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A New Approach to Powerflow Management in Transmission System Using Interline Power Flow Controller

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ABSTRACT
In this paper a new approach to power flow management in transmission system using interline Power Flow Controller (IPFC) is proposed and model for IPFC is developed and simulate by MATLAB software. Interline Power Flow Controller is a versatile device can be used to control power flows of a multi-line system or sub-networks An Interline Power Flow Controller (IPFC) is a converter based FACTS controller for series compensation with capability of controlling power flow among multi-lines within the same corridor of the transmission line. It consists of two or more Voltage Source Converters (VSCs) with a common dc-link. Real power can be transferred via the common dc-link between the VSCs and each VSC is capable of exchanging reactive power with its own transmission system.

Keyword- Interline Power Flow Controller (IPFC), Voltage Source Converter (VSC), Transmission Line, Reactive Power,

I. INDRODUCTION

The increasing use in the industry of non linear loads based on the power electronic elements introduced serious perturbation problems in the electric power distribution grids. Also, regular increase in the harmonic emissions and current unbalance in addition to high consumption of reactive power can be noticed. Recently with interconnection between power system and expansion in transmission and generation for satisfy the increasing power demand, dynamic stability of power systems are an important object in stability of the great power systems. Power System Stabilizer (PSS) have been used as a simple, effective, and economical method to increase power system oscillation stability. While PSS may not be able to suppress oscillations resulting from severe disturbances, such as three phase faults at generator terminals [I]. Flexible AC Transmission System (FACTS) controllers, such as Static Var Compensators (SVC), Static Synchronous Compensators (STATCOM), and Unified Power Flow Controller (UPFC), can be applied for damping oscillations and improve the small signal stability of power systems by adding a supplementary signal for main control loops. Interline Power Flow Controller (IPFC) is a new concept of the FACTS controller for series compensation with the unique capability of controlling power flow among multiline. The IPFC employs two or more voltage source converters (VSCs) with a common dc-link, Each VSC can provide series compensation for the selected line of the transmission system (master or slave line) and is capable of exchanging reactive power with its own transmission system. .The consumption of reactive power in industrial and domestic loads presents also an important issue in the discussion of power quality problems. The reactive power consumed by non resistive loads causes higher RMS current values in addition to extra heating of power transmission and distribution systems. The use of batteries of capacitors or synchronous machines for local reactive power production has been proposed for a long time. The accelerated development of power electronics and semiconductor production has encouraged the use of STATIC VAR compensators for the reactive power compensation. However, these solutions looks inefficient and can cause extra problems in power systems in the case of high current and voltage harmonic emissions. The fact that these systems are especially designed to compensate the fundamental based reactive power, in addition to high possibilities of interaction between these compensation elements and system harmonics make it unstable solutions in modern technologies. During the last three decades, researchers were encouraged by the development of power electronics industry, the revolution in digital signal processing production and the increasing demand for efficient solutions of power quality problems including harmonics problem. They were encouraged to develop modern, flexible, and more efficient solutions for power quality problems. These modern solutions have been given the name of IPFC compensators. The objective of these IPFC is to compensate harmonic currents and voltages in addition to selective reactive power compensation. The damping controller of low frequency oscillations in the power system must be designed at a nonlinear dynamic model of power system, but because of difficulty of this Process, generally the linear dynamic model of system at an operating point is put and analysis to design the controller and an obtained controller is investigated in the nonlinear dynamic model for its accuracy and desirable operation at damping of oscillation

Interline Power Flow Controller:

Recent developments of FACTS research have led to a new device: the Interline Power Flow Controller (IPFC). This element consists of two (or more) series voltage source converter (VSC) installed in two (or more) lines and connected at their DC terminals. Thus, in addition to serially compensate the reactive power, each VSC can provide real power to the common DC link from its own line. The IPFC gives them the possibility to solve the problem of controlling different transmission lines at a determined substation. In fact, the under-utilized lines make available a surplus power which can be used by other lines for real power control. This capability makes it possible to equalize both real and reactive power flow between the lines, to transfer power demand from overloaded to under-loaded lines, to compensate against resistive line voltage drops and the corresponding reactive line power, and to increase the effectiveness of a compensating system for dynamic disturbances. Therefore, the IPFC provides a highly effective scheme for power transmission at a multi-line substation. Fig 1 shows the Schematic representation of IPFC.

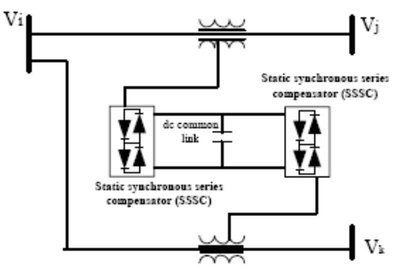

Fig 1 Schematic representation of IPFC

Controlling Scheme:

The grid voltage signal V_{abc} is transformed into V_d and V_q by the abc-dq transformation block and the phase information of voltage v_{abc}, which is acquired with a phase locked loop (PLL).

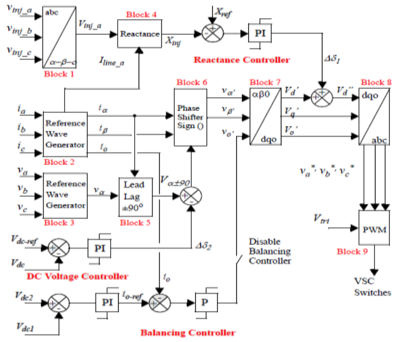

Fig 2 VSC controlling circuit

Therefore, active and reactive power decoupling can be achieved. Then the DC voltage v_{dc} is compared with a given reference voltage v_{dcref}. The error of v_{dc} and v_{dcref} will go through PI (proportional integral) controller and then compared with the d component of the three-phase voltage, then the result will go through another PI controller as an output voltage. In the meanwhile, the q component of the three-phase voltage is compared to a given value 0, and the PI controller output a value, which controls the q component of the command signal.

Then the dq components of the voltage are obtained using the mathematical relationship between the current and voltage after the inverse transformation. Afterwards, the switch control signals will be accomplished with a space vector PWM (SVPWM) control module.

Basic Structure & Principle Of Operation Of Ipfc

In its general form, the IPFC employs number of dc to dc converters, each providing series compensation for different line. The converters are linked together at their dc terminals and connected to the ac systems through their series coupling transformers. With this scheme, in addition to providing series reactive compensation, any converter can be controlled to supply active power to the common dc link from its own transmission line[5].For an IPFC with m series converters, the control degree of freedom of m-1 series converters is two, except that one series converter has one control degree of freedom since the active power exchange among the m series converters should be balanced at any time. An IPFC with two converters compensating two lines is similar to UPFC in which the magnitude and phase angle of the injected voltage in the prime system (or line) can be controlled by exchanging real power with the support system (which is also a series converter in the second line). The basic difference with a UPFC is that the support system in the later case is the shunt converter instead of a series converter. The series converter associated with the prime system of one IPFC is termed as the master converter while the series converter associated with the support system is termed as slave converter. The master converter controls both active and reactive voltage (within limits) while the slave converter controls the DC voltage across the capacitor and the reactive voltage magnitude[6].

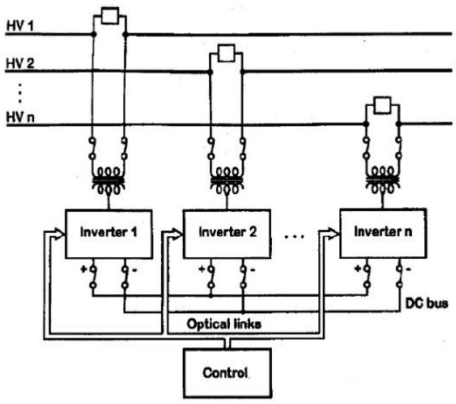

Fig.3. A Interline Power Flow Controller comprising n converters

II. SIMULATION AND RESULTS

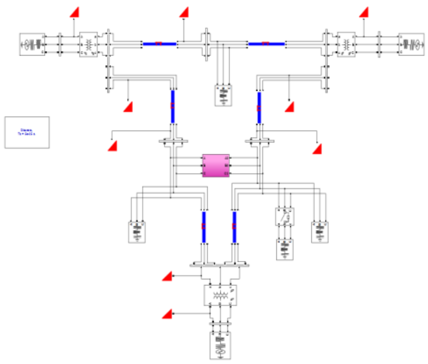

Fig 4 simulink model of IPFC controller

To investigate the effect of IPFC in power system and study it's effect of power flow the simplest power system as shown in Fig.4 are implemented as test power system. This test power system with installing IPFC is shown in Fig.4
For better understanding the effect of IPFC on power system the results of power flow including voltage magnitude and voltage profile and real and reactive power flow in all transmission lines without IPFC are presented in table 1.

Table 1 load flow analysis of IEEE 9 Bus system(fault condition)

Bus no	Base voltage	Phase angle	P	Q
1	1.04	0.00	210.07	117.64
2	1.03	0.39	163	53,80
3	1.03	-2.47	85	18.52
4	0.98	-6.80	0.00	0.00
5	0.89	-14.87	177.33	110.93
6	0.98	-8.61	78.35	30.4
7	1,00	-5.33	0.00	0.00
8	0.99	-7.18	90.13	31.55
9	1.02	-5.17	0.00	0.00

Table 2 load flow analysis of IEEE 9 Bus system(with IPFC)

Bus no	Base voltage	Phase angle	P	Q
1	1.04	0.00	107.60	46.06
2	1.03	6.81	163	17.50
3	1.03	2.27	85	3.63
4	1.02	-3.35	0.00	0.00
5	0.99	-6.69	121,12	48,57
6	0.99	-.5.53	88.97	34,60
7	1,02	1.23	0.00	0.00
8	1.01	-1.56	101.39	35.48
9	1.02	-0.44	0.00	0.00

After obtaining initial results without IPFC the three case studies are presented and analyzed to investigate the effect of IPFC.

III. CONCLUSIONS

In this paper the effect of IPFC in power system is analyzed and various parameters such as voltage profile and real and reactive power flow in transmission lines of system are investigated. A power injection model of the Inter line Power Flow Controllers (IPFC) have been presented. In this model, the complex impedance of the series coupling transformer and the line charging susceptance are Included. It shows that the incoming of IPFC can increase the bus voltage to which IPFC converters are connected and there is a significant change in the system voltage profile at the neighboring buses, increase in active power flow and decrease in reactive power flow through the lines.

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