Simulation of Closed Loop Controlled IPFC System

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Summary
This paper describes inter Line Power flow controller in power system. An Inter line power flow controller is VSC-based FACTS controller for Series compensation with the unique capability of power management among multiline's of a subs-station. The FACTS technology is essential to alleviate these difficulties by enabling utilities to get most service from their transmission facilities, FACTS controllers can control series impendence, shunt impedance, current, voltage and phase angle. The different controller's circuits are simulated using PSPICE software package. IPFC is used to improve the power flow and to provide a power balance of a transmission system. the circuit model of IPFC was developed and the same is used for simulation

Key words:
FACTS, SSSC, IPFC, TCR, PSPICE.

1. Introduction

As a result of Flexible AC transmission system, considerable effort has been spent in recent years on the development of power electronics based power flow controllers [1]. They employ self-commutated inverters as synchronous voltage sources. The power electronics based voltage sources can internally generate and absorb reactive power without the use of capacitors and reactors. They can facilitate both real and reactive power compensation and thereby can provide independent control for real and reactive power flow [2, 3].
The Interline Power Flow Controller (IPFC) schemed proposed provides, together with independent controllable reactive series compensation of each individual line, a capacity to directly transfer real power between the compensated lines. This capability makes it possible to equalize both real and reactive power flow between the lines; transfer power demand from overland to under loaded lines; compensate against resistive line voltage drops and the corresponding reactive power demand; increase the effectiveness of the overall compensating system for dynamic disturbances[4,5]. The IPFC can potentially provide and effective scheme for power transmission management at a multi-line substation.

In the literature [1] to [10], the simulation of closed lop system is not presented .In the present work ,the circuit model for closed controlled IPFC is developed and the same is used for simulation.

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1.1. Interline Power Flow Controller

The basic principles of the Interline Power Flow Controller (IPFC) employs a number of DC to AC inverters each providing series compensation for different line as showing in Fig.1.1. The series compensation is provided by Static Synchronous Series Compensators [6].

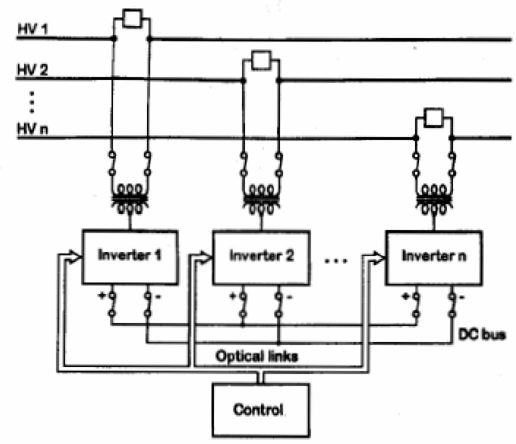

Fig 1. Block of an Inter line Power flow Controller

The Compensating inverters are linked together at the DC terminals. The compensators in addition to provide series reactive compensation can be controlled to supply real power exchange through the dc link from its own transmission line[7]. Thus surplus power available in underutilized lines is made available by other lines. This arrangement mandates the rigorous maintenance of the overall power balance at the common dc terminal by appropriate control action, using the general principle that the under loaded lines are to provide help, in the form of appropriate real power transfer, for the overloaded lines [8-10].

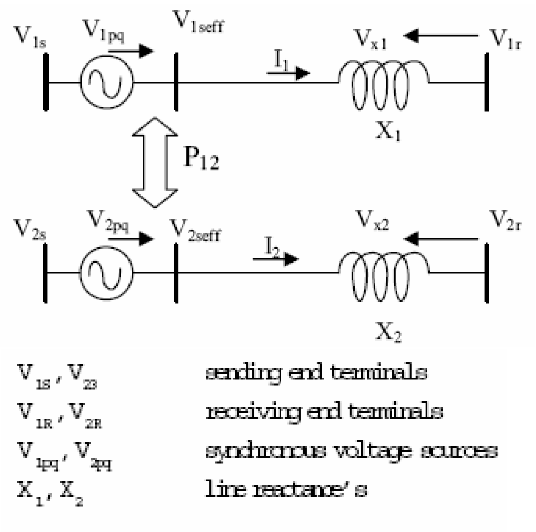

Fig 2. Basic two – Inverter Interline Power flow controller

The elementary IPFC scheme consisting of two back–to back dc to ac inverters each compensating a transmission line by series voltage injection is shown in Fig.2 Two synchronous voltage sources. With phasors V_{1pq} and V_{2pq} in series with transmission lines 1 and 2, represent the two back-to –back to dc to ac inverters. The common dc link is represented by a bi-direction link (P_{12}) for real power exchange between the two voltage sources. Transmission Line 1, represented by reactance X1, has sending ends bus with voltage phasor Vir. The sending end voltage phasor of line 2, represented by reactance X_2, is V_{2s} and the receiving end voltage phasor is V_{2R}.

All sending end and receiving end voltages are constant with fixed amplitudes, $V_{1s}=V_{1R}=V_{2s}=V_{2r}=1$p.u, and with fixed angles resulting in transmission angles, d1=d2.

The line impedances and the rating of the two compensating voltage sources are identical, that his $V_{1pqmax}=V_{2pqmax}$and X1=X2=0.5p.u.

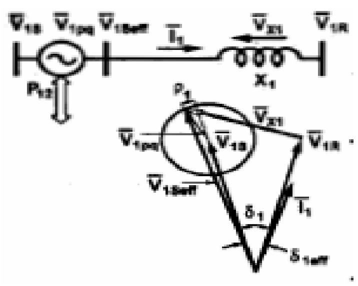

Fig 3. For prime system and phasor diagram

System 1 is selected to be prime system as shown in Fig 3 for which controllability of both real and reactive power is stipulated. Fig.3 is the phasor diagram defining to the relationship between V1s, Vx1 and the inserted phasor voltage V1pq. The inserted voltage phasor V1pq is added to the fixed end voltage phasor V1s to produce the effective sending end voltage. The difference between V1 self and V1, gives the compensated voltage Vx1, across, X1. As r1 is varied over its full 360 range, the end of phasor V1pq moves along a circle with its centre at the end of V1s.'

The rotation of phasor V1pq with angler1modulates both the magnitude and angle phasor Vx1 and therefore both real power P1R and reactive power Q1R vary with r1 in a sinusoidal manner as shown in Fig.4 The voltage source inventor (V1pq) supplies or absorbs both real power (P1pq) and reactive power (Q1pQ), which are also a sinusoidal functions of angle r.

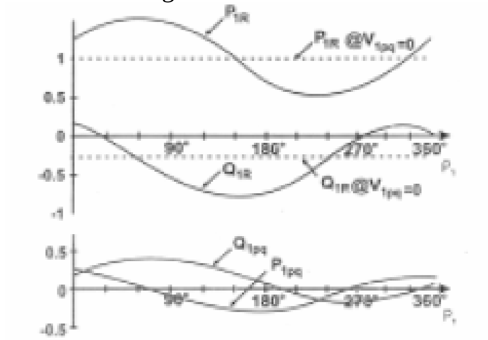

Fig.4 Variation of the Real and Reactive Power with Respect to Phase Angle

2. Simulation Results

The circuit model of IPFC is shown in Fig5a.The series transformers are represented as voltage depended voltage sources. The real power wave form with out IPFC is shown in Fig.5b.The real power with IPFC is shown in Fig 5c. From fig5c, it can be seen that the real power is increased.

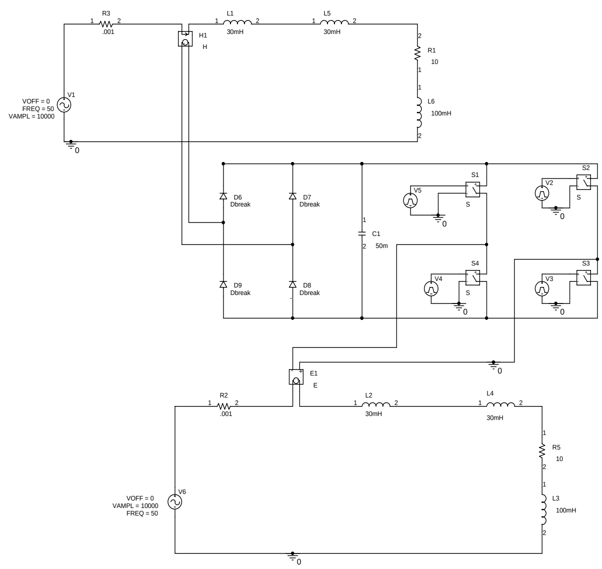

Fig 5a. Circuit model of IPFC with phase difference

The circuit model of IPFC with different values of voltages is shown in Fig .6a.Lines 1&2 operate at 11kv and 10kv respectively.

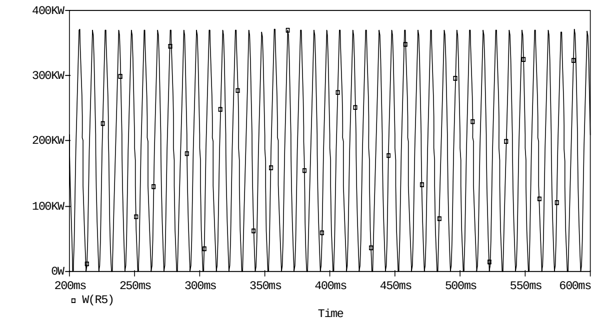

Fig.5b. Real power with out IPFC

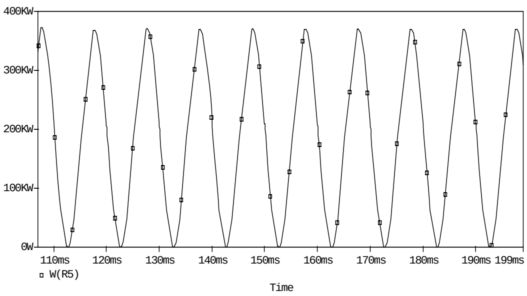

Fig.5c. Real power with IPFC

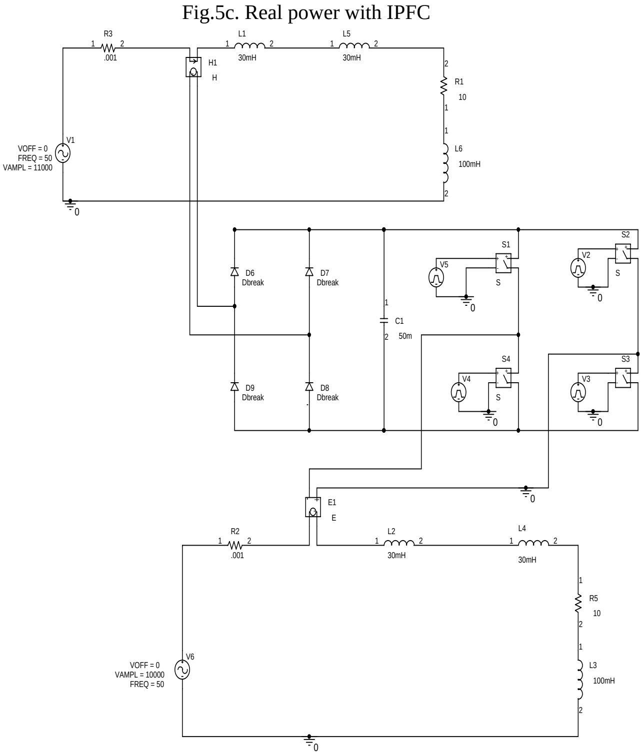

Fig 6a. Circuit model of IPFC with different values and voltages.

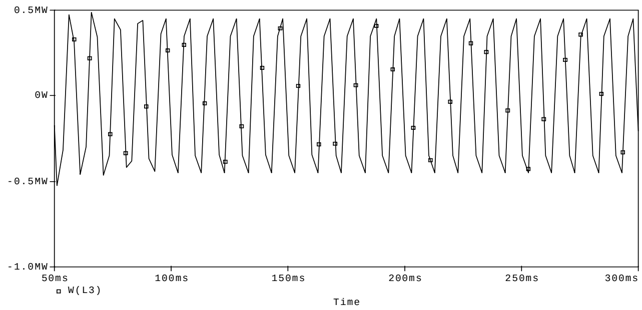

Fig 6b.The Reactive power with out IPFC

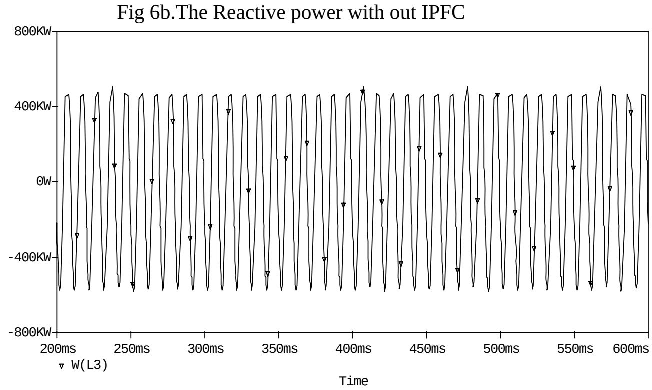

Fig 6c.The Reactive power with IPFC

From Fig.6c, it can be observed that the Reactive power is increased.

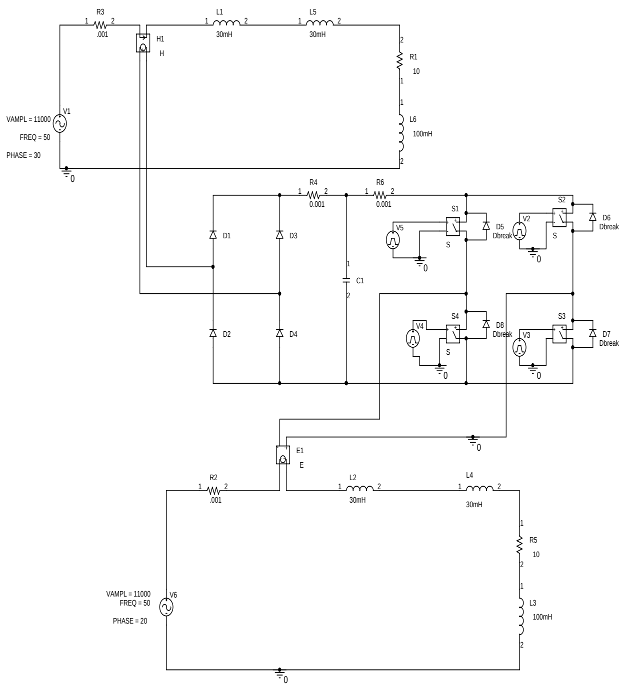

Fig 7a.circuit model with different phase angles.

The circuit model with different phase angle is shown in Fig 7a.source at line1 and 2 operate at 20^o and 30°

respectively. Real and reactive powers in lines1 are shown in Fig 7b&7c respectively.

Line 1

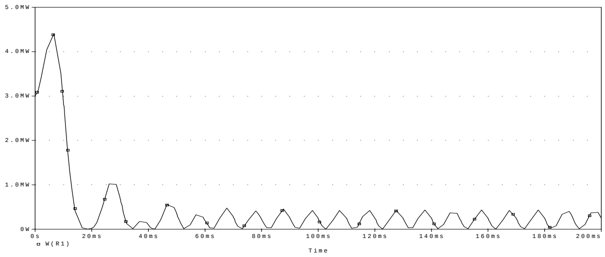

Fig7b.

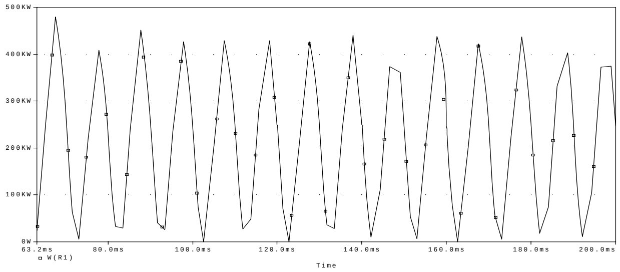

Fig7c.

Line2

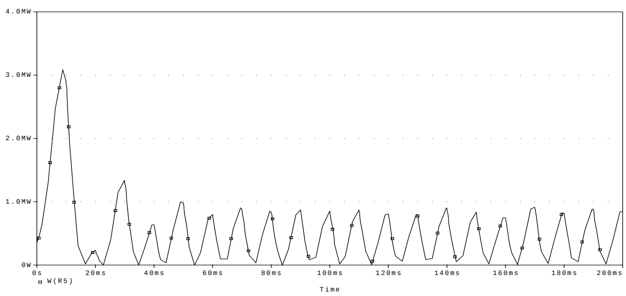

Fig 7d.

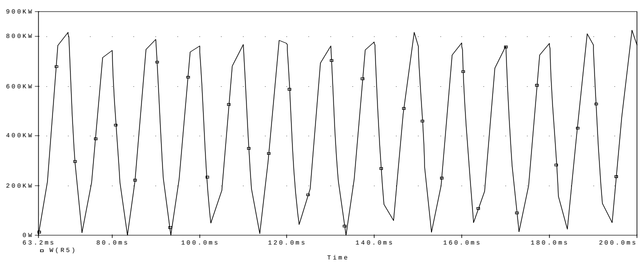

Fig 7e.

3. Closed Loop System

In the control circuit the ac voltages are rectified using diode bridge rectifiers. The outputs of rectifiers are attenuated using potential dividers .The outputs of lines 1&2 are applied to the differential amplifier. IPFC is enabled when the voltages are different .The circuit model of closed loop system is shown in fig 8a .The voltage across the switch S is shown in fig 8b.

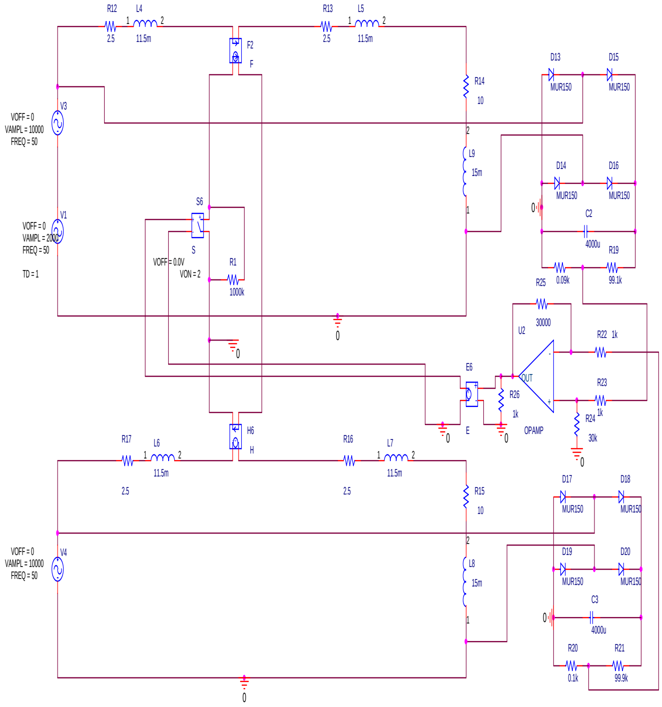

Fig 8a Closed Loop System of IPFC

Real powers in lines 1&2 are shown in Figures 8c&8d.The reactive power through lines 1&2 are shown in Figures 8e & 8f respectively. From the above Figures, It can be observed that the real power increases when the IPFC is enabled.

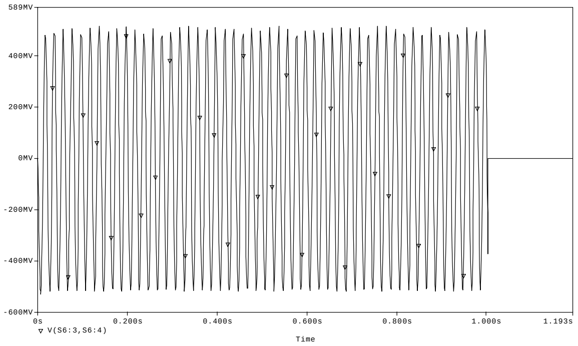

Fig 8b.Voltage across the switch

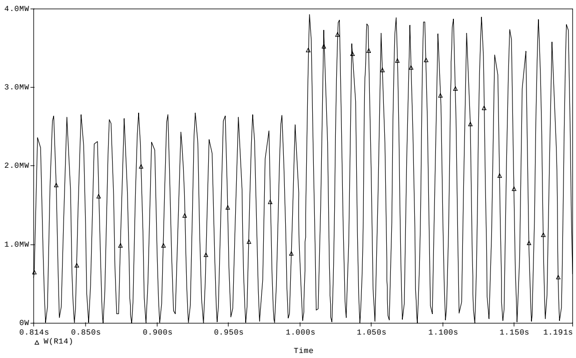

Fig 8c.Real power in the 1st Line

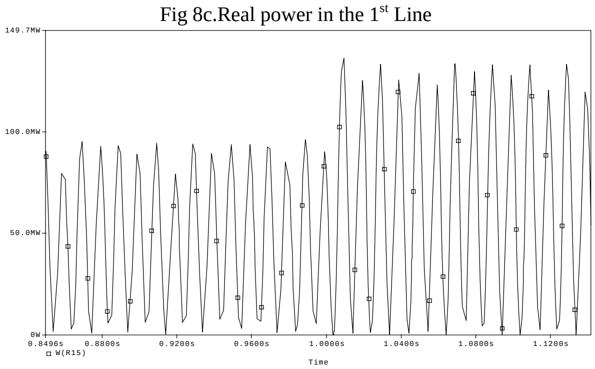

Fig 8d.Real power in the 2nd Line

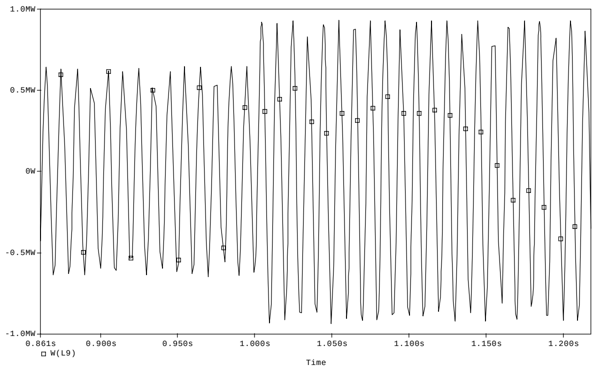

Fig 8e.Reactive power in the 1st Line

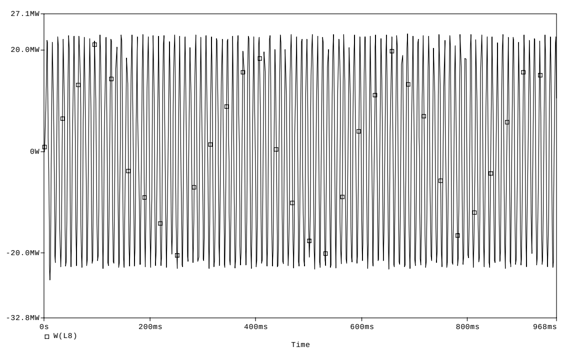

Fig 8f. Reactive power in Line2

4. Conclusion

Circuit model with phase difference and voltage difference were simulated to study the real and reactive power flows. The circuit model for open loop and closed loop systems are presented. They are used to simulate the 2 line system to study real and reactive power flows .It is observed that the real and reactive powers are increased by the presence of IPFC.IPFC is a viable solution to balance the power flow through transmission system.

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