Master Slave Control Of Interline Power Flow Controller Using PSO Technique

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ABSTRACT

Electrical energy is transported from the generating point to the point of use through interconnected transmission lines .The flow of electricity through the transmission lines can be effectively and efficiently controlled by using interline power flow controllers instead of going for a new transmission lines.The construction of a new transmission lines is increasingly difficult because of various reasons such as regulatory, environmental, and public policies, as well as escalating cost [7].This paper Explains the Matlab/simulink model of interline power flow controller for a single phase four bus system for understanding of power flow in a transmission line .when interline power flow controller is installed between any two transmission lines the power flow in those lines will be greatly affected. Optimal injected parameters for the installed IPFC derived for the reduced transmission line losses using particle swarm optimization. And for implementing this we have taken IEEE-30 bus system data.

Keywords - **FACTS, IPFC, SSSC, VSI, PSO MATLAB/SIMULINK.**

I. INTRODUCTION

Interline Power Flow Controller (IPFC), is an advanced voltage-sourced converter (VSC) based FACTS (Flexible AC Transmission Systems) controller suitable for the power flow management of multiline systems. In recent years, power demand has increased substantially while the expansion of power generation and transmission has been severely limited due to limited resources and environmental restrictions [1]. In its general form the interline power flow controller employs number of DC to AC inverters each providing series compensation for a different line The reactive voltage injected by individual Voltage Source Converter (VSC) can be controlled to regulate active power flow in the respective line. While one VSC regulates the DC voltage, the other one controls the reactive power flows in the lines by injecting series active voltage. Since each inverter is also able to provide reactive compensation, the IPFC is able to carry out an overall real and reactive power compensation of the total transmission system. This capability makes it possible to equalize both real and reactive power flow between the lines, transfer power from overloaded to under loaded lines, compensate against reactive voltage drops and the corresponding reactive line power, and to increase the effectiveness of the compensating system against dynamic Disturbances [4].In this paper, a circuit model for IPFC is developed and simulation of interline power flow controller is done using the four bus system circuit model. Simulation is done using MATLAB/ simulink. The control parameters of voltage source converters used in Interline Power Flow Controller (IPFC) are designed to realize optimal power flow in power System with Newton-Raphson method. Based on the steady state model, the sizing of the controller in the network is formulated as an optimization problem to minimize the transmission line loss in the network. The power flow control constraints due to the use of interline power flow controller are included in optimal power flow problem in addition to the normal conventional constraints. Simulations results are obtained on standard IEEE 30-bus system to minimize the transmission line losses and optimal parameters of the controller are derived.

II. MATLAB/SIMULINK SIMULATION FOR IPFC

Digital Simulation of IPFC system is done using MATLAB simulink and the results are presented. A. model for IPFC system the single phase model of four bus system with IPFC is shown in figure 1. The transformer between the lines is indicated by a dependent voltage source [3]. By providing converters between two transmission lines, the reactive power, active power can be controlled.

In this IPFC model scopes are connected to observe the real and reactive powers in the loads.

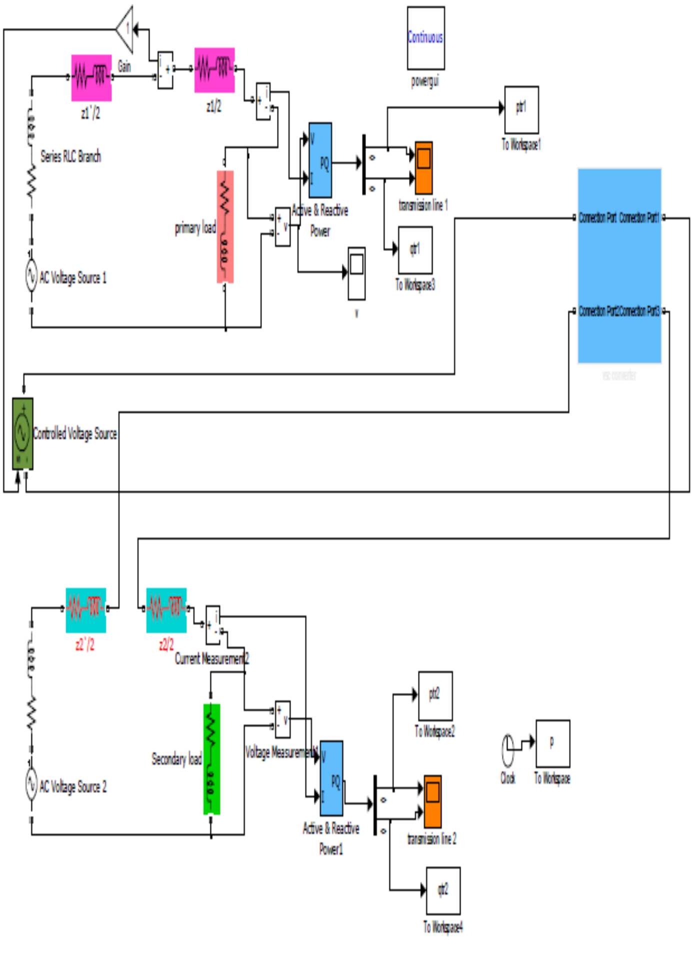


Fig1. Matlab Circuit model of IPFC system

For this IPFC model simulation results are presented as follows

Fig 2.Active Power flow in the transmission line 1

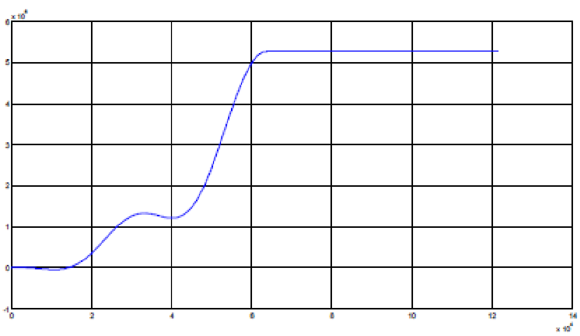


Fig 3. Active Power flow in the transmission line 2

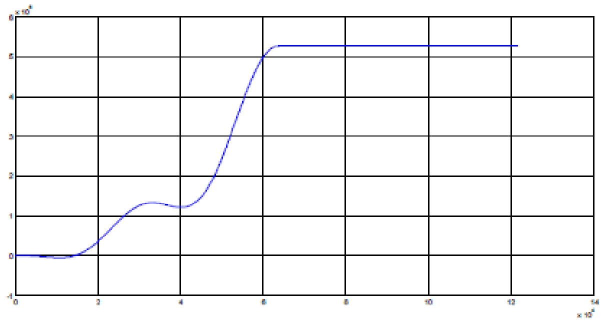


Fig 4. Reactive power flow in the transmission line 1

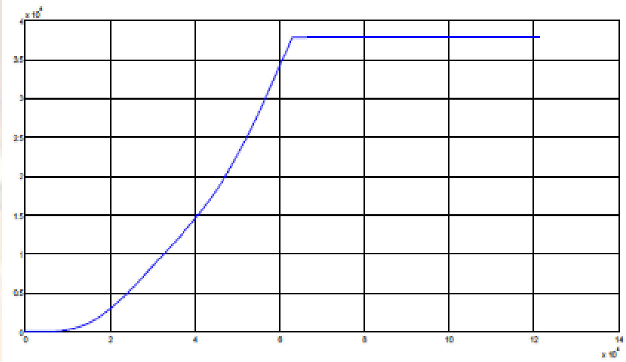
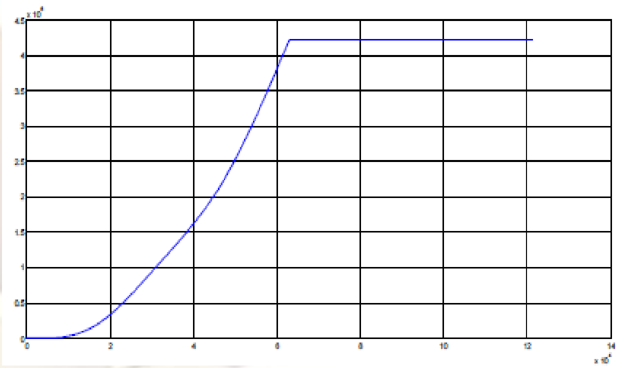


Fig 5. Reactive power flow in the transmission line 2

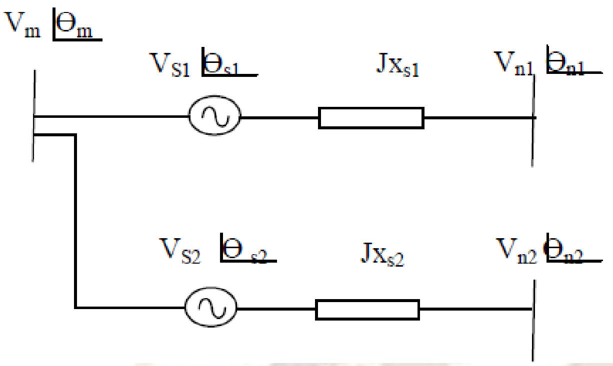


From these results we come to know that by controlling IPFC in an efficient way we can control the power flow. For efficient control of IPFC first we need to consider power flow equations.

III. POWER FLOW EQUATIONS OF IPFC

As shown in Fig 6. The two-voltage source converters of IPFC can model as two ideal voltage sources one connected in series and other in with the two buses.

Fig6. Equivalent Circuit of IPFC



The output of series voltage magnitude *Vse* controlled between the limits *Vinjmin* ≤ *Vinj* ≤*Vinjmax and* the angle Θ*inj* between the limits 0 ≤ Θinj ≤ 2Π respectively. The magnitude and the angle of the converter output voltage used to control the power flow mode and voltage at the nodes.IPFC power Equations (5). Based on the equivalent circuit as shown in Fig 2. The complex power injected by series converter I can be written as

$$S_{s1} = P_{s1} + JQ_{s1}$$

The active (P_{s1}) and reactive (Q_{s1}) powers injected by the series converter I are given by

$P_{s1} = -b_1\ V_m\ V_{s1} \cos(90-m+s_1\ ) + b_1\ V_{n1}\ V_{s1} \cos(90-m+s_1\ )$ …………………………(1)

$Q_{s1} = -b_1\ V_m\ V_{s1} \sin(90-m+s_1\ ) + b_1\ V_{n1}\ V_{s1} \sin(90-n_1+s_1) + b_1\ V^2_{s1}$ - …………………………(2)

Where $b_1 = 1/X_{s1}$ ……………………………..(3)

Where X_{s1} is series transformer reactance similarly the active (P_{s2}) and reactive (Q_{s2}) powers injected by the series converter II are given by

$P_{s2} = -b_2\ V_m\ V_{s2} \cos(90-m+s_2\ ) + b_2\ V_{n2}\ V_{s2} \cos(90-m+s_2\ )$ …………………………(4)

$Q_{s2} = -b_2\ V_m\ V_{s2} \sin(90-m+s_2\ ) + b_2\ V_{n2}\ V_{s2} \sin(90-n_2+s_2) + b_2\ V^2_{s2}$ - …………………………(5)

The active and reactive power flow in direction m-n_1 is given by $P_{mn1} = -b_1\ V_m\ V_{s1} \cos(90+m-s_1\ ) - b_1\ V_{n1}\ V_{s1} \cos(90+m-s_1)$ …………………………(6)

$Q_{mn1} = -b_1\ V_m\ V_{s1} \sin(90+m+s_1) + b_1\ V_{n1}\ V_{s1} \sin(90-n_1+s_1\ ) + b_1\ V^2_{s1}$ - …………………………(7)

The active and reactive power flow in direction m-n2 is given by $P_{mn2} = -b_2\ V_m\ V_{s2} \cos(90+m-s_2\ ) - b_2\ V_{n2}\ V_{s2} \cos(90+m-s_2)$ …………………………(8)

$Q_{mn1} = -b_2 V_m\ V_{s2}\ \sin(90+m+s_2\ ) + b_2\ V_{n2}\ V_{s1\backslash 2} \sin(90+n_2-s_2\ ) + b_2 V^2_{s2}$ - …………………………(9)

From the above equations we can say that power flow of the power system can be controlled by the series injected voltages. These injected voltages with variable magnitude and variable angle generated by the vsc converters. To find these injected parameters We are going to use PSo optimization technique.

IV. PARTICLE SWARM OPTIMIZATION

Iterative optimization is as old as life itself. Particle swarm optimization (PSO) was developed by Kennedy and Eberhart in 1995, based on the swarm behavior such as fish and bird schooling in nature. Many algorithms (such as ant colony algorithms and virtual ant algorithms) use the behavior of the so-called swarm intelligence. Though particle swarm optimization has many similarities with genetic algorithms and virtual ant algorithms, but it is much simpler because it does not use mutation/crossover operators or pheromone. Instead, it uses the real-number randomness and the global communication among the swarm particles. In this sense, it is also easier to implement as there is no encoding or decoding of the parameters into binary strings as those in genetic algorithms [6]. This algorithm searches a space of an objective function by adjusting the trajectories of individual agents, called particles, as the piecewise path formed by positional vectors in a quasitochastic manner. The particle movement has two major components: a stochastic component and a deterministic component. The particle is attracted toward the position of the current global best while at the same time it has a tendency to move randomly. When a particle finds a location that is better than any previously found locations, then it updates it as the new current best for particle i. There is a current best for all n particles. The aim is to find the global best among all. The current best until the objective no longer improves or after a certain number of iterations.

In PSO, the particles are “flown” through the problem space by following the current optimum particles. Each particle keeps track of its coordinates in the problem space, which are associated with the best solution (fitness) that it has achieved so far. This implies that each particle has memory, which allows it to remember the best position on the feasible search space that has ever visited. This value is commonly called Pbst. Another best value that is tracked by the particle swarm optimizer is the best value obtained so far by any particle in the neighborhood of the particle. This location is commonly called Gbst. The basic concept behind the PSO technique consists of change in the velocity (or accelerating) of each particle toward its Pbst and Gbst positions at each time step. This means that each particle tries to modify its current position and velocity according to the distance between its current position Pbst and , and the distance between its current position and Gbst. The position and velocity vectors of the i^{th} particle of a d-dimensional search space can be represented as $X_i = (x_{i1}, x_{i2}, \ldots\ldots\ldots x_{id})$ and $V_i = (v_{i1}, v_{i2}, \ldots\ldots\ldots v_{id})$ respectively. On the basis of the value of the evaluation function, the best previous position of a particle is recorded and represented as $Pbest_i = (P_{i1}, P_{i2}, \ldots\ldots\ldots P_{id})$. If the g^{th} particle is the best among all particles in the group so far, it is represented as $Gbst = Pbst_g = (P_{g1}, P_{g2}, ..P_{gd})$. The particle tries to modify its position using the current velocity and the distance from Pbst and Gbst. The modified velocity and position of each particle for fitness evaluation in the next iteration are calculated using the following equations

$$v_{id}^{k+1} = w \times v_{id}^{k+1} + c_1 \times rnd_1 \times (Pbst_{id} - x_{id}^{k}) + c_2 \times rnd_2 \times (Gbest_{id} - x_{id}^{k}) \quad \ldots\ldots(10)$$

$$x_{id}^{k+1} = x_{id}^{k} + v_{id}^{k+1} \ldots..(11)$$

Here w is the inertia weight parameter, which controls the global and local exploration capabilities of the particle. c_1, c_2 are cognitive and social coefficients, rnd_1 and rnd_2 are random numbers between 0 and 1. For the proposed method, $c_1 = 2$, $c_2 = 2$. A large inertia weight factor is used during initial exploration and its value is gradually reduced as the search proceeds. The concept of time-varying inertial weight is given by.

$$w = (w_{max} - w_{min}) \times \frac{it_{max} - iter}{it_{max}} + w_{min} \ldots..(11)$$

$$w_{max} = 0.9 , w_{min} = 0.4$$

Where, it_{max} is the maximum number of iterations.

V. IPFC CONTROL USING PSO

Power Flow Analysis for IEEE 30-bus Power: Simulation is performed on power flow analysis model of IEEE 30-bus power system [2] found the voltage and phase angle at each bus .Results are presented in the following table

S.NO	BUS NO	BUS VOLTAGE (p.u)	PHASE ANGLE (Degree)
1	1	1.0600	0.0000
2	2	1.0430	-5.3543
3	3	1.0196	-7.5308
4	4	1.0104	-9.2840
5	5	1.0100	-14.1738
6	6	1.0096	-11.0581
7	7	1.0020	-12.8649
8	8	1.0100	-11.8193
9	9	1.0392	-14.0644
10	10	1.0215	-15.6706
11	11	1.0820	-14.0644
12	12	1.0496	-15.1245
13	13	1.0710	-15.1245
14	14	1.0320	-16.0018
15	15	1.0251	-16.0084
16	16	1.0304	-15.6251
17	17	1.0188	-15.8687
18	18	1.0114	-16.6067
19	19	1.0066	-16.7658
20	20	1.0095	-16.5502
21	21	1.0082	-16.2178
22	22	1.0120	-15.9811
23	23	1.0085	-16.2294
24	24	0.9991	-16.3007
25	25	1.0032	-16.0720
26	26	0.9852	-16.5038
27	27	1.0145	-15.6559
28	28	1.0078	-11.7163
29	29	0.9944	-16.9077
30	30	0.9828	-17.8067

Table 1: Bus voltages And Phase angle of IEEE 30-bus power system

Power flow analysis for IEEE-30 bus system Using PSo: The PSO is applied to minimize the transmission line losses and to find the optimal parameters of the injected voltage source magnitude and angle of VSCs of the IPFC [6].The VSCs of the IPFC installed in lines 1-2 and 1-3 of standard IEEE 30-bus bench mark power system are represented as voltage sources with voltage magnitude and phase angle. The power flow analysis program is simulated using PSo and selecting the PSO parameters as in Table2.And also setting the limits for the injected voltage magnitudes of VSC between 0.0 < V_{inj} < 0.15(P.U) and the angles between -Π/2 < Θ_{inj} < Π/2, the simulation on power flow analysis program is performed. The VSC control parameters and the system line losses are presented as in Table3.

Table 2: PSO parameters

Parameters	Value
Number Of Iterations	1000
Swarm Size	50
Problem Dimension	4
Inertia weight Factor W	.9to 0.4
Weighting Factor C1 and C2	C1=C2=2
The Random Number rand1 and rand2	Between 0 and 1

Table 3: The Control Parameters and Losses

Lines	V_{inj} (P.U)	Θ_{inj} (Rad.)	Loss without IPFC (MW)	Loss with IPFC and PSo (MW)
1-2	.1293	1.2630	5.179	.0655
1-3	.1266	.9823	3.116	.3598

VI. SIMULATION RESULTS

The results were obtained using MATLAB 7.9.0, Intel® Core (TM) 2 duo CPU, T6600 @ 2.20 GHz, 3.46 GB RAM&32 Bit Windows7 operating system.

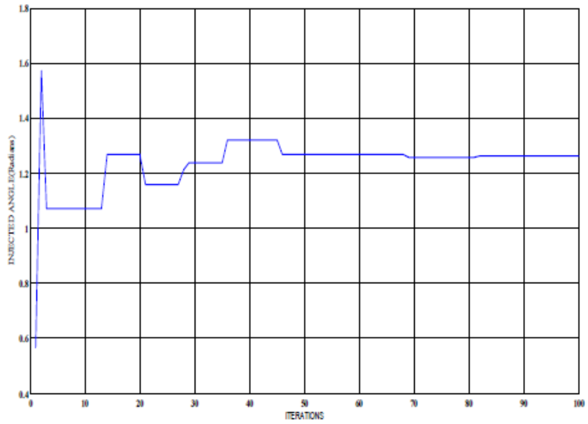


Fig7.Variation of injected angle with number of iterations

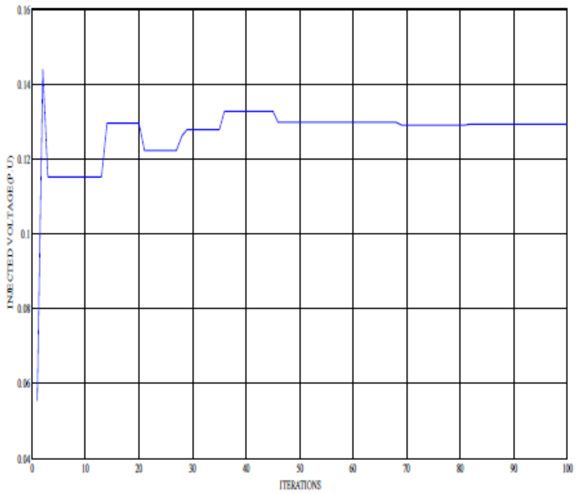


Fig8.Variation of injected Voltage with number of Iterations

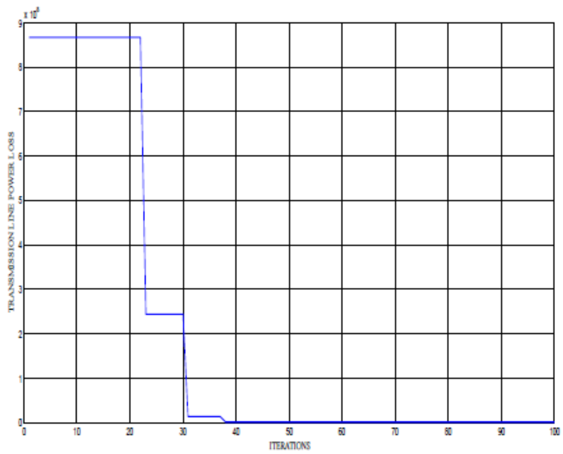


Fig9.Variation of Objective function with number of iterations

The variation of injected voltage, injected angle with the change in number of iterations in PSO for 1-2 line is shown in Fig 7 and 8. Fig9.Shows the variation of Objective with the number of iterations from this we can understand the smooth convergence of PSO technique. The transmission line loss function reaches minimum value after 40 numbers of iterations.

V. CONCLUSION

In this paper, the circuit model for IPFC system developed using Matlab/Simulink using a simple four bus system. The simulation results for the Matlab/simulink model are presented. From these Results we can say that power flow in a transmission line affected by the Injected parameters of the IPFC. The power flow analysis is simulated using Newton-Raphson load flow including the VSCs of the IPFC.Optimal parameters of IPFC (injected parameters) obtained by using particle swarm optimization with constraints. Matlab program used to validate the optimal parameters of the IPFC, and to minimize the transmission line losses of IEEE 30-bus bench mark power System.

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