A POWER INJECTION MODEL FOR IMPROVING SYSTEM PROFILE USING INTERLINE POWER FLOW CONTROLLER

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ABSTRACT

The interline power flow controller (IPFC) is a flexible AC transmission system (FACTS) controller that is used to govern power flows across various transmission lines. This paper describes a mathematical model of IPFC known as the power injection model (PIM). The controlling of active and reactive power flow may be accomplished by calculation of currents as a function of the target power flow and the bus voltage at the IPFC terminals. However, the reactive power flow is discharged and computed based on the system. The injected currents are updated and added to the load flow algorithm's initial current mismatches vector IEEE-9 bus system is used to investigate power flow regulation with the Newton Raphson (NR) power flow algorithm in transmission lines with IPFC. The MATLAB platform was used to expand the usual Newton Raphson (NR) technique.

I. INTRODUCTION

Electricity is an inseparable part of existence. In recent day's power generation, and search for alternate sources of power is a burning problem. Thus the generated electric power should be efficiently transmitted and the losses are to be reduced. Even though our power industry is in the area of advancements, it is difficult to minimize the power loss. The modern power system is becoming increasing stressed because of growing demand.

Now a day's various factors of electric power such as environmental legislations, right of way issues, capital investment, deregulation policies, and a major constraint in the construction of new transmission lines, etc are forced to operate their system in such a way that it should makes a better utilization of existing transmission facilities. It is well known that the power flow in the transmission line is a function of line impedance, magnitude and phase angle of bus voltage. If these parameters are controlled, then the power flow through transmission line can be controlled in a predetermined manner.

A. V. Naresh Babu, et al [8] presented the power flow control of multiple transmission lines using IPFC. A mathematical model of IPFC; termed as power injection model (PIM) is presented with Newton- Raphson (NR) power flow algorithm to study the power flow control in transmission lines.

M. Z. EL-Sadek, et al [13] suggested incorporation of IPFC in Load Flow Studies. Two models are incorporated with a power flow program based on Newton- Raphson algorithm. The IPFC power flow models are modified to set control of power flows of multiple lines. Based on these models it is possible to estimate the IPFC control variables and its ratings.

Laszlo Gyugyi, et al [2] proposed is a new concept for the compensation and explains the IPFC with phasor diagrams, P-Q plots and simulated waveforms.

Bindeshwar Singh, et al [9] presented a comprehensive survey of various FACTS controllers which are incorporated in load flow analysis for different point of view such as optimal power flow control, planning and operations of large-scale power system networks.

II. METHODOLOGY PROPOSED

IPFC is the combination of the multi-series converters. The multi series converters are coupled by a common DC link. The DC link provides a path to exchange active power between multi-series converters. The series converters inject the series voltages into the transmission lines through transformers [2]. The power flow through the line can be regulated by controlling the magnitudes and the angles of the converters. The injected voltage magnitudes and angles determine the active and the reactive power into the transmission lines. The converters have a capability of electromechanically generating and absorbing the reactive power. However, without losses of converters, the injected active power must be supplied by the DC link from the AC system.

The IPFC employs number of DC to AC inverters, each providing series compensation for a different line as shown in Fig. (1). 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 an almost sinusoidal voltage at variable magnitude and are linked via a common DC capacitor. SSSC is employed to increase the transferable active power on a given line and to balance the loading of a transmission network.

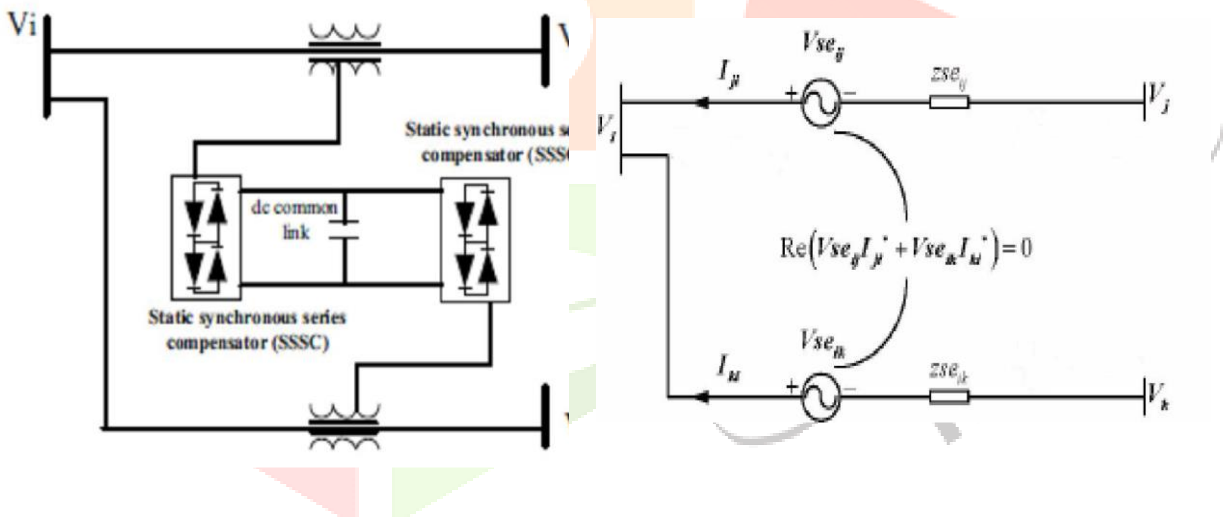

Fig. (1): Power Injection Model of IPFC

A mathematical model for IPFC which will be referred to as power injection model is derived [8]. Usually, in the steady state analysis of power systems, the VSC may be represented as a synchronous voltage source injecting an almost sinusoidal voltage with controllable magnitude and angle. Based on this, the equivalent circuit of IPFC is shown in Fig. (2).

In Fig.(2), V_i , V_j and V_k are the complex bus voltages at the buses 'i', 'j' and 'k' respectively, defined as $V_x = V_x\angle\theta_x$ (x=i, j and k). V_{sein} is the complex controllable series injected voltage source, defined as $V_{sein} = V_{sein}\angle\theta_{sein}$ (n=j ,k) and Z_{sein} (n=j ,k) is the series coupling transformer impedance [13].

The active and reactive power injections at each bus can be easily calculated by representing IPFC as current source. For the sake of simplicity, the resistance of the transmission lines and the series coupling transformers are neglected. The power injections at buses are summarized as

$$P_{inj,i} = \sum_{n=j,k} V_i Vseb_{in} \sin(\theta_i - \theta se_{in}) ----------(1)$$

$$Q_{inj,i} = -\sum_{n=j,k} V_i Vseb_{in} \cos(\theta_i - \theta se_{in}) ---------- (2)$$

$$P_{inj,i} = -V_n Vse_{in} b_{in} \sin(\theta_n - \theta se_{in}) ----------(3)$$

$$Q_{inj,i} = V_n Vse_{in} b_{in} \sin(\theta_n - \theta se_{in}) ----------- (4)$$

The equivalent power injection model of an IPFC is shown in Fig. (3). As IPFC is neither absorbs nor injects active power with respect to the ac system; the active power exchange between the converters via the dc link is zero, i.e.

$$Re\left(Vse_{ij} I_{ji}^{*} + Vse_{ik} I_{ki}^{*}\right) = 0 ----------(5)$$

Where the superscript * denotes the conjugate of a complex number. If the resistances of series transformers are neglected, (5) can be written as

$$\sum_{m=i,j,k} P_{inj,m} = 0 ----------(6)$$

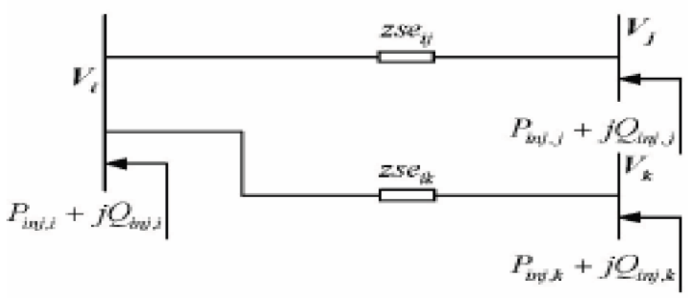

Fig. (2): Power injection model of two converter IPFC

Normally in the steady state operation, the IPFC is used to control the active and reactive power flows in the transmission lines in which it is placed. The active and reactive power flow control constraints are,

$$P_{ni} - P_{ni}^{spec} = 0 ----------(7)$$

$$Q_{ni} - Q_{ni}^{spec} = 0 ----------(8)$$

Where n=j, k; P_{nispec} , Q_{nispec} are the specified active and reactive power flow control references respectively, and

$$P_{ni} = Re(V_n I_{ni}^{*}) ----------(9)$$

$$Q_{ni} = Im(V_n I_{ni}^{*}) ----------(10)$$

Thus, the power balance equations are as follows

$$P_{gm} + P_{inj,m} - P_{im} - P_{line,m} = 0 ----------(11)$$

$$Q_{gm} + Q_{inj,m} - Q_{im} - Q_{line,m} = 0 ----------(12)$$

Where P_{gm} and Q_{gm} are generation active and reactive powers, P_{im} and Q_{im} are load active and reactive powers. $P_{line,m}$ and $Q_{line,m}$ are conventional transmitted active and reactive powers at the bus m=i, j and k

III. LOAD FLOW ANALYSIS - NEWTON RAPHSON METHOD

From the mathematical modelling point of view, the set of nonlinear, algebraic equations that describe the electrical power network under the steady state conditions are solved for the power flow solutions.

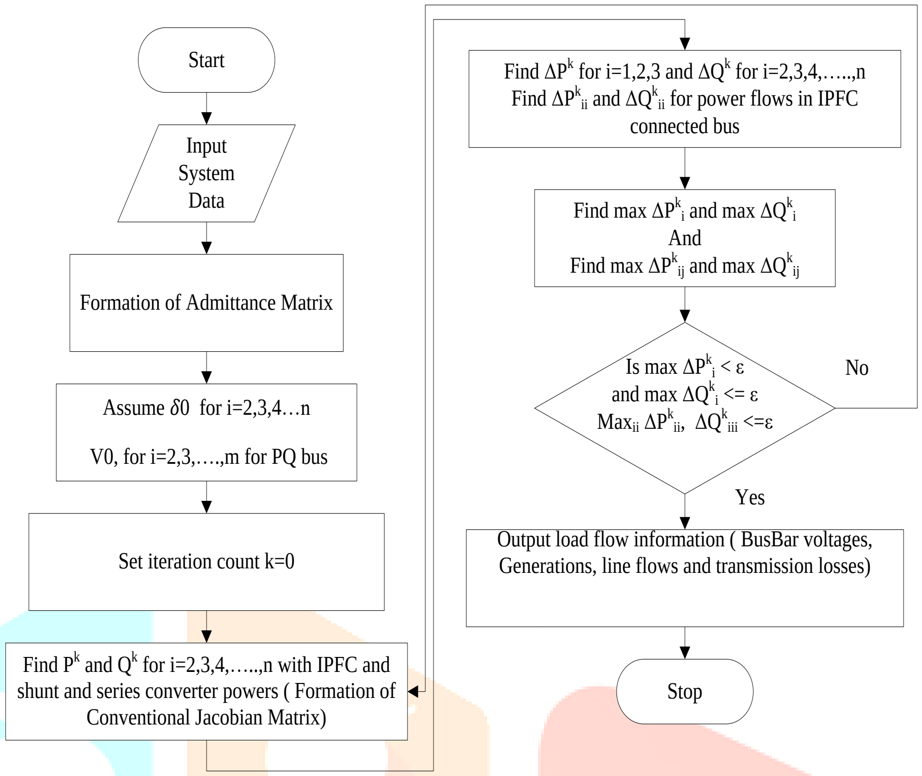

Fig.(3): Flow chart of N-R method

IV. SIMULATION AND RESULT

The test system is shown in Fig (4) Bus one is considered as slack bus, while bus 2 and bus 3 are generator buses and other buses are load buses. For all the cases, the convergence is 1X10-5 p.u. System base MVA is 100.

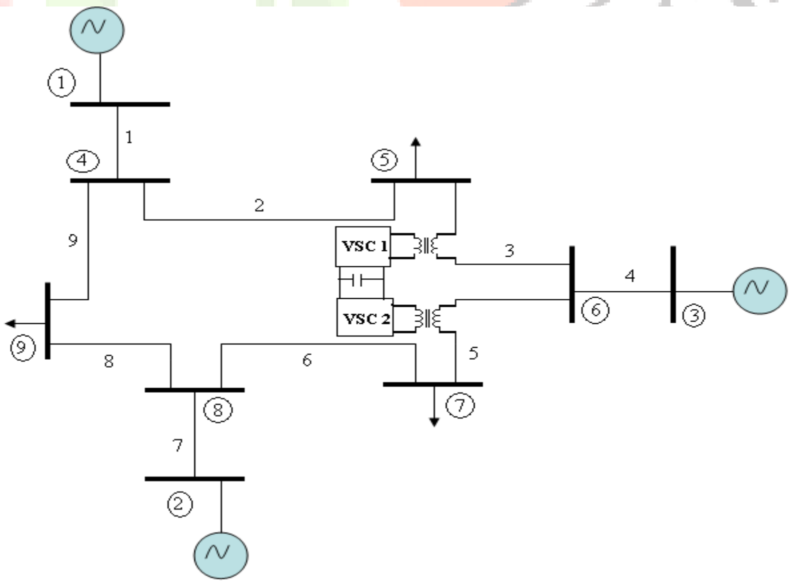

Fig.(4): IEEE-9 bus system

Table (1): Active & Reactive Power demand and Bus parameters

Bus No	Type	Pd (MW)	Qd (MVAR)
1	3	0.0	0.0
2	2	0.0	0.0
3	2	0.0	0.0

From Bus	To Bus	R (p.u)	X (p.u)	B (p.u)
1	4	0.0	0.0576	0
4	5	0.0171	0.09201	0.1580
5	6	0.03901	0.1702	0.3580

4	1	0.0	0.0
5	1	105.0	50.0
6	1	0.0	0.0
7	1	215.0	80.0
8	1	0.0	0.0
9	1	125.0	50.0

3	6	0.0	0.058601	0.0
6	7	0.011902	0.1008.06	0.20901
7	8	0.00850	0.07201	0.1490
8	2	0.0	0.06250	0.250
8	9	0.0320	0.1610	0.3060
9	4	0.010	0.0850	0.1760

Table (2): Active & Reactive Power generated

Bus No	Pg (MW)	Qg (MVAR)	Qmax (MVAR)	Qmin (MVAR)
1	0.0	0.0	300.0	-300.0
2	163.0	0.0	300.0	-300.0
3	85.0	0.0	300.0	-300.0

The two converters of IPFC are embedded in lines 3 and 5 respectively and bus 6 is selected as common bus for the two converters. The complex bus voltages, active and reactive power flows of the test system without and with IPFC are summarized in Table (3).

From Table (3) it can be seen that the voltages at slack bus and generator bus are same without and with IPFC and there is a change in load bus voltages. Especially, the voltage at bus 6 increases remarkably to which IPFC converters are connected. It is also evident that the active power flow in line 5 increases to double of its values from without IPFC to with IPFC.

Table (3): Volatge and power flow with & without IPFC

Bus No	Voltage (p.u)	
	Without IPFC	With IPFC
1	1.04	1.04
2	1.0200 - 1.3271i	1.0170 - 1.3332i
3	0.84161 - 0.8825i	0.83902 - 0.8831i
4	0.9998 - 0.2483i	1.0011 - 0.2472i
5	0.9467 - 0.5359i	0.9494 - 0.5353i
6	0.87021 - 0.9141i	0.8764 – 0.9135i
7	0.9429 - 1.2367i	0.9499 - 1.2417i
8	1.0618 - 1.4010i	1.0596 - 1.4083i
9	1.3960 - 2.086i	1.3889 - 2.090i

Line No	Power Flow (p.u)	
	Without IPFC	With IPFC
1	4.4816+0.7239i	4.4625+0.7053i
2	-3.1173 + 0.7699i	-3.1283 + 0.78999i
3	2.0665 - 1.2420i	2.0964 - 1.2076i
4	0.0208 - 0.8868i	0.0219 - 0.8403i
5	1.6801 - 3.7444i	1.7086 - 3.6045i
6	0.3971 + 4.3436i	0.4117 + 4.3886i
7	-0.3169 + 2.3663i	-0.3219 + 2.4061i
8	-0.0128 - 8.1638i	-0.0139 - 8.1309i

V. CONCLUSION

A power injection model of the inter line power flow controller (IPFC) has been presented. This model is incorporated in Newton-Raphson power flow algorithm to demonstrate the performance of IPFC. Results on the test system show that, the active power flow through the lines in which IPFC is placed increases. Also, there is a significant change in the system voltage profile at the neighbouring buses and increase in the voltage at a bus to which IPFC converters are connected .This shows that multi control capability of IPFC which plays an important role in power systems.

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