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Congestion Management in a Deregulated Power System Using Fuzzy Logic with IPFC

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Abstract*- Congestion management is a major problem that the independent system operator would face in scheduling and rescheduling process in a deregulated electricity market era. One of the most practiced, an obvious method is cost-free method that is using the FACTS devices which minimizes the deviations of rescheduling process and another method is non-cost-free method. A contribution made in the present paper was a technique for reliving the congested power flow in a transmission line has been introduced using Fuzzy Logic with Interline Power Flow Controller. The effectiveness of the method has been analyzed on IEEE 7-bus system.
KeyWords — Flexible Alternative Current Transmission Systems, Interline Power Flow Controller, Congestion Management, Fuzzy Logic Controller.

I. INTRODUCTION

Electrical power generation in a country has a bigger challenge to meet the growing demands for the rise in demand. The increase of the demand is due to rapid industries, urbanization and increase in population of the developing countries. As a measure to meet the increasing demand ensuring adequate availability and reliability, private participation is being encouraged. Because of this, power trading, grid maintenance. etc., becomes a complex issues. Among them, congestion management is a prime issue. When the consumption of electric power causes the transmission system to operate beyond transfer limits, the system is said to be under congestion. Congestion is the most fundamental transmission management problem. Congestion management is the process to avoid or relieve the congestion. In a broader sense, congestion management is considered as a systematic approach for scheduling and matching generation and loads in order to reduce congestion. Installation of flexible alternative current transmission system (FACTS) devices can handle issues related to congestion management.

In general, two paradigm methods were employed to relieve congestion in transmission lines. One is cost free method and the other is non-cost free method where the former include actions like outage of congested lines or operation of transformer taps or phase shifters or FACTS devices. These means are termed as, 'cost free' because the marginal costs (and not the capital costs) involved in their usage, are nominal. Non-cost free methods include re-dispatch of generation and curtailment of pool loads and/or by curtailment of bilateral networks. Among the mentioned two main techniques, cost free means do have advantages such as not involving economic matters; so generation companies and distribution companies will not be involved. Hence, optimal operation of FACTS devices as one such technology can reduce the transmission congestion and leads to better usage of the existing grid infrastructure, along with many others. Besides, using FACTS devices gives more opportunity to independent system operators (ISO). Various issues associated with the usage of FACTS devices are, their optimal location, appropriate size, setting, cost and modeling. This paper deals with the interline power controller for congestion management in competitive power markets. Up to now, the sensitivity factor method with linear programming is being used to enhance the static performance of the system However; there are some disadvantages in the existing method such that it may not capture the non-linearity associated with the power, linear programming method along with FACTS devices which increase the cost and it I not reliable for complex systems. The objective of this paper is to develop an algorithm to relieve congestion by using IPFC in a transmission line. A fuzzy logic controller is proposed to control active power flow for congestion management. The proposed algorithm is tested successfully on the IEEE 7-bus system. The efficiency of the proposed method is making promising to solve congestion problem in a power system network with suitable FACTS device.

II. INTERLINE POWER FLOW CONTROLLER

In its general form the interline power flow controller employs number of DC to AC inverters each providing series compensation for a different line. IPFC is designed as a power flow controller with two or more independently controllable Static Synchronous Series Compensators (SSSC)which are solid state voltage source converters injecting almost sinusoidal voltage at variable magnitude and are linked via a common DC link. SSSC is employed to increase the transferable active power on a given line and to balance the loading in the transmission network.

In addition, active power can be exchanged through these series converters via the common DC link in IPFC. It is noted that the sum of the active powers from VSCs to the transmission lines should be zero when the losses of the converter circuits can be ignored. A combination of the series connected VSC can inject a voltage with controllable magnitude and phase angle at the fundamental frequency while DC link voltage can be maintained at a desired level. The common DC link is represented by a bidirectional link for active power exchange between an IPFC uses two or more VSCs that share a common dc-link.

Each VSC injects a voltage - with controllable amplitude and phase angle - into the power transmission line through a coupling transformer. Each VSC provides series reactive power compensation for an individual line and it can also supply/absorb active power to/from the common dc-link. Thus, an IPFC has an additional degree of free demo control active power flow in the power system when compared to a traditional compensator.

This capability makes it possible to transfer power from over-loaded lines to under-loaded lines and reduce the line resistive voltage drop, and improve the stability of the power system.The coupling transformer, in which the primary windings of the master and slave converters are (pseudo) star-connected while their secondary windings are connected in series with each phase of the transmission line.

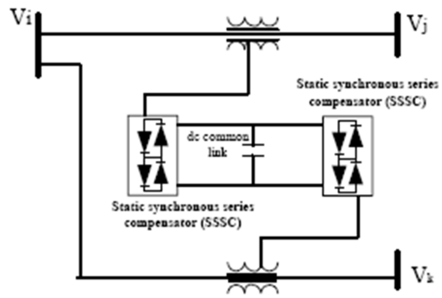

Fig.1. The basic configuration of IPFC

III. IPFC MODELLING

The IPFC is the most versatile and effective device. The IPFC consists of voltage source converters; connected one in series and the other in shunt and both are connected back to back through a D.C capacitor. In order to investigate the impact of IPFC on power systems effectively, it is essential to formulate their correct and appropriate model. In the area power flow analysis, the IPFC model has series voltage source and a shunt current source model or both the series and the shunt. It is represented by voltage sources which present a decoupled model which is simple to implement but it has some restrictions. Alternately IPFC model is represented by two voltage sources called the voltage source model (VSM) and another model called the power injection model (PIM). The injection model of IPFC device is explained above. The fig.2 shows the injection model of IPFC located between buses i and j and its phasor diagram are shown in fig.3.

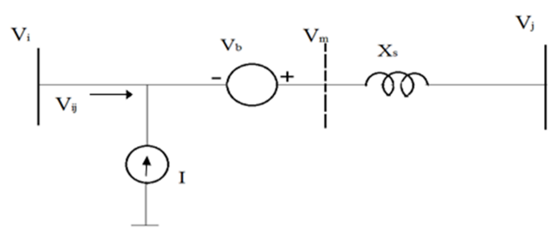

Fig.2. Injection model of IPFC

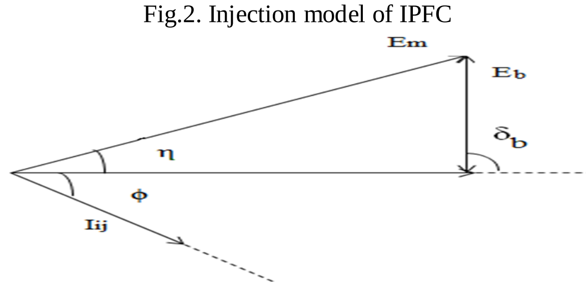

Fig.3. Phasor diagram

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The simulation model of IPFC is shown in the Fig.4. The system related to IPFC is grouped under the IPFC model. In this system, the v1 voltage which is obtained from transmission line 1 is compared with the reference value v1 in IPFC model (shunt branch). Ise current which is calculated in the block of the transmission line 2 is given to IPFC model (Series branch), and it is compared with the reference currents obtained from the active and reactive power references. According to the given active and reactive power references, IPFC model (Series branch) produces a voltage of Vse and sends it to transmission line 2. Shunt current (Ish) and load current (lL) are given to the transmission line 1. The current Ise is obtained from the transmission line 2 has been sent to transmission line 1 to provide the current cycle of the transmission system.

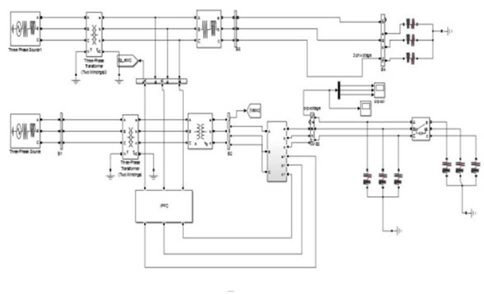

Fig.4. Simulation model of IPFC

IV. FUZZY LOGIC CONTROLLER

The concept of fuzzy logic was developed to address uncertainty and imprecision which widely exists in engineering problems. Fuzzy logic controllers are rule based controllers. Fuzzy Logic Controller for solving the congestion management problem involves various steps. The steps are as follows:

Fuzzification: The process of converting a real number into a fuzzy number is called fuzzification. Knowledge base: This includes, defining the membership functions for each input to the fuzzy controller and designing necessary rules which specify fuzzy controller output using fuzzy variables. Inference engine: This is mechanism which simulates human decisions and influences the control action based on fuzz logic. Defuzzification: This is a process which converts fuzzy controller output, fuzzy number, to a real numerical value.

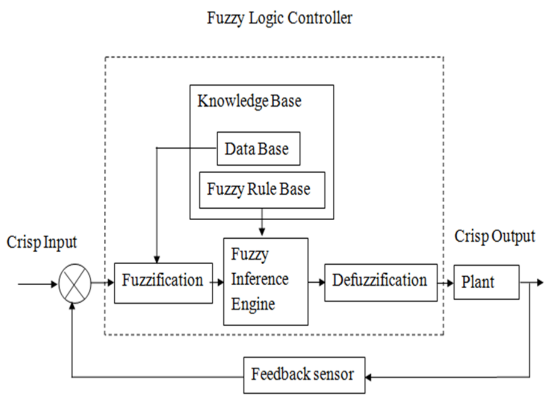

Fig.5. Block diagram of Fuzzy Logic Controller

The fuzzy logic controller block diagram consists of fuzzification, defuzzification, fuzzy inference system and knowledge base. The knowledge base contains data base and fuzzy rule base. The fuzzy logic controller block diagram is shown in Fig. 5

V. SIMULATION MODELLING

The IEEE 7 bus system has been considered and it is simulated using Matlab/Simulink. In the IEEE 7 bus system the fault is created at bus 3. The circuit breaker is used to trip the circuit when there is a fault in the bus. The fault is created already at bus 3 hence the circuit breaker gets tripped. At the time of opening, the customers will utilize the power from the transmission line or load side and also the occurrence of fault, there is congestion in the transmission line. Due to congestion the remaining transmission line are affected. Because of this fault there is a change in Independent System Operator and changes in the scheduling price also. To avoid congestion in the transmission line on the IEEE 7 bus system the intelligent techniques was used along with FACTS devices. By using the Interline Power Flow Controller with fuzzy logic controller in the congested transmission line, the voltage obtained is linear to the customers without changes the scheduling price in a deregulated power system.

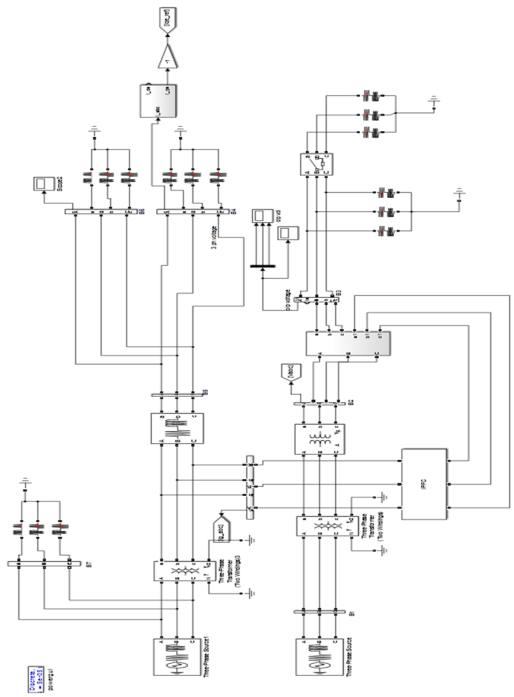

Fig.6. MATLAB/Simulink of FLC based IPFC

The primary reason for choosing the Fuzzy Logic Controller in this research is that the flexibility offered by it because congestion is uncertainty in the deregulated power system. In which the control strategy is represented by a set of rules and it does not require the exact set of equations to represent the system. IPFC is used to control the power flow in a transmission system. The IPFC device along with FLC is placed in between the bus 1 and bus 2. It is used to control the power flow through bus. The shunt and series converters can exchange power through a DC bus. The series converter can inject a maximum of nominal line-to-ground voltage in series with the line. The pulses for the IPFC device were given through the fuzzy logic controller in order to control the power flow in the transmission line. With the coding of fuzzy logic controller, the congestion in the system can be controlled which is made in IEEE 7 bus system. The fig.6 shows the MATLAB/Simulink of Fuzzy Logic Controller based Unified Power Flow Controller.

VI. RESULTS AND DISCUSION

In the present work IEEE 7 bus system has been used to control the congested transmission line using the Interline Power Flow Controller (IPFC) along with Fuzzy Logic Controller (FLC) in the MATLAB/SIMULINK was simulated successfully. The normal three phase voltage at bus 3 and at bus 6 before the occurrence of the congestion in the IEEE 7 bus system is shown fig.7 and the three phase voltage under congestion at bus 3 are shown in fig.8 and fig.9. After the clearance of congested transmission line with the help of Unified Power Flow Controller along with Fuzzy Logic Controller at bus 3, at bus 4 and at bus 6. The three phase voltages after congestion are shown in fig.10, fig.11 and fig.12.

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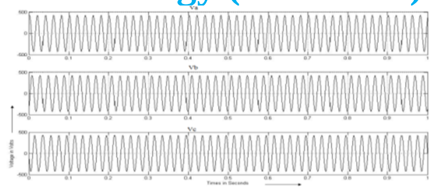

Fig.7. Three phase voltage before congestion at bus 3

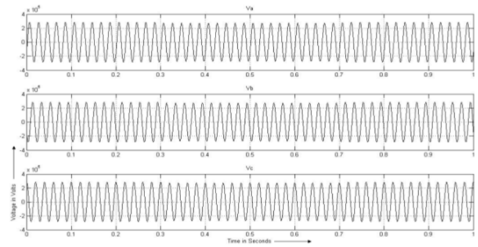

Fig.8. Three phase voltage under congestion at bus 3

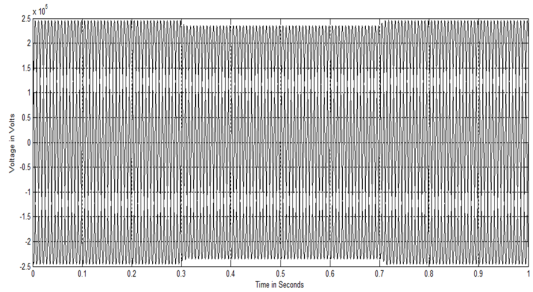

Fig. 9. Three phase voltage under congestion at bus 6

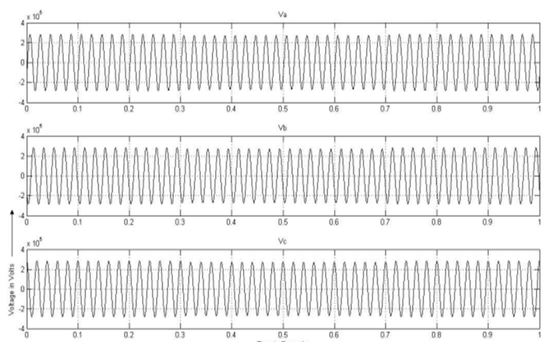

Fig.10. Three phase voltage after congestion at bus 3

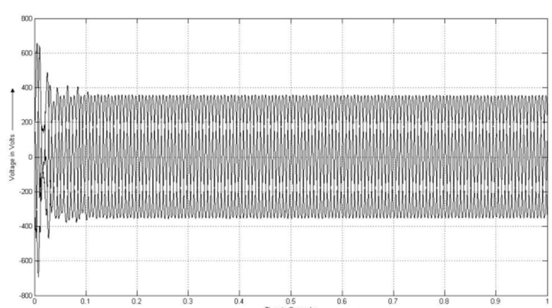

Fig.11. Three phase voltage after congestion at bus 6

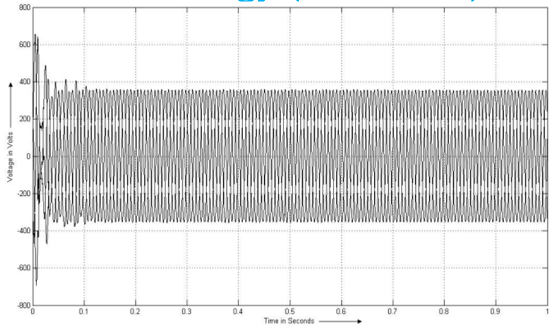

Fig.12. Three phase voltage after congestion at bus 4

VII. CONCLUSION

In this work the result obtained during the congestion of the transmission line is effectively managed by using the Fuzzy Logic Controller with Interline Power Flow Controller device. A fuzzy logic controller is proposed to control the Interline Power Flow Controller device depending on real and reactive power. Fuzzy logic controller is an uncertainty, which has been developed to solve the congestion management problem. The effectiveness of this algorithm has been tested on IEEE 7 bus system successfully. And the congestion is relieved in the transmission line without the rescheduling process. The work provides more choice, better regulation, cost minimization and better voltage regulation for consumers and the application is grid side utilities, mainly in restructured power system area. Hence, fuzzy logic controller is an economically beneficial and the Interline Power Flow Controller is a cost saving device.

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