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Optimal Power Flow Control for Congestion Management by Interline Power Flow Controller

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ABSTRACT: In a deregulated electricity market it may at times become difficult to dispatch all the required power that is scheduled to flow due to congestion in transmission lines. An Interline Power Flow Controller (IPFC) can be used to reduce the system loss and power flow in the heavily loaded line, improve stability and loadability of the system. This paper proposes a Disparity Line Utilization Factor for the optimal placement and Fuzzy-Neural Network based optimal tuning of IPFC to control the congestion in transmission lines. In general, a sample test power system without FACTS devices has generated more reactive power, decreased real power, more harmonics, small power factor and poor dynamic performance under line and load variations. In order to improve the real power, compensating the reactive power, proficient power factor and excellent load voltage regulation in the sample test power system, an Power Flow Controller is designed. The D-Q technique is utilized here to derive the reference current of the converter and its D.C link capacitor voltage is regulated. Also, the reference voltage of the inverter is arrived by park transformation technique and its load voltage is controlled. Here, a sample test power system is taken for study. Further as the conventional PI controllers are designed at one nominal operating point they are not competent to respond satisfactorily in dynamic operating conditions. This can be circumvented by a Fuzzy and Neural network based power flow controller and its detailed Simulink model is developed using MATLAB and the overall performance analysis is carried out under different operating state of affairs.

KEY WORDS: Flexible AC Transmission System, Interline Power Flow Controller, Fuzzy Logic, Power quality

I. INTRODUCTION

In this current scenario the transmission systems are being strapped closer to their thermal limits while focus on the quality of power delivered is greater than ever. Electrical energy demands rise, progressive interlinking is taking place on a continental level and leads to heavily stressed power systems. Unwittingly the transmission network has the challenge to deliver bulk electric power continuously in prompt power quality and hence transmission congestion problems arise. The potential problems are further aggravated by delicate and sensitive loads due to industrialization and urbanization of life style. In contradiction of this background there is a growing need for constructing new transmission lines and additional power generation units.

In order to maximize the capacity and increase the controllability, deregulation of power systems around the world is anticipated. But environmental lawmaking, rights of ways issues and deregulation policies hinder the construction of new transmission lines. To rectify such troubles, embedding Flexible Alternating Current Transmission System (FACTS) controllers in power system play a vital role and may offer proficient control with safe working conditions. Among all other the converter based series FACTS controllers, the Interline Power Flow Controller (IPFC) can provide good solution for congestion management in a multiline power system.

II. ISSUES IN POWER SYSTEM

In the past three decades Power System Stabilizers (PSS) have been extensively used to improve the system stability. Basically power system stability is the ability of an electric power system, for a given initial operating condition, to regain a state of operating equilibrium after being subjected to a physical disturbance, most system variables bounded practically and the entire system remains intact. In the case of reactive power compensation, capacitor bank/ series compensators were used but at the same time which increases the line voltage drops. Hence influences load flow in parallel lines and increases system stability. But, once the capacitor is damaged then the entire power flow scheme is

interrupted and so the maintenance is difficult. Another important limitation of PSS is that it can damp out local oscillations and not inter area modes of oscillations. In addition, it can cause great changes in the voltage profile under severe disturbances and they may result in leading power factor operation and losing system stability. In this context, during 1986 the vision of FACTS is formulated in the Electric Power Research Institute (EPRI) to increase transmission capacity and power flow control of the transmission lines. In the general expression to make it electronically controllable, the FACTS concept is based on the substantial incorporation of power electronic devices and methods into the high voltage side of the network (IEEE/CIGRE, 1995). The main objectives of the FACTS are enhancement of Available Transmittable Capacity (ATC), to improve power flow in a selective line and mitigate dynamic disturbances.

III. FACTS CONTROLLERS

The sustain advancement in power semiconductor industry, high power rating and high speed gate turn off power electronic devices like GTO, IGBT emerged. These developments offer a new generation of FACTS controllers called converter based FACTS controllers with promising features in flexible power flow control, transient stability and power system oscillation damping enhancement. In general, the FACTS controllers are broadly classified as series controllers, shunt controllers, combined series controllers and combined series shunt controllers. Thyristor Controlled Series Capacitor (TCSC), Thyristor Controlled Phase Angle Regulators (TCPAR), and Static Synchronous Series Compensators (SSSC) come under the first category. Static Var Compensator (SVC) and Static Synchronous Compensator (STATCOM) are some examples of shunt controllers. Series Power Flow controller (SPFC) is the combined series-series controller. Similarly, Unified Power Flow Controller is the combined series-shunt controllers.

IV. INTERLINE POWER FLOW CONTROLLER

In general, transmission line losses are huge due to the distance between generating units and load centers. In order to minimize the power losses and also to ensure high-quality power supply up to the end user, steps must be taken. To rectify such troubles, embedding FACTS controllers in power system play a vital role and may offer proficient control with safe working conditions. Among all the other converter based series FACTS controllers, the Interline Power Flow Controller can provide congestion management in a multilines power system. The detailed Simulink model of SPFC was developed and its suitability in power flow control of multilines subsystem was tested under different conditions. ANN and Fuzzy based modified controllers for converters operation were used to improve the performance of SPFC.

V. WORKING PRINCIPLE OF IPFC

Inter line power flow controller (SPFC) was proposed by Gyugi in 1998 and its specialty is not only its multi functionality but also its controllability of multi transmission lines in a substation. Controlling the converter operation and hence real power flow in specific corridor through reactive power compensation without huge AC capacitor bank and bulk reactor are possible. The controllable converter output voltage was injected into the transmission lines using properly designed series transformer. The reactive power control can be totally independent in each converter whereas the real power flowing into or out of each converter has to be coordinated in such a way that the DC link voltage is kept constant. Also the overall surplus power from the under-utilized lines can be used by other over loaded lines for real power compensation. The single line diagram is shown in Figure 1 for better understanding.

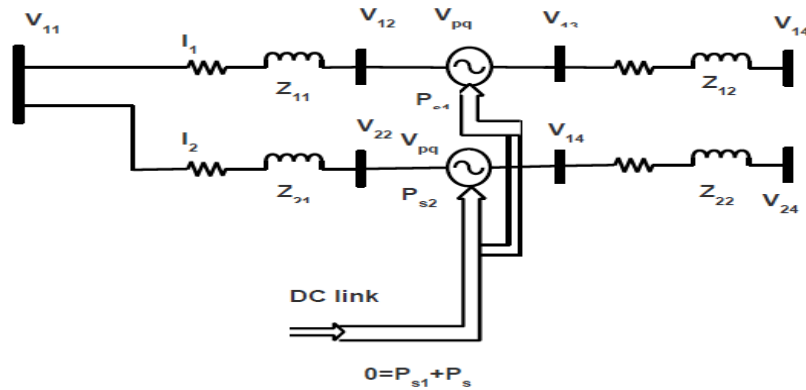


Figure 1. Single line diagram of SPFC

VI. PROPOSED MODIFIED SPFC WITH NERO-FUZZY CONTROL

In this work converter1 is meant for both real and reactive power flow control. For this a fuzzy based controller is designed because it can handle nonlinearity more robust than conventional nonlinear controllers. Converter2 is meant for reactive power compensation and to maintain DC link voltage constant. A Neural Network (NN) based controller is designed to meet out the converter2 controlling operation.

1. Fuzzy Control Scheme for Master Converter of SPFC

The Fuzzy Logic Controller (FLC) has many advantages than the conventional PI controllers. It can handle nonlinearity and more robust than conventional nonlinear controllers. It is a controller based on the concepts of fuzzy sets, linguistic variables and approximate reasoning to evaluate rules. The set of rules are represents the control decision mechanisms required to adjust the effect of certain cases. The internal structure of FLC is shown in below Figure.2

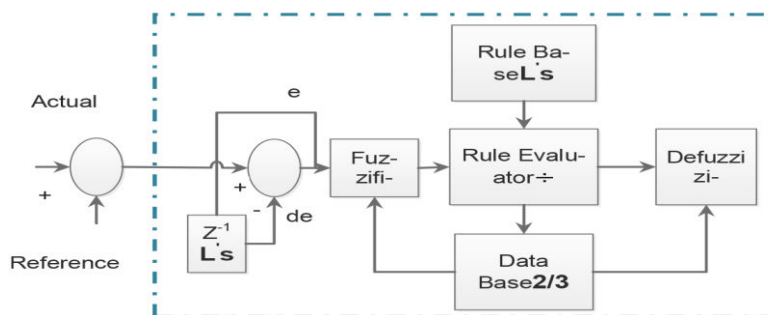


Figure 2. Internal structure of fuzzy logic controller.

2. ANN Control Scheme for Slave Converter of SPFC

Neural Network (NN) has been widely used to solve complex problems of pattern recognition and they can recognize patterns very fast after they have already been trained. The training process requires a training algorithm, which uses the training data set to adjust the networks weights and bias so as to minimize an error function, such as the mean squared error function (MSE), and try to classify all patterns in the training data set [21]. The internal structure of ANN control is depicted in Figure.3.

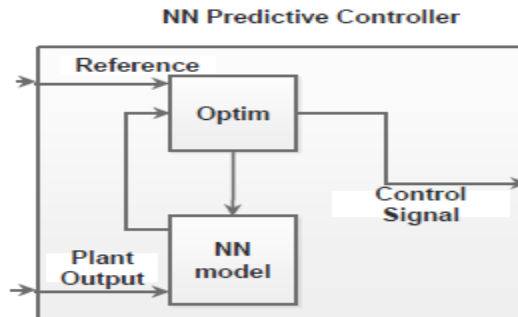


Figure 3. The structure of ANN control.

VII. SIMULATION RESULT

In this Paper, circuit model of SPFC with four bus test system is presented. The open loop IPFC circuit model was developed. Two three phase converters were designed and connected back to back with each other. The AC side controlled voltage was fed to the transmission lines by using two different series transformers. It is clear that by injecting proper series voltage the impedance of the transmission line was changed into either inductive or capacitive. To study the dynamic response of the system in real and reactive power demand at load1 was created. The real and reactive power at the receiving end was measured and the results show that the power at the load side traces the set reference values. Similar changes were created at load 2 side and the corresponding wave forms are depicted in Figures 4.

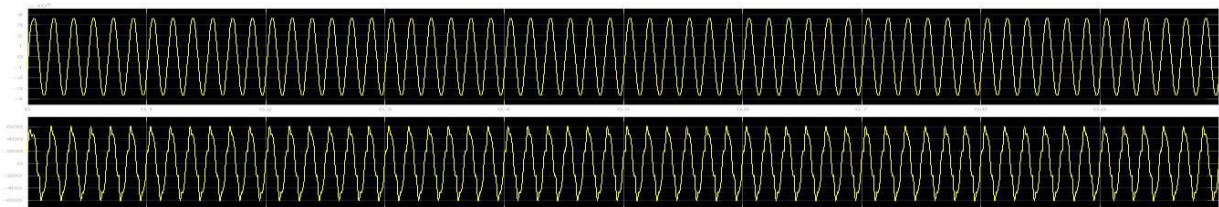


Fig 4 Voltage and current at Load 1 side

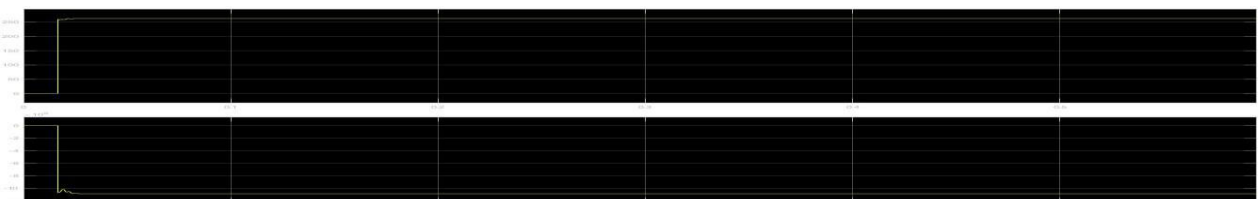


Fig.5 Active and reactive power(MW & MVAR) at Load 1 side

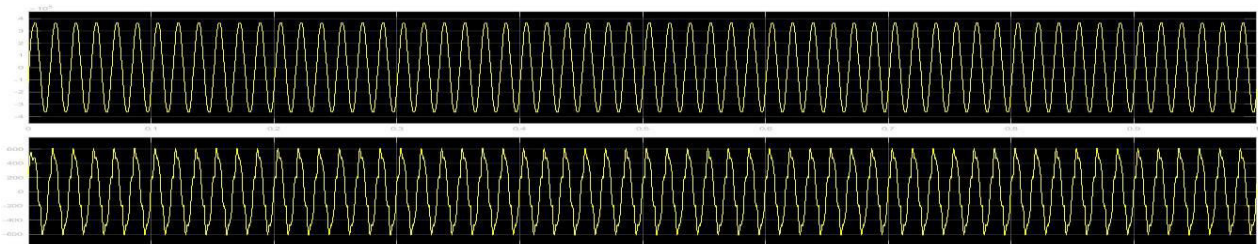


Fig.6 Voltage and current at Load 2 side

a detailed circuit model of SPFC that consists of two converters for real power flow control and reactive power compensation. A Fuzzy based converter1 operation is meant for independent real and reactive power control of sytem1. The NN based converter2 limited operation is meant for reactive power compensation of system 2 and to maintain common DC link voltage of the system. Four inputs and two outputs Mamdani based Rule set are used for FIS. A back propagation training algorithm is used for NN. The performance of overall system with this modified IPFC is studied and the simulation results show that using FLC and ANN enhance the system performance in steady state and limited in transient state. In future the training algorithm has modified for ANN and numbers of rules are to be increased in FLC to meet out the setback in transient state performance.

VIII. CONCLUSION

The boundless electrical power demand enlarges the size and complexity of the power system. Obviously the transmittable power has to travel over a long distance at very high voltage levels. Also due to the number of interconnections, operation of power system becomes challenging one and congestion arises in it. In the real situation, power flow control becomes a significant task in power system. Moreover, constructing a new transmission network becomes a challenging one. This leads the usage of the existing system up to its thermal limits by incorporating FACTS devices. Care must be taken, because such over powering leads to congestion which may collapse the entire system. Hence this research work focuses on effective control tools and algorithms to solve such congestion problems.

The interactions of the two converters through the common dc link required efficient controller. Hence a Fuzzy based controller for master converter operation and ANN based controller for slave converter operation was designed. Hence it is recommended that an SPFC can use for congestion management in a multilines system.

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