International Journal of Electrical and Power Engineering 2 (2): 99-103, 2008
ISSN: 1990-7958

Digital Simulation of Closed Loop Controlled IPFC Using PSPICE

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Abstract: This study describes closed loop controlled inter Line Power flow controller used 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 multilines 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. Different FACTS 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

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 (Hingorani and Gyugyi, 2000). 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 (Song and Johns, 1999; Gyugyi, 2000).

The Interline Power Flow Controller (IPFC) scheme 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 (Gyugyi, 1998, 1999). The IPFC can potentially provide and effective scheme for power transmission management at a multi-line substation.In the literature (Hingorani and Gyugyi, 2000) to, the simulation of closed loop system with phase angle difference is not presented. In the present work,the circuit model for closed controlled IPFC is developed and the same is used for simulation.

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. The series compensation is provided by Static Synchronous Series Compensators (Papic, 1997). 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 (Sen, 1998). Thus surplus power available in underutilized lines is made available by other lines. This arrangement mandates the rigorous maintenance the overall power balance at the dc

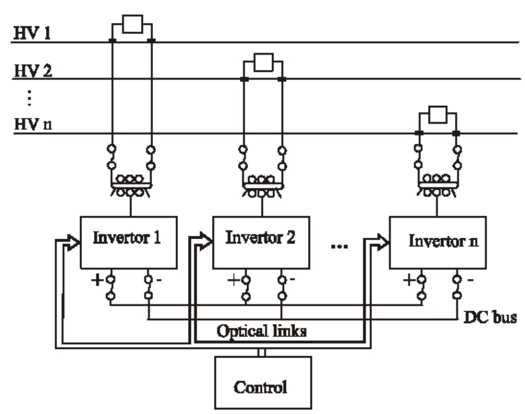

Fig. 1: Block diagram of an inter line power flow controller

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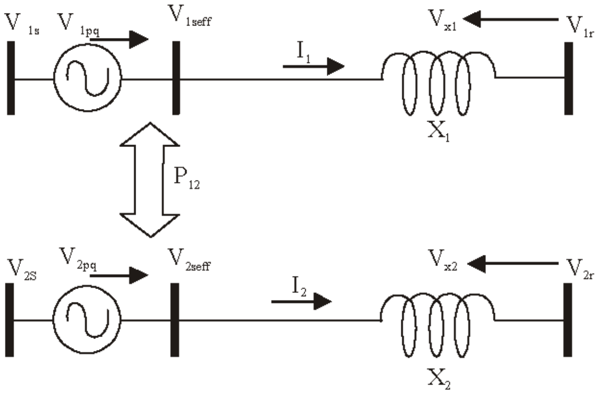

Fig. 2: Basic interline power flow controller

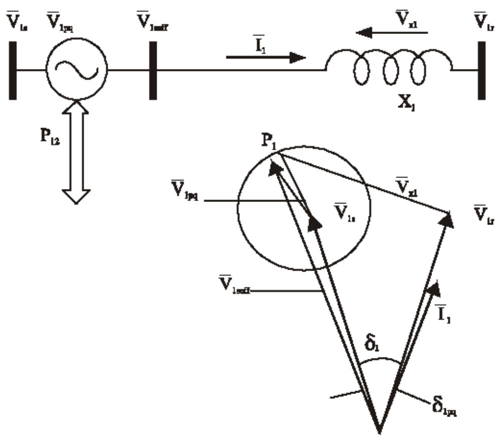

Fig. 3: For prime system and phasor diagram

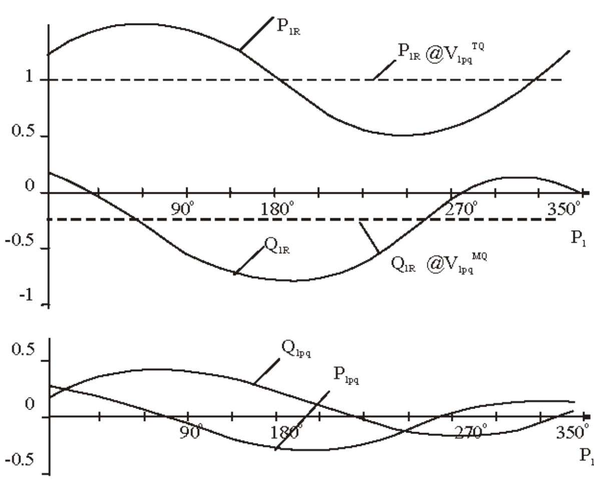

Fig. 4: Variation of the real and reactive power with respect to phase angle

common of 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 (Zhang, 2003; Jianhong *et al.*, 2002). The elementary IPFC scheme consisting of 2 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 for real power exchange between the two voltage sources. Transmission Line 1, represented by reactance X_1, 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, $d_1=d_2$.

The line impedances and the rating of the two compensating voltage sources are identical, that his $V_{1pqmax}=V_{2pqmax}$and $X_1=X_2=0.5$p.u.

Figure 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.

RESULTS

The circuit model of IPFC is shown in Fig. 5a. The series transformers are represented as voltage depended voltage sources. The real power waveform without IPFC is shown in Fig. 5b. The real power with IPFC is shown in Fig. 5c. From Fig. 5c, it can be seen that the real power is increased.

The circuit model of IPFC with different values of voltages is shown in Fig. 6a. Lines 1study 2 operate at 11kv and 10kv, respectively. From Fig. 6c, it can be observed that the reactive power is increased.

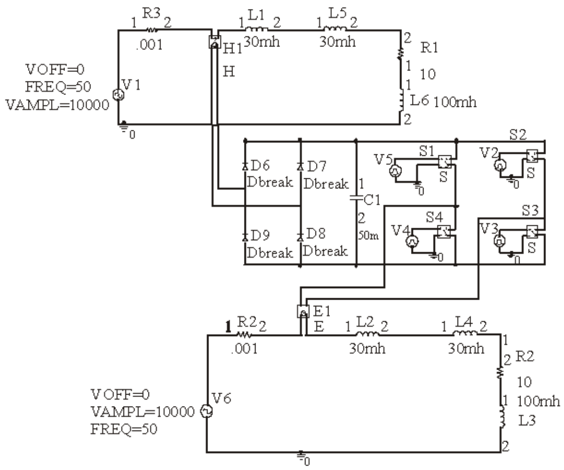

Fig. 5a: Circuit model of IPFC with phase different

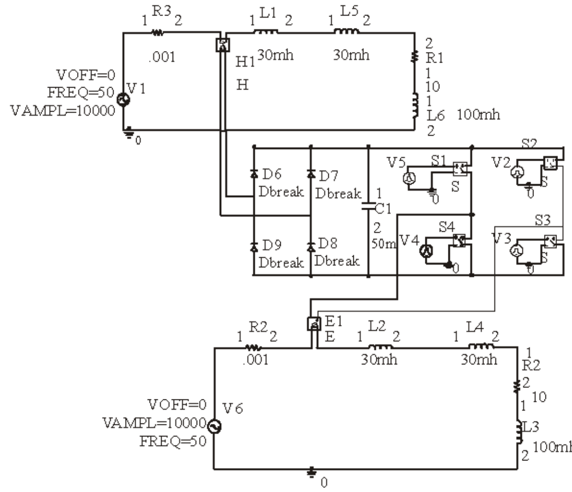

Fig. 6a: Circuit model of IPFC with different values and voltages

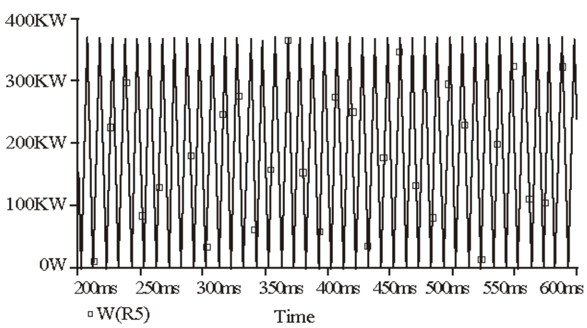

Fig. 5b: Real power with out IPFC

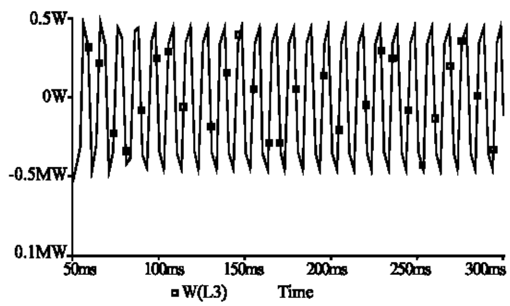

Fig. 6b: The Reactive power with out IPFC

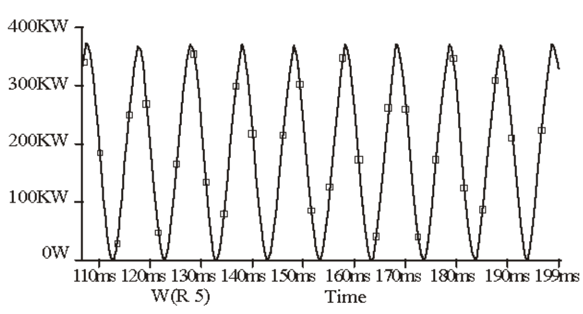

Fig. 5c: Real power with out IPFC

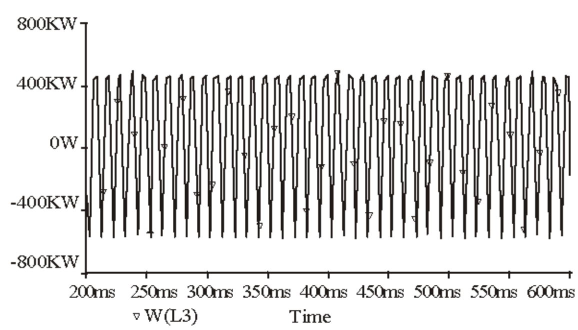

Fig. 6c: The reactive power with IPFC

The circuit model with different phase angles is shown in Fig. 7a. Sources at lines1 and 2 operate at 20° and 30° respectively. Real and reactive powers in line1 are shown in Fig. 7b study c respectively. Real and reactive powers in line 2 are shown in Fig. 7d study e, respectively.

Closed loop system: IPFC closed loop with phase angle difference between two lines is shown in Fig. 8. Two transmission lines, one with phase angle 0° and other with the 20° considered. To show the difference in power flow between two lines for difference phase angle between supply, two voltage

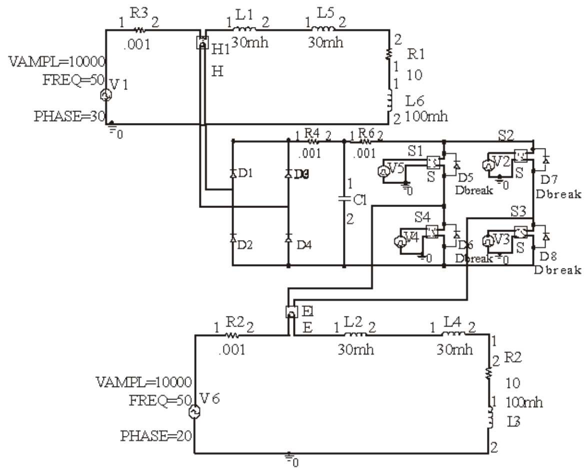

Fig. 7a: Circuit model with different phase angles

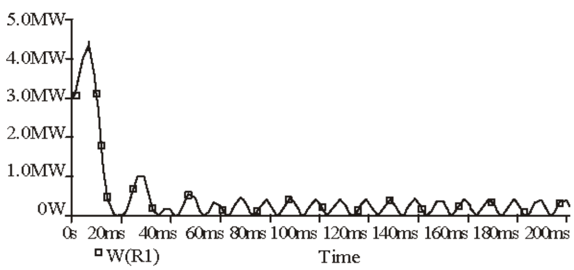

Fig. 7b: Real power in line1

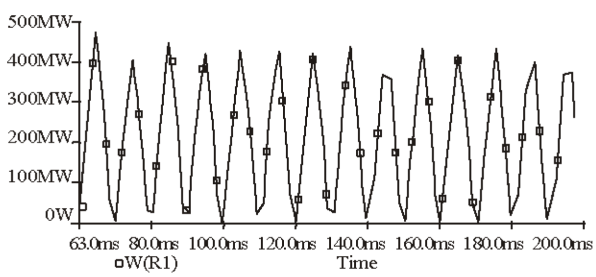

Fig. 7c: Reactive power in line1

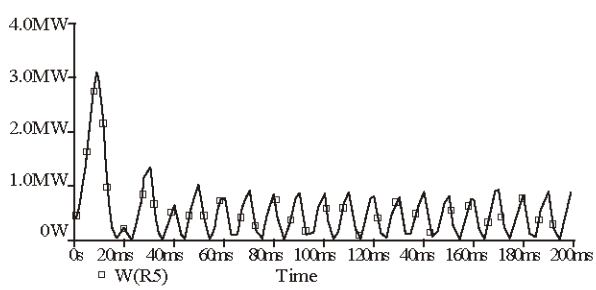

Fig. 7d: Real power in line2

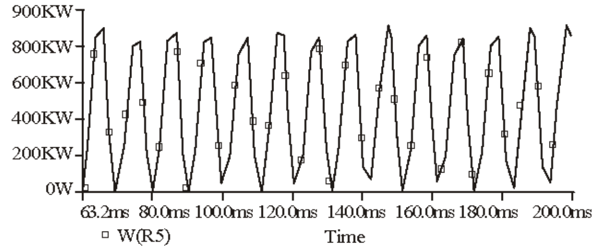

Fig. 7e: Reactive power in line 2

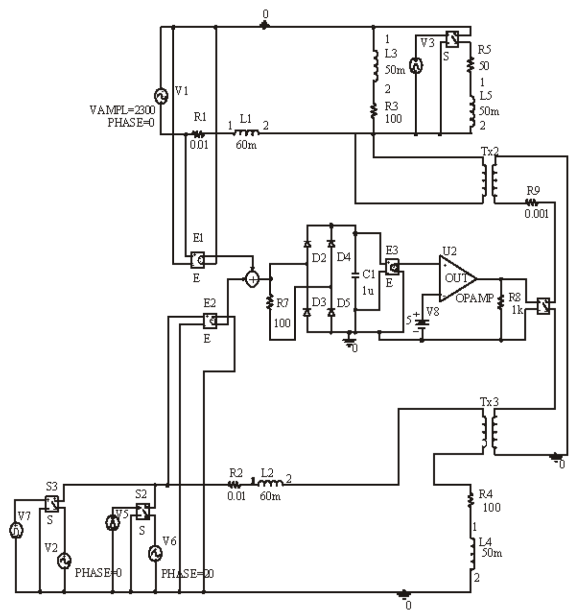

Fig. 8: Circuit model of closed loop system with phase difference

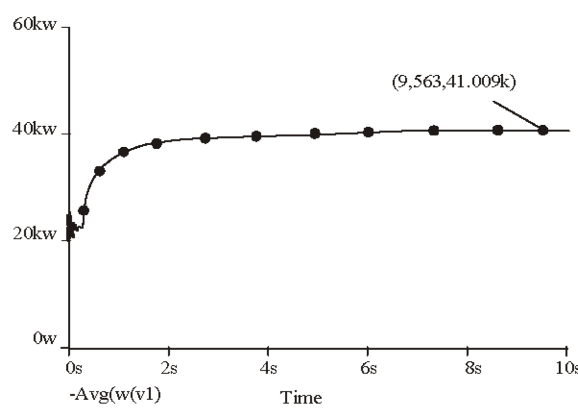

Fig. 8a: Input power in the over loaded line with compensation

sources are considered at the second transmission line. one source operates phase angle 0° and other with 20°.

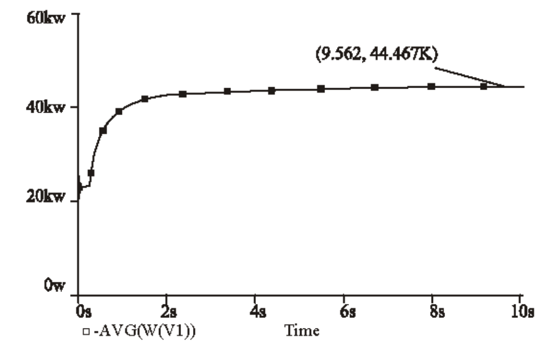

Fig. 8b: Input power of over loaded line without compensation

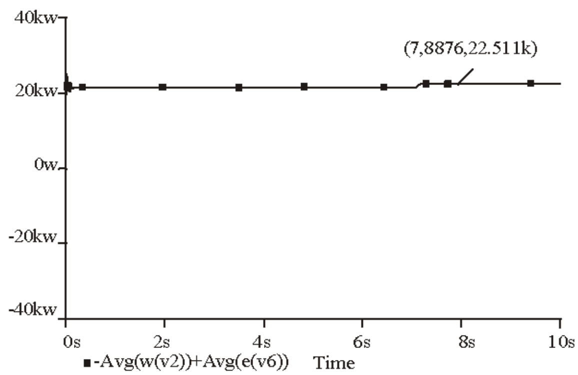

Fig. 8c: Input power in the normal loaded line with compensation

Real power with and with out compensation over loaded line is shown in the Fig. 8a and b.From Fig. 8a and b it can be seen that real power drawn from the source with compensation is less than the real power compensation drawn from the source with out compensation. Figure 8c shown that input power in the normal load line with compensation.

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 two 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. The IPFC is a viable solution to balance the power flow in a transmission system.

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