

Power Flow Control by IPFC (Interline Power Flow Controller)

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Abstract: The transportation of electrical energy is through transmission lines. Hence FACT devices came into picture to make these transmission lines more efficient. FACTS have made considerable impact on the control of power flow in the transmission lines. One of the Fact devices is IPFC. It's a new concept for the compensation and effective power flow management of multi-line transmission systems. This paper studies the general system of IPFC and simulation is done of the model of interline power flow controller for a single phase three bus system for understanding of power flow in a transmission line in the MATLAB/SIMULINK.

Keywords: FACTS, SSSC, VSC.

I. INTRODUCTION

Increasing transmission capacity requirements can be achieved by either constructing new transmission lines or increasing the transfer capability of existing transmission facilities. Restructuring of transmission line and increasing demand on the transmission network has resulted in reduction of stability margins and increased the risks of cascading outages and blackout (voltage collapse)[1]. FACTS (Flexible AC Transmission Systems) devices are often presented and implemented for power flow regulation to improve the transfer capability of existing transmission lines [2]. These FACTS controller can be grouped into two different types, variable impedance type and Voltage Source Converters (VSC's) [3]. VSCs include STATCOM, SSSC, UPFC, and IPFC. Among the FACTS components, Unified Power Flow Controller (UPFC) and Interline Power Flow Controller (IPFC) are the most advanced in FACTS controllers [4]. These are able to control independently the throughput active and reactive powers. The interline power-flow controller (IPFC) is a new and advanced FACTS controller, which can be used for effective power flow management among transmission corridors. IPFC is extension of SSSCs in multiple lines. The general form of IPFC consists of back-to-back VSCs. The voltages produced by these VSCs are injected in the lines through injection transformers (or series transformers). In this paper an attempt is made to develop a model of IPFC for a basic transmission line and is simulated in MATLAB/SIMULINK. The basic structure of IPFC is dealt in part II. Part III will discuss about the simulation model of IPFC, and results and conclusions drawn from the results are presented in Part IV.

II. BASIC STRUCTURE OF IPFC

The IPFC employs a number of SSSCs with a common dc link, each of them provides series compensation for a selected line of the transmission system. The schematic representation of IPFC is as shown in Fig:1. As shown in the fig 1, two SSSC's are connected back-to-back with a common dc link. SSSC are employed to increase the active power to be transformed on a given line and thereby balance the loading of a transmission network. Active power can be exchanged through these series converters via common dc link. The total sum of the output of active power from the converters to the

transmission line should be zero, considering the fact that converters' losses are ignored. The equivalent circuit diagram of the IPFC is shown in fig 2.

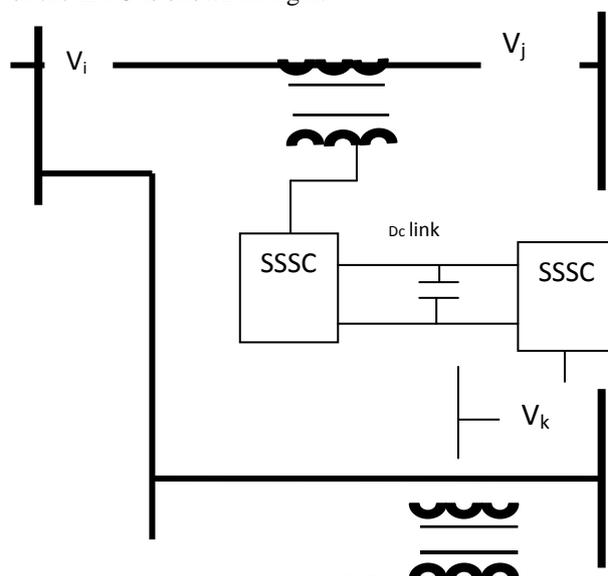


Figure 1. schematic representation of IPFC

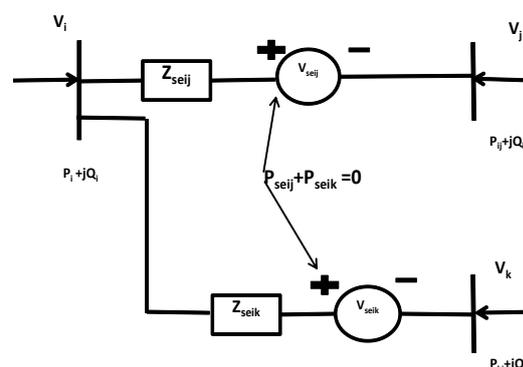


Figure 2. Equivalent circuit of IPFC.

Equations that govern IPFC are given below [5]:

$$P_i = V_i^2 g_{ij} - \sum_{j=1}^n V_i V_j (g_{ij} \cos(\theta_j - \theta_i) + b_{ij} \sin(\theta_j - \theta_i)) - j = 1 n V_i V_{seij} (g_{ij} \cos(\theta_i - \theta_{seij}) + b_{ij} \sin(\theta_i - \theta_{seij})) \quad (1)$$

$$Q_i = V_i^2 b_{ii} - \sum_{j=1}^n V_i V_j (g_{ij} \sin(\theta_j - \theta_i) + b_{ij} \sin(\theta_j - \theta_i)) - j = 1 n V_i V_{seij} (g_{ij} \sin(\theta_i - \theta_{seij}) + b_{ij} \sin(\theta_i - \theta_{seij})) \quad (2)$$

Where, V is the bus voltage;
 θ is bus angle;
 V_{se} is magnitude of injected voltage;
 θ_{se} is the angle of injected voltage.

III. MATLAB Simulation

Simulation of IPFC system is done using MATLAB SIMULINK. A basic transmission line model without IPFC is simulated and then with IPFC is simulated.

A. Without IPFC

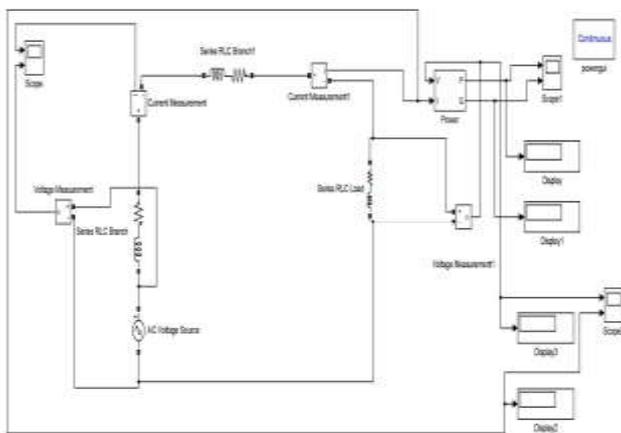


Figure 3. Transmission line without IPFC

Fig 3 shows the SIMULINK model of basic transmission line. 11kV is the source voltage. The line impedance is (5+j0.033) Ω. The active load is taken as 10MW and reactive load is 50MVAR. Here power flow is without any compensation. Simulation results of the above system are shown below. The real power flow is 1.62MW and reactive power flow is 3.27MVAR. The load voltage is 2.9kV. Graphs are shown below.

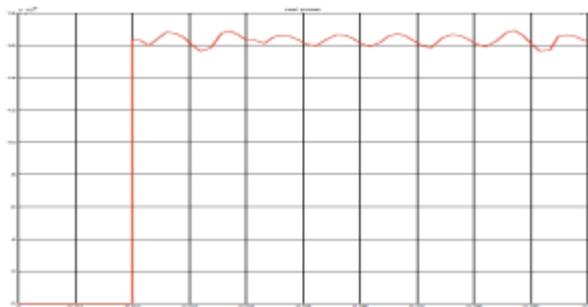


Figure 4. Real power

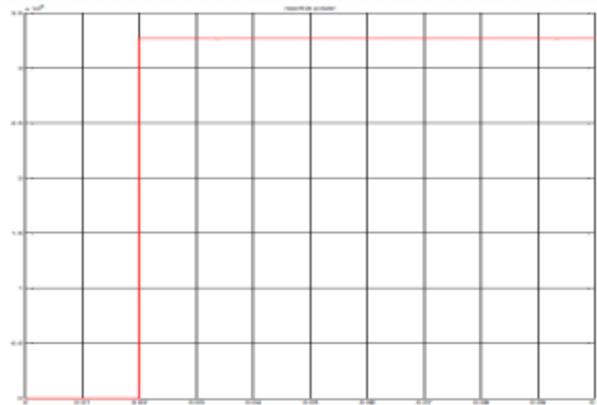


Figure 5. Reactive power

B. With IPFC

The transmission model is now compensated with IPFC.

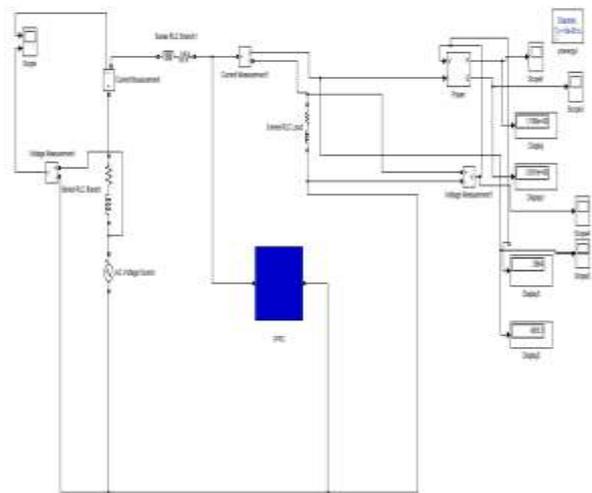


Figure 6. Simulink model using IPFC

Figure 6 shows the transmission line modeled with IPFC between the two lines. The subsystem of IPFC is shown in figure 7. The switching of the thyristor is done through pulse generator. The duty cycle is appropriately selected for proper generation of pulses.

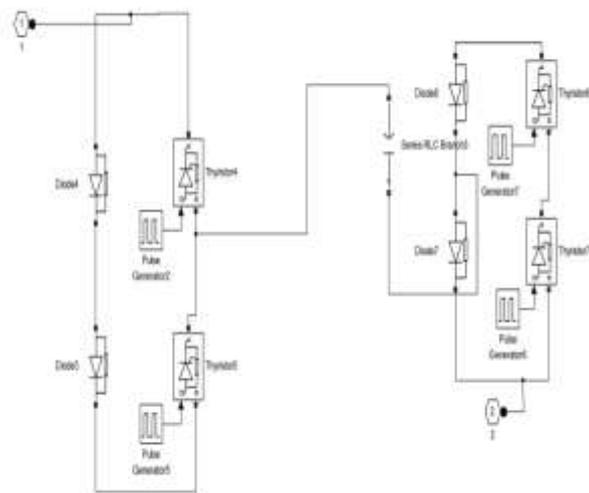


Figure 7. Subsystem of IPFC.

The real power and reactive power after IPFC implementation is 2.098MW and 4.196MVAR with capacitor value of 300 μ F. The voltage profile has improved to 3.5kV and also load current has improved.

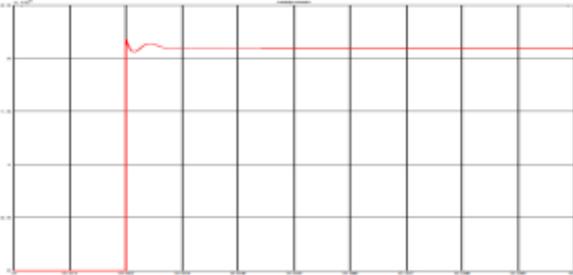


Figure 8. Real power with IPFC

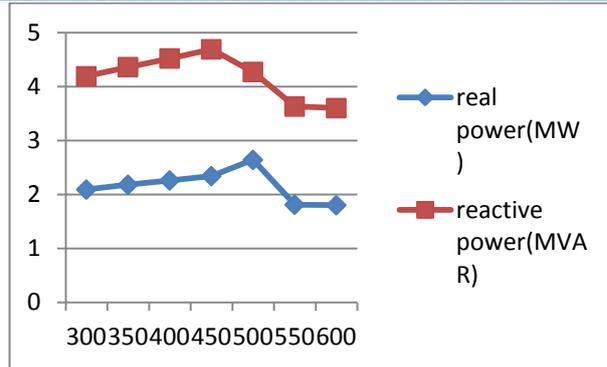


Figure 12. Power flows for different capacitor values.

IV. Conclusion:

In this paper, voltage and power profile has been improved through implementation of IPFC. With these simulation results it can be inferred that with the implementation of IPFC, voltage profile, real power flow and reactive power flow can be controlled, upto a certain value of capacitor values.

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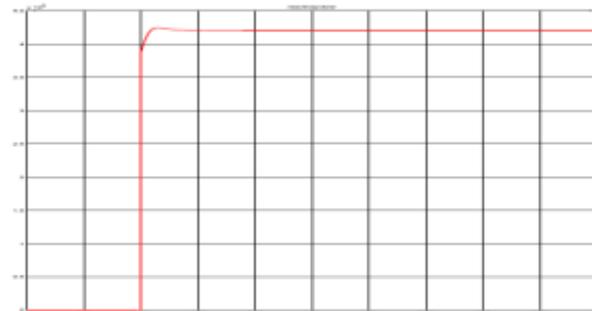


Figure 9. Reactive power with IPFC

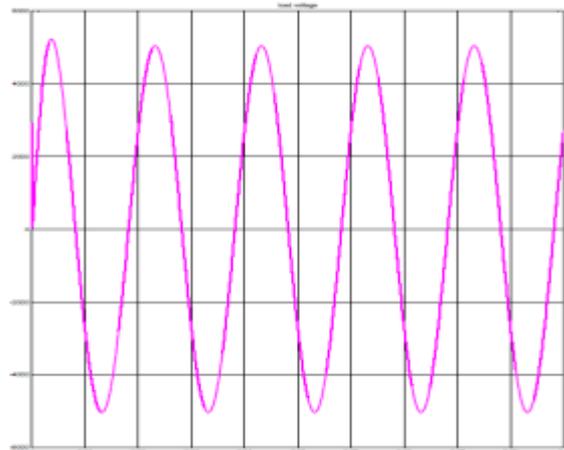


Figure 10. Load voltage with IPFC

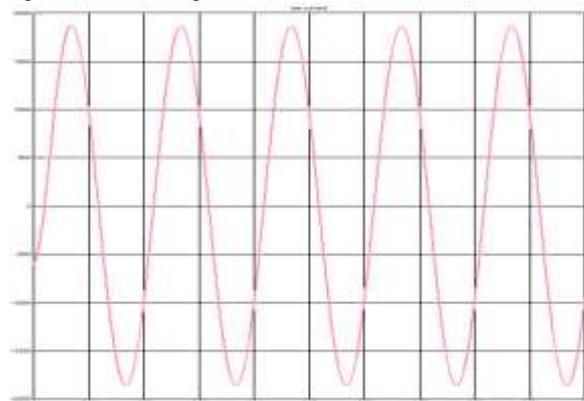


Figure 11. Load current with IPFC

For different capacitor values, active and reactive power flows are obtained. With increase in capacitor value, active and reactive power, voltage profile also increases. But after certain value of capacitor, the power flow decreases. After 500 μ F, power flow decreases as evident from the graph shown below.