Modeling of HPFC Controller Using Multi - Machine Power System with Acting as Different Control Modes

A. Murugan, V. Ramakrishnan

Abstract--- Mainly this paper is focusing about the power flow model of the HPFC created for insistent state investigations of intensity frameworks with the help of different control system model. Then numerical investigations exhibited here are completed utilizing a two-area network model. This HPFC controller is using for controlling Real Power, Voltage control, Power Changes from the system parameters. In FACTS device the HPFC controller has been multitalented to its capability control of Real and Reactive Power. Also HPFC controller modeling has been done with the help of mathematical equations for different modes of operation as per kundur 2 area 4 machine 12 bus system. With the help of 2 area power system model is shown about PVV, PQQ, shunt Susceptance and Impedance control of system model. Each and every method is showing different kind of performance including of HPFC Controller. For better performance of power system only has been used the HPFC Controllers comparing other Controllers in FACTS Device. These and all is considering about different modes of operation. With the help of MATLAB Software different modes of modeling has been simulated. Transmission frameworks are normally substantial and complex electrical circuits consisting of several age/utilization hubs and a large number of transmission lines. Controlling the flow of intensity between the hubs in such complex circuits is a testing issue. It is additionally confused by the need to control the voltage at every hub to inside a little resistance of the appraised esteem. The strategy is approved by multi-machine-9 bus system utilizing MATLAB content record.

Keywords--- FACTS, UPFC, HPFC, Power Flow, Voltage Magnitude, PVV, PQQ, Modeling of HPFC.

I. INTRODUCTION

Now a day we need the more power for living in this world because of populations are increasing in all places. So that purpose we can't generate the more power but can be minimize the losses in transmission line with the help of FACTS Devices. The HPFC Controller is acting the one of the type in FACTS Devices. When comparing with other FACTS Devices this will be shows better performance in power system. In some persons has been completed the project based on the STATCOM and UPFC several voltage converter FACTS Devices. Along with this controller the UPFC in adaptable (versatile or flexible) device that can be controlled different control system variables separately. Those control variables are Bus Voltages and active and Reactive power flow of overhead transmission line in power system. In this paper has been discussed about Hybrid Power Flow Controller.

Previously mechanical relay, contactors etc are using to control the power flow in transmission line for security of overhead transmission system. The shunt converter and series converter of UPFC is controlling of synchronizing with the help of active and Reactive Power. This control approach is uses for achieving power flow control and damping improvement of a multi machine power system. As well as the HPFC controller internal variables are characterized in this system and it allowing exact devices limit. Along with this HPFC Controller is includes the different multiple control Modes.

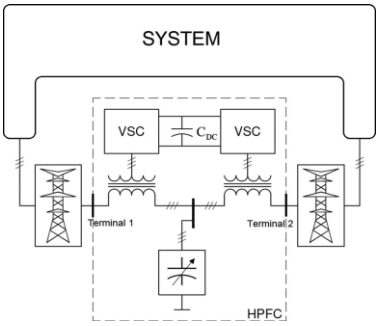

Fig.1: Structure of HPFC System

The system point of view HPFC controller circuit model has been shown. It shows hat two series Voltage sources correspond to the important components of the controller because of its have a variable susceptance. Along with voltage sources is presented the voltage V_i and V_j. The HPFC controller is available four possible control modes. Those modes are mentioned as the PVV Mode, PQQ Mode, V Mode and Z_s Mode. Even though this kind of controller is mainly depends upon the PVV and PQQ Mode sources other than of V and Z_S Modes. P, V_i, V_j are set points of PVV and similarly P,Q_1,Q_2 are set points of PQQ Mode. If this controller limits are attained in PQQ Mode at that time the estimations of P, Q_1 and Q_2 are proficient by the utmost proposed in HPFC Controller. As well as power cannot be normalized in voltage mode due to controller as far as possible came to in two arrangement voltage sources skirted. In the event that the shunt susceptance might be touched base at certain power exchange level implies that time controller point returned as a Z_S Mode. The V and Zs modes are defined as follows $V_i = V_j = V_m$ and $V_a = V_b = 0$.

II. HPFC EQUIVALENT CIRCUIT

The current magnitudes are mentioned as I_i and I_j
The voltage inverter magnitudes are mentioned as V_i and

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A. Murugan, Research Scholar, Sathyabama Institute of Science and Technology, Chennai, Tamil Nadu, India. (e-mail: murugana2007@gmail.com)
Dr.V. Ramakrishnan, Dean, Madha Engineering College, Chennai, Tamil Nadu, India.

V_j. The shunt device magnitude and Susceptance magnitudes are mentioned as V_{dm} and B_m From this equivalent circuit can be calculated the magnitudes along with angles shown in below.

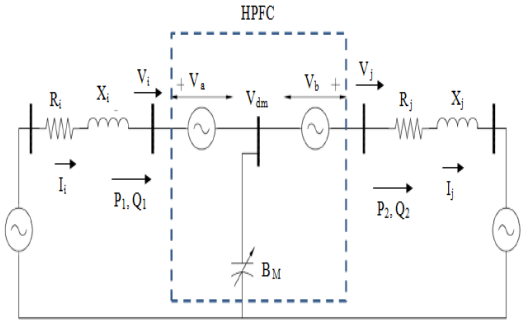


Fig.2: Equivalent Circuit

$$I_i = I_i \angle \delta_i \quad (1)$$

$$V_i = V_i \angle \delta_i \quad (2)$$

$$I_j = I_j \angle \delta_j \quad (3)$$

$$V_j = V_j \angle \delta_j \quad (4)$$

$$V_a = V_a \angle \delta_a \quad (5)$$

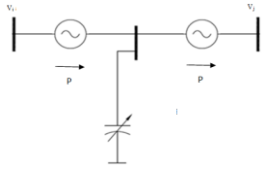
$$V_b = V_b \angle \delta_b \quad (6)$$

$$V_{dm} = V_{dm} \angle \delta_{dm} \quad (7)$$

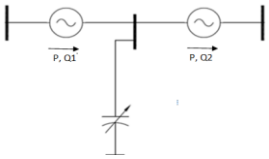
In this equivalent circuit entirely different from Ordinary Circuit Diagram. Sending end side and Receiving end side is having the resistance (R_i) with reactance (X_i) as well as both powers (P_i and Q_i) are included in this circuit. Similarly this sending end side and receiving end side flowing current and Voltage along with its corresponding or respective angle. In the middle of equivalent circuit is available HPFC controller for producing better performance because of its middle point capacitance.

III. POWER FLOW CONTROL

This power flow solutions is mainly focusing for to calculate the steady state conditions, Power flows Phasor voltages. Actually if input is given from the system to solve operating point calculating power flows. Then operating point is calculating the value of HPFC based on these equations. After all iterations are completed it checking the boundary conditions included the HPFC System values.



(i) PVV Diagram



(ii) Fig.4: PQQ Diagram

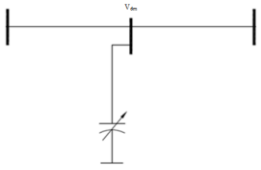


Fig.5: V

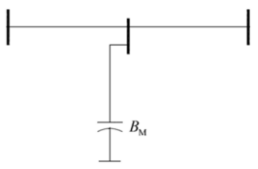


Fig.6: Zs

Fig.3: Different Modes of Operation

If the output is wrong means once again the iterations will be conducted automatically till getting exact output. As well as if not getting proper output in the iterations will be conducted through the way of checking point in power system. Then it is combined together with the execution output place. Once all iterations are completed final result will be indicated with the help of HPFC System.

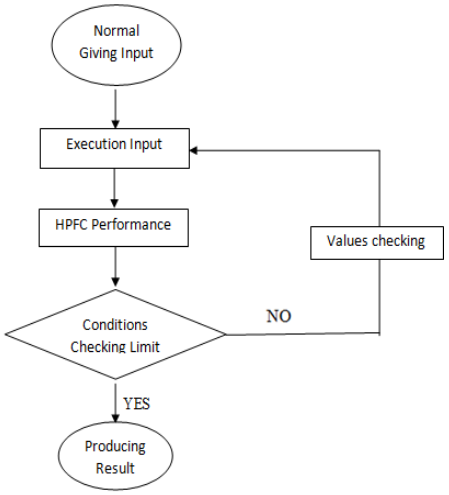


Fig.4: Flow Chart of HPFC Performance

IV. POWER FLOW CONTROL

The accompanying generation of FACTS controllers for the advancement of FACTS controllers

4.1. First Generation:

The static Var Compensators (SVC), Thyristor Controlled Series Capacitor (TCSC), and Thyristor Controlled Phase Shifting Transformer (TCPST) are called as First Generation of FACTS Controllers.

4.2. The Second Generation:

The Static Synchronous Compensator (STATCOM), Static Synchronous Series Compensator (SSSC), Unified Power Flow Controller (UPFC), and Interline Power Flow Controller (IPFC) are called as second generation of FACTS controllers.

4.3. Third Generation

The Fuzzy model reference learning controller (FMRLC) and Hybrid Power Flow Controller (HPFC) are called as third generation of FACTS controllers.

From above generation everyone knows about only first and second generation but few peoples only knows about Third generation. So here we also considered about HPFC controller for modeled this device.

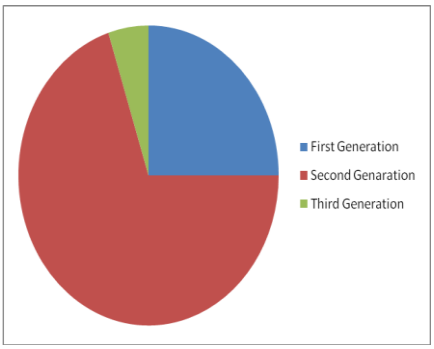


Fig.5: Generation of FACTS Controllers

A hybrid method is available in series capacitive compensation. Then it is accessible of two phases are connected by fixed series capacitor along with this one more phase is connected by a TCSC in arrangement with a settled capacitor.

In FACTS Device TCSC is mainly used to damp the low frequency oscillations.

In addition to evaluate effect of the TCSC in damping Low frequency oscillations purpose only is conceded the Fast Fourier Transform.

V. TWO AREA POWER SYSTEM MODEL

In this paper is mainly focusing with two area network model as shown in fig. This model has presented about 2 area power system which is connected linking area 1 to area 2 using Long Transmission line with the help of Series FACTS device. This model has presented about variable impedance, capacitor, reactor, variable frequency, sub synchronous and harmonic frequencies. In series with the line all series controllers are injected voltage. The current flow is corresponding to injected series with line because even the variable impedance is increased via current flow.

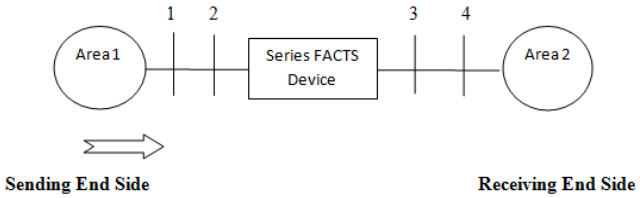


Fig. 6: Series connection

This model has presented about 2 area power system which is connected linking area 1 to area 2 using Long Transmission line with the help of Shunt FACTS device. The variable impedance, variable connection and other devices are presented in Shunt Controller. Each and every this kind of shunt controllers and all injecting current addicted to the system time condition. Even variable shunt impedance is also over connected to ted voltage barrier or line voltage created a variable current flow and hereafter corresponds to current into the line. As search for injected advanced is in phase quadrature by the whole of the line voltage, the variable reactive power is fundamentally contributed or consumed by means of shunt controller.

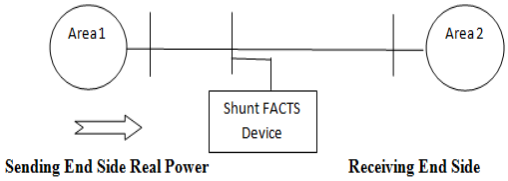


Fig.7: Shunt connection of Two Area FACTS Device

VI. HPFC MODELLING

Here some of the variables and parameters are used in this controller. That and all is given in below.

- Both Currents I_i and I_j
- Inverter voltages V_a and V_b
- Shunt device voltage and susceptance V_m and B_M.

Normally the V_a and V_b value is chosen very small because of max allowable device to keep inverter rating and cost as low as could be allowed. So that limit $V_m = |V_i - V_a| = |V_j - V_b|$ is reliant on the terminal voltages V_1 and V_2. To improve stability model two series branches current and voltage magnitude limits represented directly.

The controller terminals of voltage magnitude and active power flow are controlled independently. Suppose the system conditions are changes means the HPFC system may switch to the control modes. Actually in this modeling has to be considered only 4 modes shown in figure 3.then set points for P, V_1,V_2 are desired means that entire PVV mode starts operating. By doing linearization only can be calculated the PVV mode values.

The limit violates will not be determined by modifying P, Q_1, Q_2 Values if PQQ mode. The series voltages are bypassed in V mode means that time voltage magnitude V_m will be presented in standardized mode. The PVV device is responding to the very much increasing demand because of slightly modification in HPFC System. To keep away from excess of device ratings using more constrain in PVV System. If the controller point is fixed value in the network because of power transfer level will be maintaining constant in shunt susceptance. These and all observed from Z mode. From this V and Z modes, $V_1 = V_2 = V_{dm}$ and $V_a = V_b = 0$. Here dc link may be presented the constant voltages in equivalent circuit due to assuming in al lossless in controller. Then with the help of converters the total active powers are generating means internal losses are comes to reach at zero or omitted. So the zero net active power switchover or replaced between the device terminals and the grid.

Finally different kinds of control modes are shown in fig below. The set points of P, V1, V2 values are desired means PVV controller start to activating. If main variable of the controller limits reaches in I_i, I_j, V_a and V_b to PQQ mode, then its set points in P, Q_1, Q_2 are desired for determined the violation limit.

The controller network two modes are similarly presents here due to this PVV and PQQ mode closely meet the criteria. The shunt bus voltages magnitude V_{dm} is adjusted with the help of shunt susceptance B_M in two series voltage mode.

6.1. PVV Mode

The controller is underestimated to direct the dynamic power stream and the terminal voltages in the level. At that point this is dependable controller remains inside its breaking points. The point of confinement infringement isn't decreased through changes the BM esteem, controller is underestimated change to take vitally represent the PQQ Mode.

6.2. PQQ Mode

Actually the current and voltages are presented and producing output in within this limits at both in same time. Then the concerning internal voltages and current are presented in sensitivity of the controller for maintaining same limits the current and voltage values are changes. With the help of sensitivity matrix G and the magnitude limits P, Q_1, Q_2 values are given in this paper. As well as the new power flow results are getting converges like Neuton - Rahson Method. If any violation is presents means its share equal in incremental steps. This procedure continuously doing until the convergence is attained in the Power flow. When this iterations are going on continuously because the limits are checking correctly. Once the maximum iterations reached and displayed the results if not achieving the convergence.

PQQ Set point Calculations

The P, Q1, Q2 values are calculating with the help of following equations along with sensitivity analysis. So the devices terminal voltages are inflexible using G matrix.

$$G = \begin{bmatrix} \frac{\partial P}{\partial I_s} & \frac{\partial P}{\partial I_R} & \frac{\partial P}{\partial V_s} & \frac{\partial P}{\partial V_R} \\ \frac{\partial Q_1}{\partial i_S} & \frac{\partial Q_1}{\partial I_R} & \frac{\partial Q_1}{\partial V_s} & \frac{\partial Q_1}{\partial V_R} \\ \frac{\partial Q_2}{\partial I_s} & \frac{\partial Q_2}{\partial I_R} & \frac{\partial Q_2}{\partial V_s} & \frac{\partial Q_2}{\partial V_R} \end{bmatrix} \quad (8)$$

Where o is alludes to the beginning estimations of every required variables.

Factor K is 0.5 is the iterative procedure m circle counter.

Modern sensitivity matrix:

In PQQ mode all conditions was inferred by just suspicions esteems. For the most part in control stream conditions are exhibited of whatever is left of the framework was not considered here due to discarded in focused on working mode conditions. So the small amount of values only using in Va and Vb to adjustment to the terminal voltage. Then using this equations sensitivity value has to be improved on the subject of Va and Vb. Finally these equations may be written by following way.

$$dv_a \simeq dv_1 \text{ and } dv_b \simeq dv_2 \quad (9)$$

$$\frac{\partial p}{\partial v_a} = \propto * \frac{\partial p}{\partial v_1} \quad (10)$$

$$\frac{\partial p}{\partial v_b} = \propto * \frac{\partial p}{\partial v_2} \quad (11)$$

Shunt Susceptance B_M

The shunt devices voltages and BM are mainly committed by inverter output of the voltage magnitude. If Vm value is lies amongst Vdm1 and Vdm2 then it accomplished the littlest qualities for Va and Vb.

6.3. Magnitude of Voltage Mode

In this method is shown about two series voltage sources. This series voltages are bypassed $V_i = V_j = V_{dm}$. By means of the variable shunt susceptance B_M value is normalized or controlled the voltage magnitude terminals in the given level. In any case, it isn't having the dynamic power stream in the gadget. Consequently the control stream is run envisioning the gadget terminals and the shunt transport merged into one transport with controlled voltage greatness. In this manner the control stream does not merged and the control mode changes are moved to Z mode. Something different with respect to the present furthest reaches of the inverter is chiefly try out the most astounding of info and yield streams or currents (I_i and I_j)

6.4. Mode of Impedance

The Zs mode is available to min regulating capacity in HPFC. If the B_M value is fixed at its min value and $V_i = V_j = V_{dm}$, then the device can be shown at a at a uninvolved settled shunt susceptance in control stream conditions or power flow equations.

Usually FACTS device is connected in Transmission Side only. So in this diagram also HPFC controller is connecting between Bus 8 and Bus 11. By means of the help three set points the active power flow and voltage magnitude PVV is controlling from controller. As well as the loads and all connected between Bus 2 and Bus 9.These two loads are used as transfer the power connecting these two points. Also these values and all will be increasing 0.1 p.u awaiting power flow not worked out.

Then parameter values and all showed in below.

Sending and Ending End Current Magnitude value max (for I_i and I_j) : 1 p.u

Voltage magnitude value max (for V_i and V_j) : 0.04 p.u

The four equal steps of shunt susceptance value:

0.5 P.u each ($0 \leq BM \leq 3$ p.u)

Set point of voltage magnitude in all terminals: 0.9 p.u

The maximum load is connected at Bus 9 because of end side connected as well as this value will be increased from 3.01 p.u to 4.02 p.u (301MW to 402MW).from the graph HPFC controller output is better comparing Without HPFC Controller because it shows maximum loadability and voltage profile.

The following diagram shows about different operating point in shunt susceptance and control modes. Then these kinds of devices and all started from PVV Mode because of depending on system load increasing conditions.

The greater and minor corridors active power is flowing through active power connecting two areas of power system. Then the HPFC controller connects to minor corridor because of power flow connecting or controlling in line.

VII. SIMULATION RESULTS

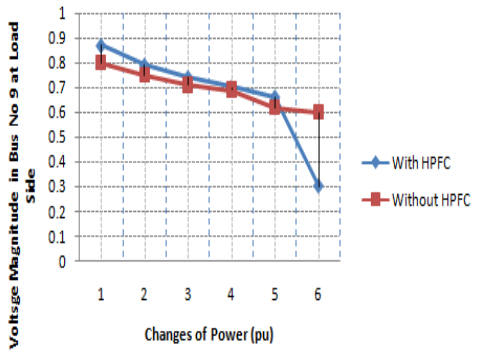


Fig.8: With and without HPFC Controller of PV Curves in Bus 9.

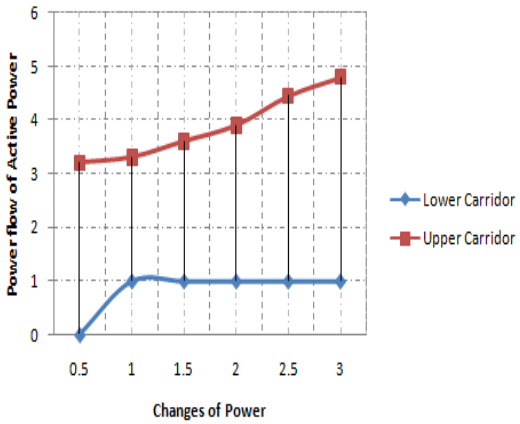


Fig. 9: Active Power Flow of tie line corridors.

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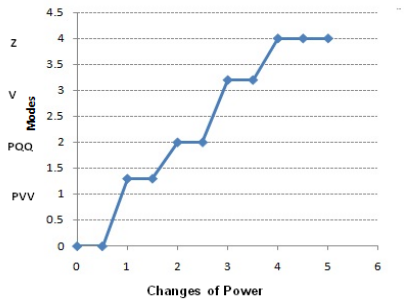

Fig.10: HPFC control modes level increases for the two-area system.

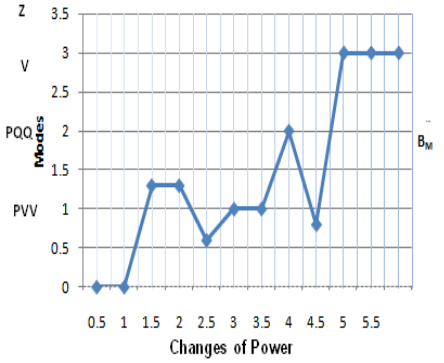

Fig. 11: HPFC control modes and BM as the loading level increases for the two-area system.

VIII. CONCLUSION

This paper shows about the diverse examinations and Control modes have been talked about. The HPFC working focuses are executed in this paper. The HPFC System sensible possibilities are chatted utilizing reenactment comes about. Consequently, the execution attributes of the HPFC of intensity framework are appeared to be like those generally connected with the UPFC. This paper is talked about various kind method of task i.e., PVV Mode, PQQ Mode, Impedance Mode and Voltage Mode. The numerical exhibition intensity framework components are considered in the displaying and additionally the multi machine test framework appeared in this paper.

APPENDIX

Table 1: Generator Datas

Bus No	P_G(p.u)	V(p.u)	Q_G (p.u)	δ
1	7	1.03	1.85	20.2
2	7	1.01	2.35	10.5
3	7.19	1.03	1.76	-6.8
4	7	1.01	2.02	-17.0

Table 2: Load Datas

Bus No	PL (p.u)	QL (p.u)
7	9.67	1
9	17.67	1

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