International Journal of Scientific & Engineering Research, Volume 5, Issue 8,August-2014
ISSN 2229-5518

Comparison various UPFC based Damping Controller for low frequency oscillation

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Abstract— In this paper we have compare various UPFC based Damping controller for low frequency oscillations. We know power system is combination of generation, transmission and distribution. It is a very large network and low frequency oscillation occurrences due to loss of synchronisum, breaking of conductors. These low frequency oscillations also affected the system stability. Here we design a fuzzy logic based damping controller and phase compensation technique based damping controller for minimizing such low frequency oscillations as well as enhance system stability.comparision is done with the help of simulink.

Index Terms— Stability, Steady State Stability, Transient Stability, Facts, UPFC, Phase Compensation Technique, fuzzy logic

1 Introduction

Successful operation of a power system depends largely on the Engineer's ability to provide reliable and uninterrupted service to the loads. The reliability of the power supply implies much more than merely being available.

The first requirement of reliable service is to keep the synchronous generators running in parallel and with adequate capacity to meet the load demand.

A second requirement of reliable electrical service is to maintain the integrity of the power network. The high-voltage transmission system connects the generating stations and the load centres. Interruptions in this network may hinder the flow of power to the load.

Synchronism frequently may be lost in that transition period, or growing oscillations may occur over a transmission line, eventually leading to its tripping. These problems must be studied by the power system engineer and fall under the heading power system stability

2 STABILITY

The tendency of a power system to develop restoring forces equal to or greater than the disturbing forces to maintain the state of equilibrium is known as "Stability" [2].

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The problem of interest is one where a power system operating under a steady load condition is perturbed, causing the readjustment of the Voltage angles of the synchronous machines. If such an occurrence creates an unbalance between the system generation and load, it results in the establishment of a new steady-state operating condition, with the subsequent adjustment of the voltage angles. The perturbation could be a major disturbance such as the loss of a generator, a fault or the loss of a line, or a combination of such events. It could also be a small load or random load changes occurring under normal operating conditions. Adjustment to the new operating condition is called the transient period. The system behaviour during this time is called the dynamic system performance, which is of concern in defining system stability. The main criterion for stability is that the synchronous machines maintain synchronism at the end of the transient period. So we can say that if the oscillatory response of a power system during the transient period following a disturbance is damped and the system settles in a finite time to a new steady operating condition, we say the system is stable. If the system is not stable, it is considered unstable. This primitive definition of stability requires that the system oscillations be damped. This condition is sometimes called asymptotic stability and means that the system contains inherent forces that tend to reduce oscillations.

2.2 STEADY STATE STABILITY

Small signal stability is the ability of power system to maintain synchronous operation under small disturbances. In large power system, small signal stability problems may be either local or global in nature. Local modes are associated with the oscillations of generating units at a particular station with respect to the rest of system; these oscillations are localized in a small part of power system. Global modes are associated with the oscillations of many machines in one part of the system against machines in the other parts; these oscillations are also called inter-area mode oscillation [3]. In an interconnected power system, the rotors of each synchronous machine in the system rotate at the same average electrical speed. The power delivered by the generator to the power system is equal to the mechanical power applied by the prime mover, neglecting losses. During steady state operation, the electrical power out balances the mechanical power in. The mechanical power input to the shaft from the prime mover is the product of torque and speed, PM= TM ω. The mechanical torque is in the direction of rotation. An electrical torque is applied to the shaft by the generator and is in a direction opposite of rotation as seen in Figure 1.1 below

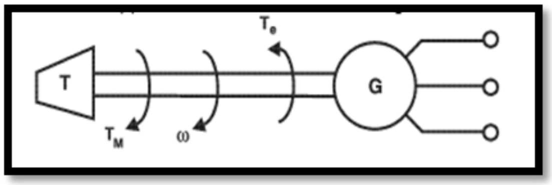

Fig.1: Mechanical and Electrical Torque Applied to the Shaft

2.2 TRANSIENT STABILITY

Transient stability is the ability of the power system to maintain synchronism when subjected to a severe transient disturbance [2]. The resulting system response involves large excursions of generator rotor angles and is influenced by the non linear power angle relationship. Stability depends on both the initial operating state of the system and severity of the disturbance. Usually the system is altered so that the post disturbance steady state operation differs from that prior to the disturbance.

2.3 FACTS

The rapid development of power electronics technology provides exciting opportunities to develop new power system equipment for better utilization of existing systems [5]. A number of control devices under the term FACTS technology have been proposed and implemented. Applications of this technology started with the Static Var Compensator (SVC) since 1970 and were followed by the Thyristor Controlled Series Compensator (TCSC). Then advances in power electronics devices allowed the use of the second generation of FACTS devices based on the self-commutated Voltage-Sourced Converter (VSC) using Gate-Turn-Off thyristor technology. It includes the Static synchronous Compensator (STATCOM), Static Synchronous Series Compensator (SSSC), VSC-based Static Phase Shifter (SPS), Unified Power Flow Controller (UPFC) and Interline Power Flow Controller (IPFC).FACTS are utilized for accomplishing the following objectives [6]:

1. Increase / control of power transmission capacity in a line, and for preventing loop flows.
2. Improvement of system transient stability limit.
3. Enhancement of system damping.
4. Mitigation of sub synchronous resonance.
5. Alleviation of voltage instability.
6. Limiting short circuit currents.
7. Improvement of HVDC converter terminal performance.

Thyristor Based FACTS Controllers
a) Static Var Compensator (SVC)
b) Thyristor Controlled Series Compensator (TCSC)

Voltage Source Converter (VSC) Based Controllers
a) Static Synchronous Compensator (STATCOM)
b) Static Synchronous Series Compensator (SSSC)
c) Unified Power Flow Controller (UPFC)

3 UNIFIED POWER FLOW CONTROLLER

The Unified Power Flow Controller (UPFC) concept was proposed by Gyugi in 1991. The UPFC was devised for the real-time control and dynamic compensation of ac transmission systems, providing multifunctional flexibility required to solve many the problems facing the power delivery industry. Within the framework of traditional power transmission concepts, the UPFC is able to control, simultaneously or selectively all the parameters affecting power flow in the transmission line (i.e. voltage, impedance, and phase angle), and this unique capability is signified by the adjective “unified” in its name. Alternatively, it can independently control both the real and reactive power flow in the line [8].

3.1 BASIC OPERATING PRINCIPLES

UPFC consists of two voltage sourced converters, as illustrated in Figure3.1. These back to back converters, converter 1 i.e. VSC-E and converter 2 i.e. VSC-B, are operated from a common dc link provided by a dc storage capacitor.

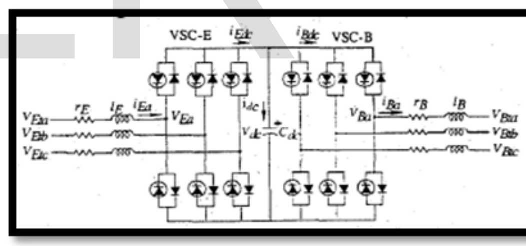

Fig.2: Detailed three phase UPFC circuit diagram

This arrangement functions as an ideal ac-to-ac power converter in which the real power can freely flow in either direction between the ac terminals of the two converters, and each converter can independently generate (or absorb) reactive power at its own ac output terminal [8].
VSC-B provides the main function of the UPFC by injecting a voltage Vpq with a controllable magnitude Vpq and phase angle ϱ in series with the line via an insertion transformer. This injected voltage acts essentially as a synchronous ac voltage source. The transmission line current flows through this voltage source resulting in reactive power exchange between it and the ac system. The reactive power exchanged at the ac terminal (i.e., at the terminal of the series insertion transformer) is generated internally by the Converter. The real power exchanged at

ISSN 2229-5518

the ac terminal is converted into dc power which appears at the dc link as a positive or negative real power demand.

The basic operation of VSC-E is to supply or absorb the real power demanded by VSC-B at the common dc link to support the real power exchange resulting from the series voltage injection. This dc link power demand of VSC- B is converted back to ac by VSC-E and coupled to the transmission line bus via a shunt connected transformer. In addition to the real power need of VSC-B, VSC-E can also generate or absorb controllable reactive power, if it is desired, and thereby provide independent shunt reactive compensation for the line

4. PHASE COMPENSATION TECHNIQUE

The ability of the UPFC to rapidly inject an ac compensating voltage Phasor with variable magnitude and angle in series with the line when needed, bestow it with superior operating characteristics. When equipped with suitable primary controllers, the UPFC can not only establish an operating point with a wide range of possible P and Q flows on the line, but also rapidly displace that operating point to another position.

A secondary control, referred to as the damping controller, is a supplementary control loop that is designed to improve transient stability of the electric power system. Low frequency oscillations in electrical power system occur frequently due to disturbances such as changes in loading conditions or a loss of a transmission line or a generating unit. These oscillations need to be controlled to maintain system stability. Several control devices such as power system stabilizers, are used to enhance power system stability. It has been show that the UPFC can also be used to effectively control these low frequency power system oscillations [13]. Recently it has shown that oscillations can be damped by introducing a supplementary signal, based on the real power flow along the transmission line, to the series converter side through the modulation of the active power flow reference signal.

4.1 STRUTURE OF UPFC BASED DAMPING CONTROLLER USING PHASE COMPENSATION TECHNIQUE

The structure of UPFC based damping controller is shown in Figure 1.3. It consists of gain, signal washout and phase compensator blocks. The parameters of the damping controller are obtained using the phase compensation technique [14]. The signal washout is the high pass filter that prevents steady changes in the speed from modifying the UPFC input parameter. The value of the washout time constant Tw should be high enough to allow signals associated with oscillations in rotor speed to pass unchanged. From the viewpoint of the washout function, the value of Tw is not critical and may be in the range of 1s to 20s. Tw equal to 10s is chosen in the present studies

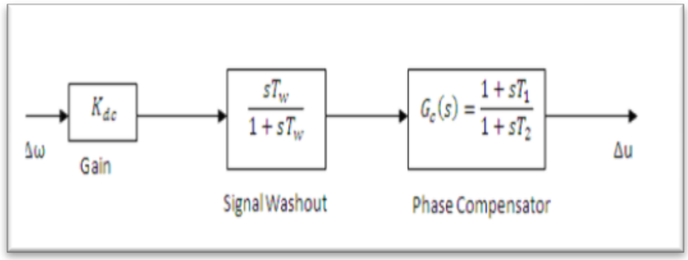

Fig: 3 Structure of UPFC based damping controller

5. FUZZY LOGIC CONTROLLER

Fuzzy logic is a derivative from classical Boolean logic and implements soft linguistic variables on a continuous range of truth values to be defined between conventional binary i.e. [0, 1]. It can often be considered a subset of conventional set theory [21]. The fuzzy logic is capable to handle approximate information in a systematic way and therefore it is suited for controlling non-linear systems and for modelling complex systems where an inexact model exists or systems where ambiguity or vagueness is common. It is advantageous to use fuzzy logic in cont roller design due to the following reasons:

1. A simpler and faster methodology.
2. It reduces the design development cycle.
3. It simplifies design complexity.
4. An alternative solution to non-linear control.
5. Improves the control performance.
6. Simple to implement
7. Reduces hardware cost

A typical fuzzy system consists of a rule base, membership functions and an inference procedure which are explained in the following sections.

The fuzzy control systems are rule-based systems in which a set of fuzzy rules represent a control decision mechanism to adjust the effects of certain system stimuli. With an effective rule base, the fuzzy control systems can replace a skilled human operator. The fuzzy logic controller provides an algorithm which can convert the linguistic control strategy based on expert knowledge into an automatic control strategy. Figure 7.1 illustrates the schematic design of a fuzzy logic controller which consists of a fuzzification interface, a knowledge base, decision making logic, and a defuzzification interface.

In fuzzification the value of input variables are measured, scale mapping that transfers the range of values of input variables into corresponding universe of discourse is performed; it performs the function of fuzzification that converts input data into suitable linguistic values which may be viewed as label fuzzy sets. The knowledge base comprises knowledge of application domain and attendant control goals. It consists

ISSN 2229-5518

of a database and linguistic control rule base. The database provides the necessary definitions, which are used to define linguistic control rules and fuzzy data manipulation in an FLC. The rule base characterizes the control goals and control policy of domain experts by means of set of linguistic control rules. The decision making logic has the capability of simulating human decision making based on fuzzy concepts. The defuzzification performs scale mapping, which converts the range of values of output variables into corresponding universe of discourse, yielding a non-fuzzy control action from an inferred control action. The different methods of defuzzification are max criterion method, mean of maxima method and centroid method.

5.1 CONTROLLER DESIGN PROCEDURE

The fuzzy logic controller (FLC) design consists of the following steps:

1) Identification of input and output variables.
2) Construction of control rules.
3) Establishing the approach for describing system state in terms of fuzzy sets, i.e. establishing fuzzification method and fuzzy membership functions.
4) Selection of the compositional rule of inference.
5) Defuzzification method, i.e., transformation of the fuzzy control statement into specific control actions.

The above steps are explained with reference to fuzzy logic based UPFC damping controller in the following section. This helps understand these steps more objectively.

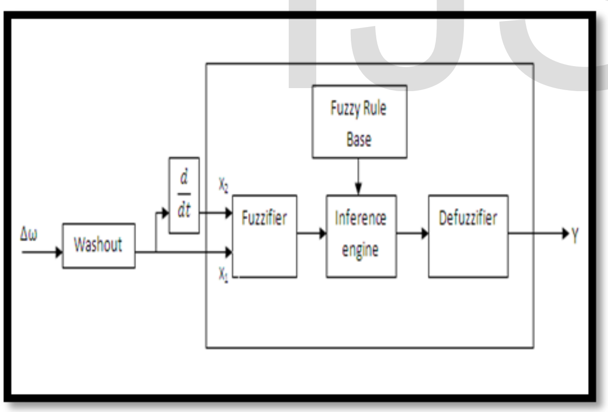

Fig.4: Fuzzy logic based UPFC damping controller

Table1: Membership Functions for Fuzzy Variable

S.NO		Membership function
1	NB	Negative Big
2	NM	Negative Medium
3	NS	Negative Small
4	ZE	Zero
5	PS	Positive Small
6	PM	Positive Medium
7	PB	Positive Big

The variables are normalized by multiplying with respective gains Kin1, Kin2, Kout so that their value lies between -1 and 1. The membership functions of the input output variables have 50% overlap between adjacent fuzzy subsets. The membership function for acceleration, speed and damping signal are shown in Figure 6.3 [23].

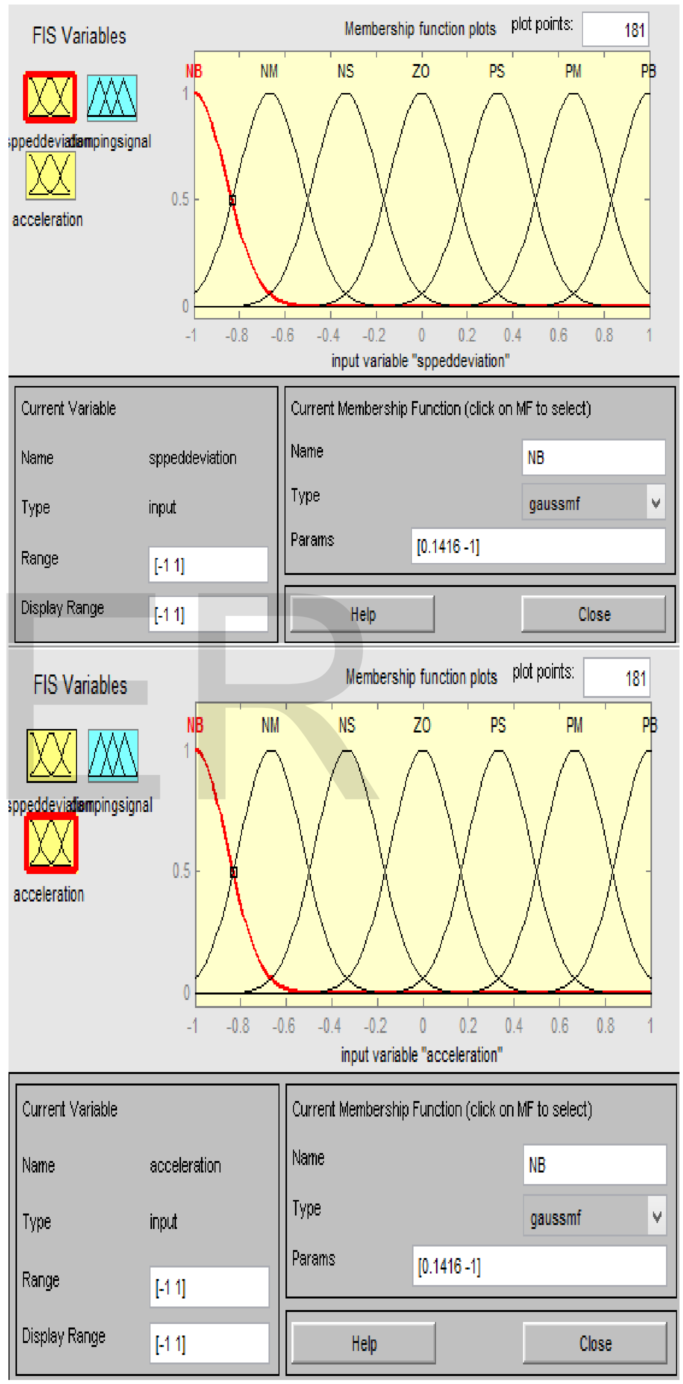

Fig.5: Membership function (input)

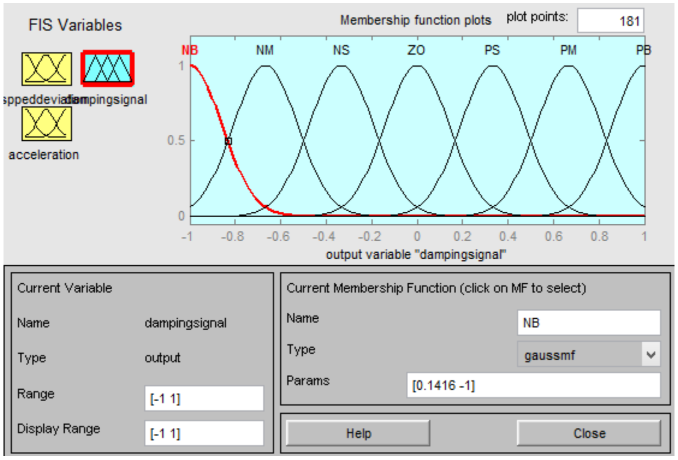

Fig.6: Membership function (output)

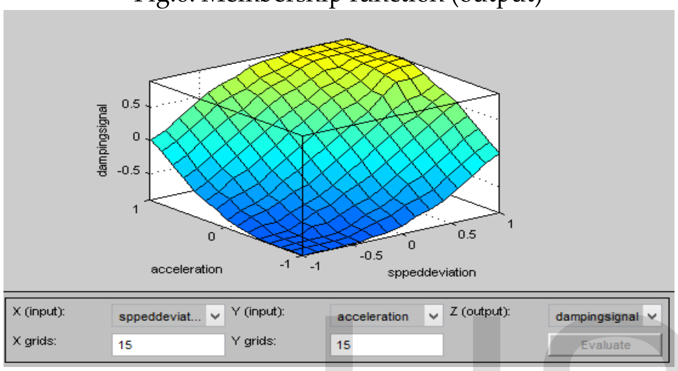

Fig.7: Surface View

6 SIMULATIONS AND RESULT

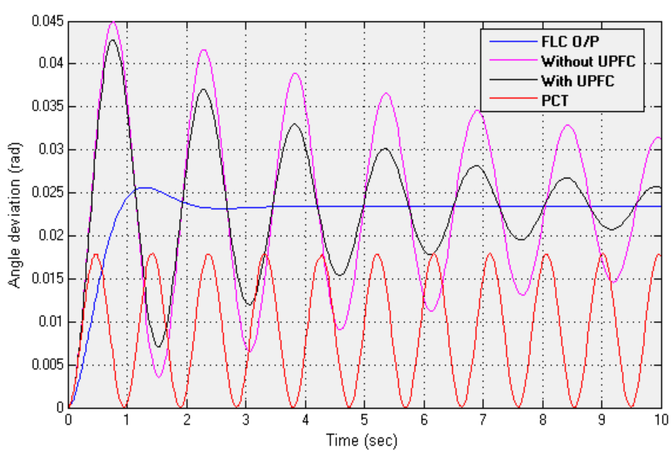

Fig.8: Response of SMIB system without UPFC, with UPFC, Phase compensation based, Fuzzy Logic Based Damping Controller

CONCLUSION

As per graphical representation shown in fig 8.Blue line shows quit stable system in comparison with black, red, and pink lines. Blue line shows response of a system based on fuzzy logic which other shows response of phase compensation technique, UPFC, without UPFC. From the above Fuzzy logic based damping controller is superior as compare to other technique based damping controller.

ACKNOWLEDGMENT

Author thanks to the Department of Electrical Engineering, AIET, Faridkot for their supports and encourgement.

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