FACTS Modeling and Simulation in Power Networks

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Abstract— **This paper presents the mathematical steady-state modeling of Static Synchronous Compensator, which is the most widely used member of Flexible Alternating Current Transmission Systems. STATCOM Power Injection Model, derived from one voltage source representation, is presented and analyzed in detailed. A program, Flexible Alternating Current Transmission Systems Power Flow in MATLAB has been developed which extends conventional Newton-Rap son algorithm based on the Power Injection Model .The STATCOM PIM and Current Injection Model implemented in Power System Analysis Toolbox are incorporated in a 5-bus system. The results obtained from simulation of the 5-bus using FACTSPF are matched with those of PSAT in acceptable tolerance and thus confirms the robustness of the PIM**.

Keywords— **FACTS, STATCOM, NR, PIM, CIM.**

I. Introduction

Flexible AC transmission system controllers are power electronics based controllers. With the applications of FACTS technology, bus voltage magnitude and power flow along the transmission lines can be more flexibly controlled. Among the FACTS controllers, the most advanced type is the controller that employs Voltage Sourced Converter as synchronous sources [1]. Representative of the VSC type FACTS controllers are the Static Synchronous Compensator, which is a shunt type controller, the Static Series Compensator, which is a series type controller and the Unified Power Flow Controller, a combined series-shunt type controller [4]. Of all the VSC the most widely used is the STATCOM. It can provide bus voltage magnitude control. Computation and control of power flow for power systems embedded with STATCOM appear to be fundamental for power system analysis and planning purposes. Power flow studies incorporating STATCOM requires accurate model in solution algorithms. The PIM models the STATCOM as shunt voltage source behind an equivalent reactance or impedance, which is also referred to as voltage source model. This steady state power injection model of STATCOM has proved reliable when incorporated in power systems and is well documented. The use of this STATCOM in power system simulators has therefore increased over the last one decade and is therefore adopted implementation in this work with the voltage expressed in rectangular coordinate.

II. STATICSYNCHRONOUS COMPENSATOR

The STATCOM is a FACTS controller based on voltage sourced converter (VSC). A VSC generate a synchronous voltage of fundamental frequency, controllable magnitude and phase angle. If a VSC is shunt-connected to a system via a coupling transformer as shown in Fig. 1, the resulting STATCOM can inject or absorb reactive power to or from the bus to which it is connected and thus regulate the bus voltage magnitude [4]. This STATCOM model is known as Power Injection Model (PIM) or Voltage Source Model (VSM).

III. POWER FLOW ANALYSIS OF POWER SYSTEM

In order to investigate the performance of the PIM of STATCOM, the CIM and PIM STATCOM were embedded in a standard 5-bus system. The test system is shown in Figure 1. The STATCOM model (PIM) was installed in the 5-bus system for voltage magnitude control. The 5-bus was also simulated using PSAT and its STATCOM current injection model used for bus voltage control. The power flow analysis of FACTSPF and that of PSAT were then compared. From the power flow results for the 5-bus system, it can be observed that the voltage magnitudes at bus Lake, bus Main and bus Elm are lower than 1.0p.u. and are therefore potential buses for the application of STATCOM.

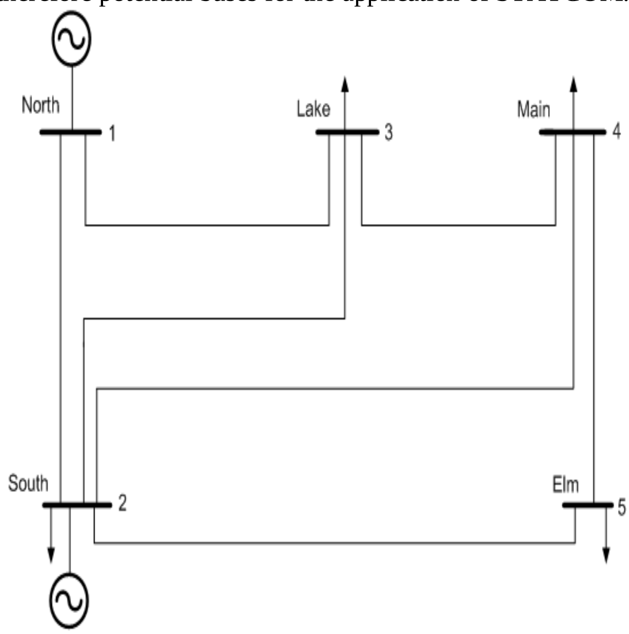

Figure 1. 5-bus Test System Source

The slack generator reduces its reactive power generation by 5.9% compared with the base case, and the reactive power flow from North to lake reduces by more than 32%. The reactive power absorbed by the south generator increased by 25% of the base case. In general, more reactive power is available in the network when compared with the base case due to the installation of STATCOM. As expected the active power flows were slightly affected. The system active power loss reduces to 6.06MW. PSAT was also used to simulate the 5-bus system with STATCOM installed to control Lake bus voltage magnitude at 1.00p.u. The power flow results for the PIM model and CIM STATCOM are similar; the only difference can be seen in Lake Voltage angle with the VSM model being 4.830 while that of CIM is 4.840. The difference can be attributed to the computation errors which are different for each program.

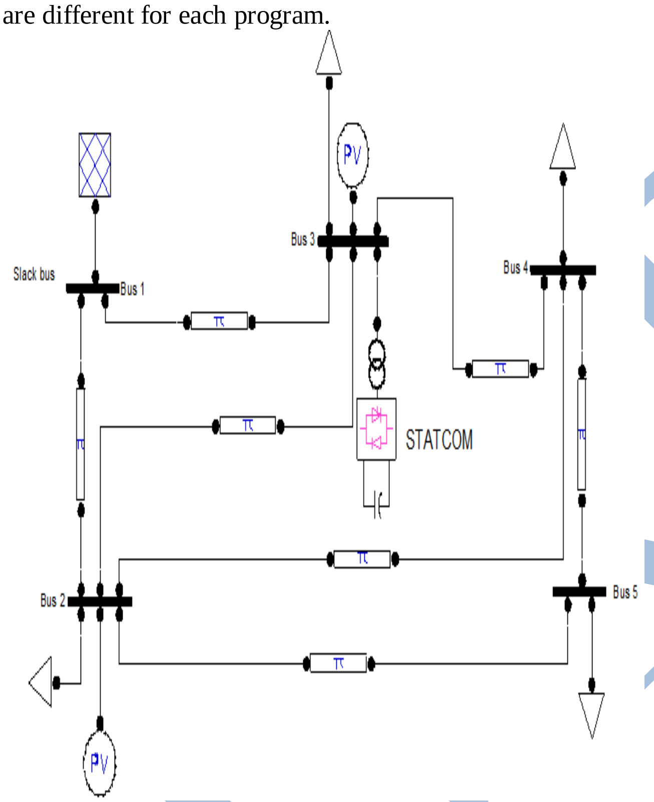

Figure 2. STATCOM-upgraded 5-bus system in PSAT

IV. SIMULATION RESULTS

The parameters of the STATCOM models are shown in Table 2b. In order to control the Lake bus voltage magnitude at 1.00 p.u., the VSM model injected a reactive power 20.47Mvar with voltage magnitude of 1.0205 p.u. and phase angle 4.830. For the CIM STATCOM, it injected a current of 0.2047p.u. The power flow and the system loss for the PIM and CIM STATCOM are essentially the same to four significant figures. Two other scenarios were simulated using the two models to control voltage magnitude at bus 4 and bus 5. The power flow analyses carried out produced similar output results. The two programs converged quadratically in five iterations to maximum absolute power mismatch of 1E-012 per unit as shown in Figure 2. Show the Power flow computation times for the two programs.

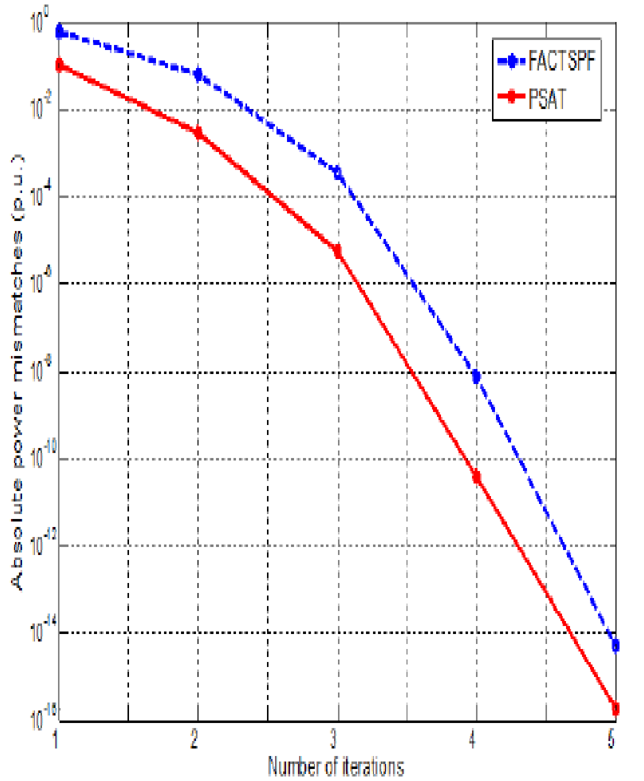

Figure 3. Absolute Power Mismatches as Function of Number of Iterations

V. CONCLUSION

In this paper the PIM of STATCOM has been presented with the voltage expressed in rectangular form. A MATLAB based power flow program developed was extended to incorporate the STATCOM and named Flexible Alternating Current Transmission System Power Flow. 5-bus power system with the incorporation of the PIM and CIM were simulated using the FACTSPF and PSAT respectively. The STATCOM was able to effectively regulate the bus voltage magnitude at which was connected. The results obtained by FACTSPF are matched with those of PSAT in acceptable tolerance and thus confirms the robustness of the PIM. The PIM of STATCOM is effective and reliable in terms of computation speed and accuracy.

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