie-line of the proposed power system.

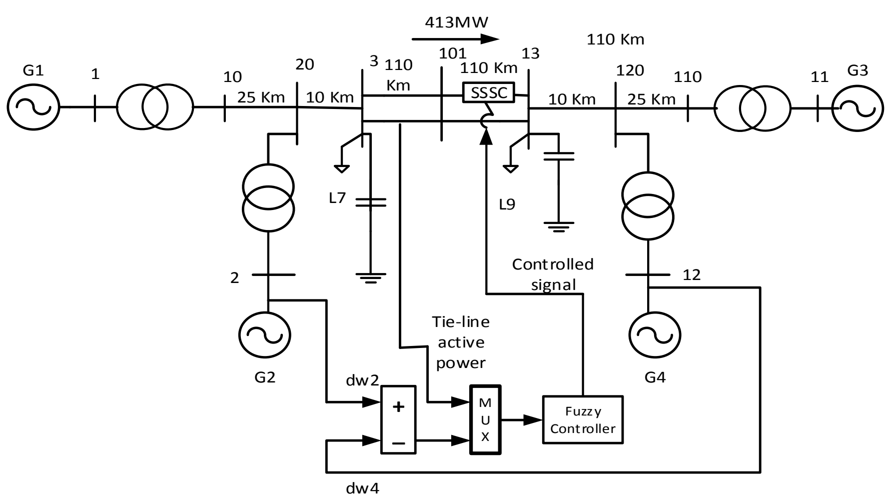

Fig. 3. Two-area four-machine interconnected power system with a SSSC installed in series with the transmission line.

To design the rule base for the fuzzy controller seven membership functions are taken for each speed deviation, tie-line active power deviation and controlled voltage. Total 49 rules bases have been designed for the optimal performance of the proposed controller which is shown in table-1. For the design of FLPSS, the max-min composition method is used for interface, centroid method for defuzzification purpose. The triangular membership is used for input, output and controlled voltage. The linguistic variables are, NL (Negative Large), NM (Negative Medium), NS (Negative Small), ZE (Zero), PS (Positive Small), PM (Positive Medium) and PL (Positive Large).
The details of rule base that are used in this paper are as follows [16]
Rule-1: IF speed deviation is negative large (NL) AND tie line active power deviation is Negative Large (NL) THEN output of fuzzy controller is Negative Large (NL).
Similarly the Rule-7: IF speed deviation is Negative Large (NL) AND tie line active power deviation is Positive Large (PL) THEN output of fuzzy controller is Zero (ZE).

Table 1: Rule Base for Proposed Type-1 FLC.

Speed Deviation (PU) (-0.005 to 0.005)	Tie-line active power Deviation (PU) (-0.4 to 0.4)						
	NL	**NM**	**NS**	**ZE**	**PS**	**PM**	**PL**
	PSS(-0.15 to 0.15) (PU)						
NL	NL	NL	NL	NL	NM	NS	ZE
NM	NL	NL	NM	NM	NS	ZE	PS
NS	NL	NM	NM	NS	ZE	PS	PM
ZE	NM	NM	NS	ZE	PS	PM	PM
PS	NM	NS	ZE	PS	PM	PM	PL
PM	NS	ZE	PS	PM	PM	PL	PL
PL	ZE	PS	PM	PL	PL	PL	PL

IV. SIMULATION RESULTS AND COMPARISON

To perform the dynamic analysis of the closed loop test system for Kundur two area four machine system as shown in figure 3, a small pulse with magnitude of 5% as a disturbance was applied to the generator G1 for 12 cycles. The simulation time was of 20 seconds. Then the response of tie-line active power flow from area-1 to area-2, rotor mechanical angle, bus voltage and rotor speed deviation are examined by considering the test system with proposed controller.

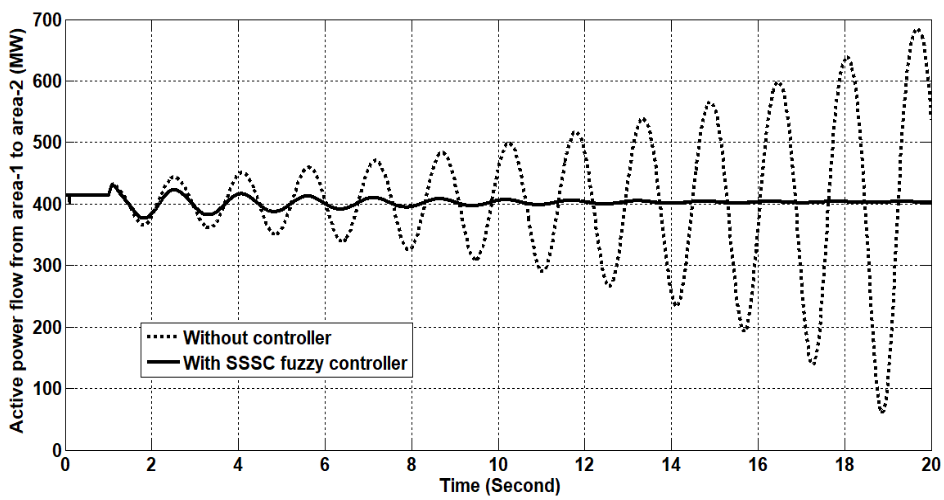

Fig. 4. Tie-Line Active Power Flow.

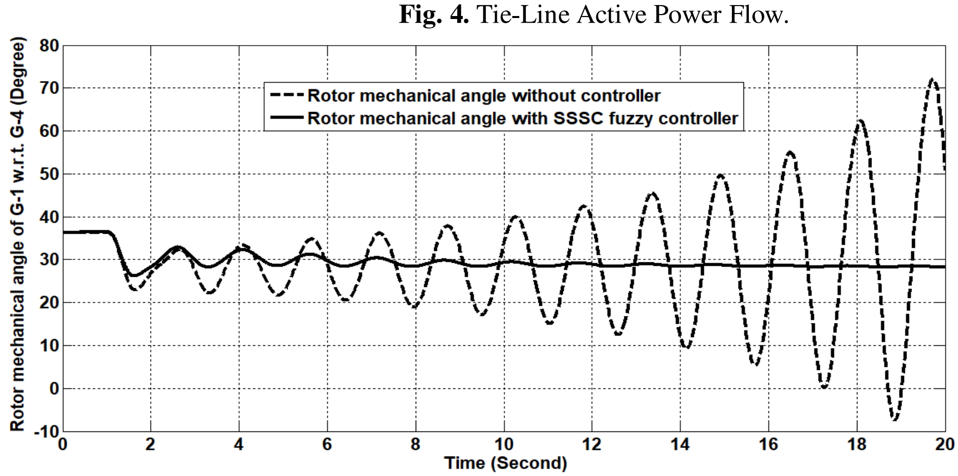

Fig. 5. Rotor Mechanical angle of G-1 w.r.t. G-4.

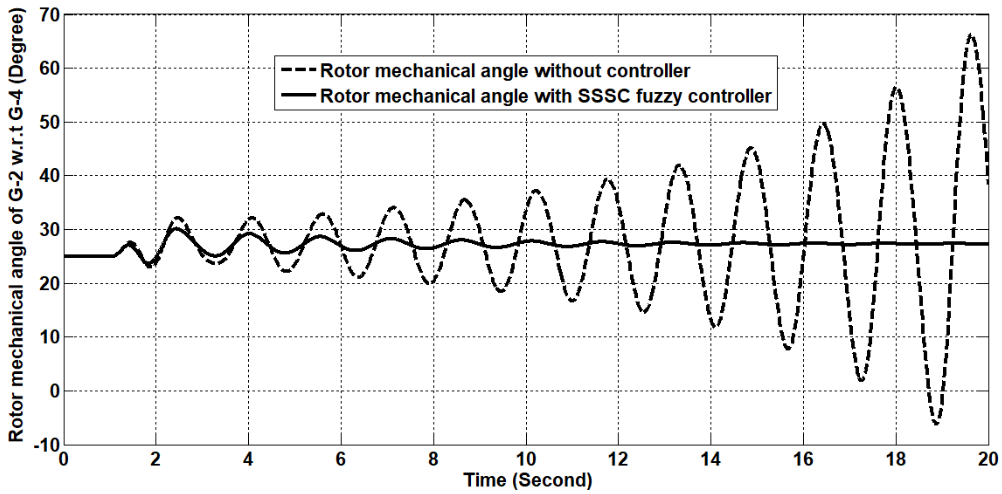

Fig. 6. Rotor Mechanical angle of G-2 w.r.t. G-4.

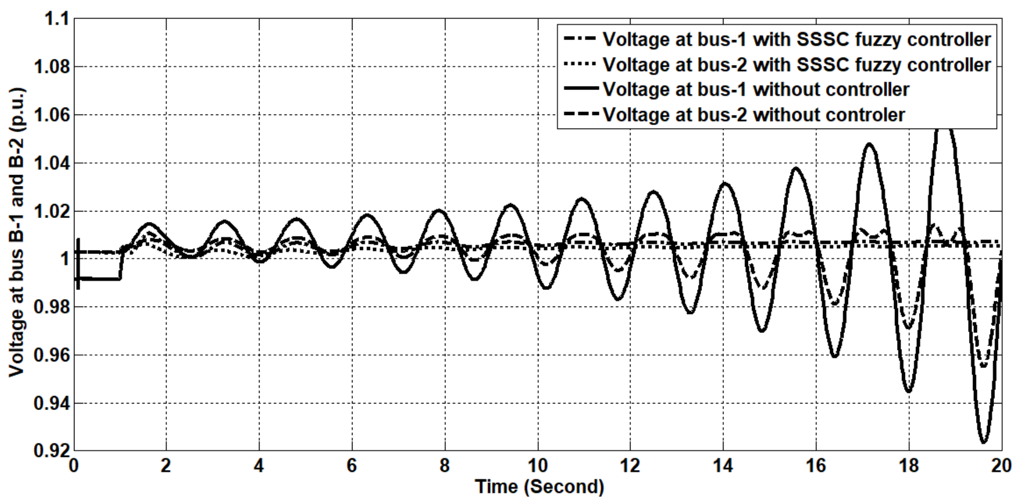

Fig. 7. Bus voltage at bus-3 & bus-13.

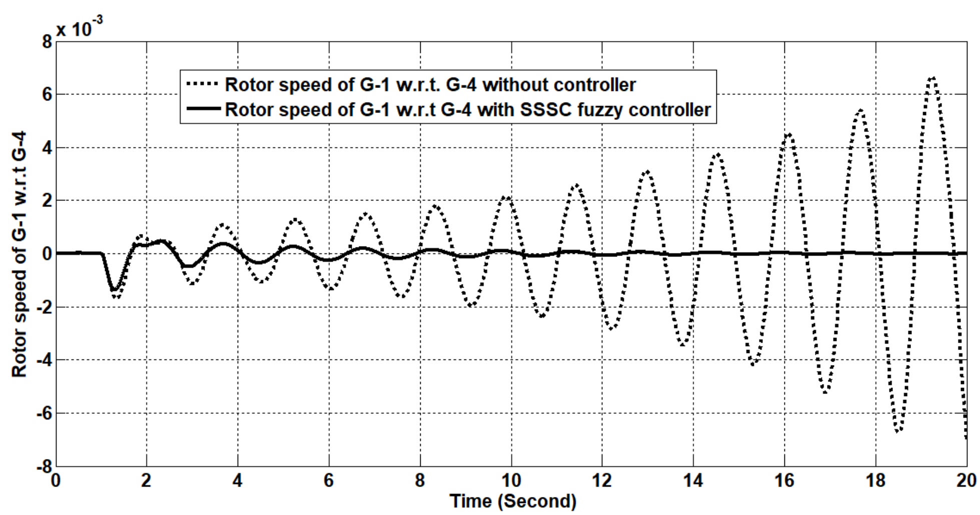

Fig. 8. Rotor speed deviation of G-1 w.r.t. G-4.

V. CONCLUSION

In this paper researcher designed a wide-area damping controller to damp out the inter-area oscillations in a large scale power system using SSSC based on fuzzy logic system. Some simulation results are carried out to verify the effectiveness of proposed controller under small disturbance. From the simulation results, it reveals that the proposed controller damps out the inter-area oscillations effectively.

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