A Comparative Study of IPFC Based Low Frequency Multimachine Power System

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Abstract - The power system design, high efficiency operation and reliability of the power systems have been considered more than before. Due to the growth in consuming electrical energy, the maximum capacity of the transmission lines should be increased. Therefore in a normal condition also the stability as well as the security is the major part of discussion. Several years the power system stabilizer act as a common control approach to damp the system oscillations. The fundamental cause of this kind of oscillation is the generation of negative damping by some components, which cancels out the inherent positive damping of the system and therefore causes very light or even negative system damping. This phenomenon is more likely to happen in some specially structured systems, for example, a weak interconnection between two regional systems, or a power plant connected to a load center over a long geographical distance. Power system engineers and research scholars have been working on this important issue since the 1960's and have performed various theoretical studies and experiment on it. However, research on this issue remains active because of the complexity of the problem and the advent of new control techniques and new fast- response devices not available when the problem was first studied. An extensive review on the following issue has been presented in this work.

Keywords- Damping Controller, Multimachine Power System, IPFC, UPFC, Fuzzy Logic.

I. INTRODUCTION

The available power generating plants are often located at distant locations for economic, environmental and safety reasons. For instance, it becomes cheaper to install a thermal power station at pit-head instead of transporting coal to load centers. Hydro power is generally available in remote areas and a nuclear plant may be located at a place away from urban areas. Additionally, modern power systems are highly interconnected. Sharing of generation reserves, exploiting load diversity and economy gained from the use of large efficient units without sacrificing reliability are the advantages of interconnection. Thus power must consequently be transmitted over long distances. To meet the load and electric market demands, new lines should be added to the system, but due to environmental reasons, the installation of electric power transmission lines are often restricted. Hence, the utilities are forced to rely on already existing infra-structure instead of building new transmission lines. In order to maximize the efficiency of generation, transmission and distribution of electric power, the transmission networks are very often pushed to their physical limits, where outage of lines or other equipment could result in the rapid failure of the entire system.

The power system may be thought of as a nonlinear system with many lightly damped electromechanical modes of oscillation. The three modes of electromechanical oscillations are:

1. Local plant mode oscillations
2. Inter-area mode oscillations
3. Torsional modes between rotating plant

In local mode, one generator swings against the rest of the system at 1.0 to 2.0 Hz. The impact of the oscillation is localized to the generator and the line connecting it to the grid. The rest of the system is normally modeled as a constant voltage source whose frequency is assumed to remain constant. This is known as the SIMB model.

Inter-area mode of oscillations is observed over a large part of the network. It involves two coherent groups of generators swinging against each other at 1Hz or less. This complex phenomenon involves many parts of the system with highly non-linear dynamic behavior. The damping characteristic of the inter-area mode is dictated by the tie-line strength, the nature of the loads and the power flow through the interconnection and the interaction of loads with the dynamics of generators and their associated controls.

Recent years lots of control devices are implemented under the FACTS technology. By implementing the FACTS devices gives the flexibility for voltage stability and regulation also the stability of the system by getting proper control signal [4].The FACTS devices are not a single but also collection of controllers which are efficiently not only work under the rated power, voltage, impedance, phase angle frequency but also under below the rated frequency. Among all FACTS devices the UPFC most popular controller due to its wide area control over power both active and reactive, it also gives the system to be used for its maximum thermal limit. It’s primarily duty to control both the powers independently. It has been shown that all three parameters that can affect the real power and reactive power in the power system can be simultaneously and independently controlled just by changing the control schemes from one type to other in UPFC.

For example, in it has been shown that the UPFC is capable of inter-area oscillation damping by means of straight controlling the UPFC's sending and receiving bus voltages. Therefore, the main aim of the UPFC is to control the active and reactive power flow through the transmission line with emulated reactance. It is widely accepted that the UPFC is not capable of damping the oscillations with its normal controller. As a result, the auxiliary damping controller should be supplemented to the normal control of UPFC in order to retrieve the oscillations and improve the system stability.

The SSSC, UPFC and IPFC FACTS devices are very promising devices in the FACTS controllers, concept. The need to distinguish the effects of the three FACTS controllers for TSE and control in the occurrence of disturbances like faults is critical since FACTS controllers have the ability to adjust the three control parameters, i.e. the bus voltage, transmission line reactance, and phase angle between two buses, either simultaneously or independently [7]. They perform this through the control of the in-phase voltage, quadrature voltage, and shunt compensation to improve voltage stability, steady state and transient stabilities of a complex interconnected power system [8, 9]. This property should be matched with other properties of FACTS like loss reduction and voltage stability for system planning and economic operation. These features have to be classified and each controller capabilities established.

II. FACTS DEVICES

A. FACTS System (FACTS):

It defined as AC transmission network integrating semiconductor based power electronic device as well as different stationary controllers to increase the capacity of power flow and also expand the controllability of the system.

B. FACTS Controller

It includes power electronic devices as well as other static devices with advance power electronic conversion and switching capability.

It is significant to describe that some other static device which is used as a controller are not belongs to the power electronic family but basically the used controller are thyristor devices. When there is use the FACTS as a reactive power controller they are provided with minimum storage at dc side. The general symbol for FACTS Controller is shown in Fig. 1.1a. FACTS Controllers are distributed into four groups.

1. Series FACTS Controllers.
2. Shunt FACTS Controllers.
3. Combined Series-Shunt FACTS Controllers.
4. Combined Series-Series FACTS Controllers.

i) Series FACTS Controllers: - These FACTS Controllers are inject the voltage series through the connected line , if this series injected voltage is in phase quadrature to the line current, the controller simply deliver or receives the variable reactive power which is illustrated in Fig. 1.1b. Other than the quadrature with injected voltage and line current the controller can involve itself for real power control.

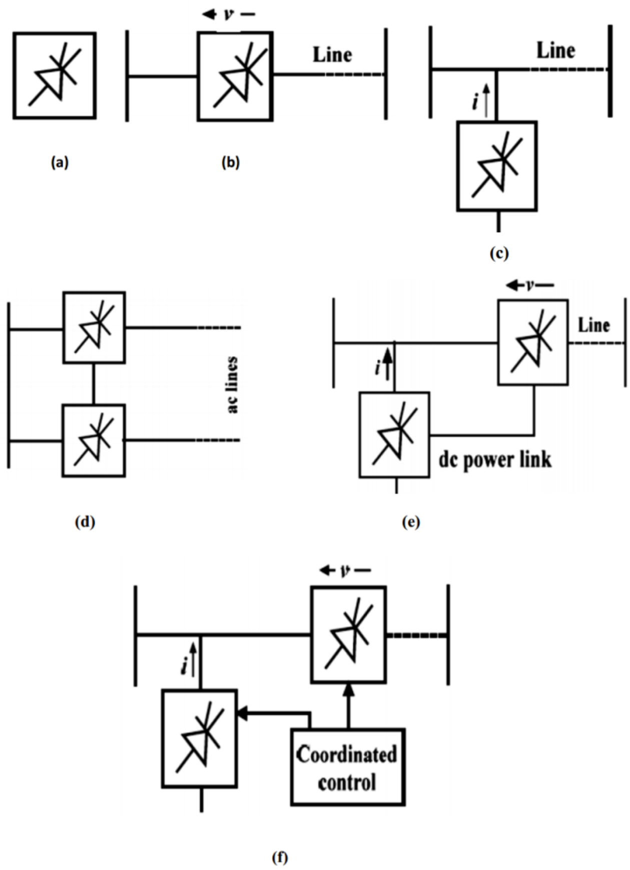

Figure 1.1 Schematic diagrams of FACTS Devices (a) Representation for FACTS Controller, (b) Representation of Series FACTS Controller, (c) Symbolic representation of shunt FACTS Controller, (d) Schematic of a series-series FACTS Controller, (e) organized series and shunt Controller, (f) unified series-shunt Controller

ii) Shunt FACTS Controllers: - The shunt FACTS Controllers have flexible impedance type i.e. reactor or capacitor adjustable source based on the power electronics , which is shunt connected to the line in order to inject variable current, as shown in Fig. 1.1c. Here up to which the current is injected to the line voltage with phase quadrature it deliveries or absorbs the reactive power to the system, other than that at any angle for voltage and current it well work for the real power flow.

iii) Combined Series-Series FACTS Controllers: -, as illustrated in Fig. 1.2d. This configuration provides autonomous series reactive power compensation for each line but also transfers real power among the lines via power link. The presence of power link between series controllers names this configuration as "Unified Series-Series Controller".

iv) Combined Series-Shunt FACTS Controllers: - These are arrangement of distinct arrangement of series and shunt controller and they connected in such way that the control of both is much synchronized manner (Fig. 1.1e) or a UPFC connected with series and shunt controller (Fig. 1.1f). The real or active power exchange is take place through the power dc link when these controllers are connected to each other and also with the line.

III. LITERATURE REVIEW

A. M. Parimi, I. Elamvazuthi, A. V. P. Kumar and V. Cherian [1] Mitigation of power system oscillations, within the frequency range of 0.1 to 2 Hz, is the problem of concern in the power industry as these oscillations, when exhibiting poor damping; affect the transmission line power transfer capability and power system stability. These low frequency oscillations greatly restrict power system operations and, in some cases, can also lead to widespread system disturbances. In this context, the Flexible AC Transmission System (FACTS) device, Interline Power Flow Controller (IPFC) employed to improve the transmission capability can be additionally utilized for damping control of power system oscillations. A fuzzy logic based IPFC damping controller is designed and compared with conventional damping controller to mitigate the low frequency oscillations for the mulitmachine power system. Case studies on three-machine nine-bus (IEEE WSCC) mulitmachine power system have been carried out in Matlab Simulink. The nonlinear simulation studies of the investigations conducted on the Multi-machine power systems installed with IPFC demonstrate that the control designs are effective in damping the power system oscillations.

P. S. A. Kumar, G. Radhakrishnan and V. Gopalakrishnan,[2] Power flow control and stability improvement of a transmission line connected with three energy sources for different loads are studied, in which Flexible AC Transmission system (FACTS) controllers are used to balance the power flow in transmission lines and increase the effective use of transmission line by improving stability of the power system. The Interline Power Flow Controller is the FACTS device used, it consists of static synchronous series compensator to reduce low frequency oscillation, and damping produced is reduced by designing an oscillation damping controller. Among the three sources of energy to transmission line one is considered as renewable wind farm that are capable of producing 9MW power. A Simulink system is developed for the proposed system and the output waveforms are analyzed for various parameters such as voltage, real and reactive power.

G. Nithya, D. Jananisri and M. Sowjanya, [3] In this exploration work, operation of IPFC is analysed in transmission line power flow control IPFC is used for controlling transmission line voltage, flow of power, decreasing power losses, and decreases the amplitude of an oscillation while transferring power. This work deals with finding the location and optimal placement of interline power flow controller to maintain the voltage profile, active and reactive power flow in transmission line in power system to obtain the maximum possible benefit of power transfer and system stability.

S. Sharma, S. Kulkarni, A. Maksud, S. R. Wagh and N. M. Singh,[4] The crucial issue of loss of synchronization in post-disturbance conditions may lead to blackouts if corrective action is delayed. The complication increases due to large computation burden and time for wide-area network where thyristor-controlled series compensator (TCSC) is used as controller for transient stability enhancement. The trade-off in accuracy and speed in generating control law using linearized models becomes ineffective for changed operating scenarios. In addition, forming multi-machine linearized model becomes challenging when TCSC appears as non-separable element of a dense admittance matrix, which can be separated as a control variable in single-machine infinite-bus system. Overcoming the limitations of linearized controllers, the present exploration verifies the Kuramoto mean-field condition using Kron reduction with non-trivial transfer conductances for unstable post-fault scenario. To regain synchronization effectively, necessary TCSC compensation has adjusted network parameters as proved by MATLAB simulations performed on 12-bus system, where real-time data is acquired by phasor measurement units.

H. Rtibi, S. Elloumi and N. Benhadj Braiek,[5] In this exploration, there are investigate the problem of the decentralized robust stabilizing control approach and mainly the decentralized robust guaranteed cost control for robust stabilization of interconnected multimachine power systems. The proposed feedback control schemes are developed to ensure the asymptotic stability of the nonlinear uncertain large scale system and formulated in a minimization problem within the framework of linear matrix inequalities (LMIs) which resolution yields the decentralized control gain matrices. The effectiveness of the proposed control techniques are demonstrated through numerical simulations on a nonlinear uncertain power system with three interconnected machines, for different cases of perturbations.

U. K. Soni,[6] This work introduces new technique named Reference Voltage Compensation in conjunction with STATCOM based on Proportional Integral and Derivative control action which reduces much the transient peak and settling time of the voltage and reactive power output which were still present after application of the statcom. In this work the proposed PID based Reference Voltage compensation has been used to damp out the oscillations of multi-machine power system and regulate the bus voltage at which the STATCOM is connected and maintain the reactive power. The results found for the cases without STATCOM, with STATCOM and STATCOM with RVC has been studied for various load capacities, various load switching timings and faults of different periods at various timings. It has been found that the RVC using PID control concept has proved to have an excellent performance over the other similar techniques in the improvement of power system stability by reducing settling time and peaks of transient oscillation due to faults and load switching and improving pf thereby increased system life.

Table 1: Summary if Literature Review

SR. NO.	TITLE	AUTHOR	YEAR	METHODOLOGY
1	Fuzzy logic based control for IPFC for damping low frequency oscillations in multimachine power system	A. M. Parimi, I. Elamvazuthi, A. V. P. Kumar and V. Cherian,	2015	The Flexible AC Transmission System (FACTS) device, Interline Power Flow Controller (IPFC) employed to improve the transmission capability can be additionally utilized for damping control of power system oscillations.
2	Stability improvement and power flow control of a grid connected offshore wind farm system using IPFC	P. S. A. Kumar, G. Radhakrishnan and V. Gopalakrishnan,	2014	The Interline Power Flow Controller is the FACTS device used
3	Performance assessment of IPFC in power transmission systems,	G. Nithya, D. Jananisri and M. Sowjanya,	2014	operation of IPFC is analysed in transmission line power flow control IPFC is used for controlling transmission line voltage
4	Transient stability assessment and synchronization of multimachine power system using Kuramoto model,	S. Sharma, S. Kulkarni, A. Maksud, S. R. Wagh and N. M. Singh,	2013	thyristor-controlled series compensator (TCSC) is used as controller for transient stability enhancement
5	Decentralized robust guaranteed cost control for multimachine power systems,	H. Rtibi, S. Elloumi and N. Benhadj Braiek,	2013	investigate the problem of the decentralized robust stabilizing control approach
6	Power quality improvement using PID based Reference Voltage Compensation with STATCOM,	U. K. Soni,	2013	introduces new technique named Reference Voltage Compensation in conjunction with STATCOM based on Proportional Integral and Derivative control action
7	Optimal coordinate control of PSS with series and shunt FACTS stabilizers for damping power oscillations,	R. Narne and P. C. Panda,	2012	The coordinated tuning of shunt and series flexible AC transmission systems (FACTS) damping controllers with power system stabilizer (PSS) is presented

R. Narne and P. C. Panda, [7] The coordinated tuning of shunt and series flexible AC transmission systems (FACTS) damping controllers with power system stabilizer (PSS) is presented. Here static var compensator (SVC) and static synchronous series compensator (SSSC) based controllers are coordinated with PSS to enhance the damping of power system oscillations. The design of proposed damping controller under different loading conditions is formulated as an eigen value based optimization problem. The controller gains of a linearized power system with proposed controller are optimized using genetic algorithm (GA). The test power system employed with PSS, SVC and SSSC. Finally, the proposed coordinated controller performance is tested with both eigen value analysis and time domain simulations. The simulation results of three different control schemes employed on the test system are compared. Efficient damping under different loading conditions is obtained by employing the proposed coordinated controller.

IV. PROBLEM STATEMENT

Power systems over the worldwide becoming complex day to day and continuous requirements are coming for stable, secured, controlled, economic and better quality power. These requirements become more essential when environment becoming more vital and important deregulation. Power transfer capacity in transmission system is limited due to various factors such as transient and steady state stability, thermal limit, damping of the connected system. The consequence of the degree of various parameters limit are given the electrical damping of power system require to be mitigate to steady oscillations allowed Power transmission. FACTS System and Distributed Flexible AC Transmission System provides feasible and cost-effective solution to these problems and so these devices are required to use worldwide for improving performance of power systems.

V. CONCLUSION

In this work an extensive review on various methodologies and schemes utilized for power control has been presented. The main advantage of traditional techniques of designing linear controllers for damping purposes is that, generally, they will yield better performance at the operating points for which they are designed. However, they may suffer the drawback that once the operating point drifts from those expected, their performance deteriorates. Fuzzy logic can be used to bring adaptiveness to stabilizers so that optimality is not sacrificed as a cost for robustness. The situation for FACTS devices-based controllers is fairly different from the PSS case. While FACTS devices enjoy their faster response time, they often lack direct access to generator speed signals. Although individual compensations differ, all the three FACTS devices not only damp the system oscillations of the multimachine system but also reduce the oscillations transient periods accordingly.

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