A Swarm Intelligence Approach for Voltage Profile Improvement by Optimal Placement of Multi-Type FACTS Device

Dr.P. Selvan and D.C. Kumaresan

Abstract--- *In recent years, voltage instability issues have become an active area of research in power systems. A number of research works have been carried out to examine the voltage stability in power system. In certain scenarios, transformations in operating conditions would result in a progressively and uncontrolled fall of voltages resulting in voltage collapse. In this paper, Static Var Compensator (SVC) and Unified Power Flow Controller (UPFC) are used to reduce the power loss and to maintain the voltage stability. This research work uses a metaheuristic algorithm called Particle Swarm Optimization (PSO) to compute the optimal allocation of these devices. The performance of this technique is tested using IEEE-30 bus system through the MatLab/Simulink simulation software package. Newton Raphson method is implemented for load flow studies. The simulation results of test system show that the location of SVC together with UPFC has been able to enhance the voltage level of the test power system and also minimize the transmission line losses.*

Keywords--- *Flexible AC Transmission Systems (FACTS), Particle Swarm Optimization (PSO), Real and Reactive Power, Static Var Compensator (SVC), Unified Power Flow Controller (UPFC), Voltage Stability*

I. INTRODUCTION

Modern power systems are prone to widespread failures. With the increase in power demand, operation and planning of large interconnected power system are becoming more and more complex, so power system will become less secure. In some cases, changes in operating conditions could cause a progressively and uncontrolled fall of voltages leading to voltage collapse[4],[6].Application of Flexible AC Transmission Systems (FACTS) technology is currently being pursued very intensively to achieve better control over the transmission lines. One of the most important operational functions is the optimal reactive power control since inadequate reactive power supply can bring up some problems such as bad voltage profiles, additional losses and equipment overloads. Much research work mainly based on non-linear and linear programming have been carried out to solve this problem. This paper presents a detailed study on use of SVC and UPFC to increase the capacity and flexibility of a transmission network.SVC is one of the best device that it can contribute to improve the voltage profile in the transient state and therefore, in improving the quality performance of the electric service. UPFC controls all the power system parameters simultaneously [1]. Thus the power transmission capabilities can be improved and loss can be

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minimized. Optimization methods and techniques have also been used in solving voltage stability problems. Many different mathematical approaches includes i) lambda iteration method ii) gradient method, iii) Newtons method, iv) linear programming and v) interior point method Apart from analytical approaches, there also exist intelligent search methods. Intelligent search methods includes genetic algorithm, evolutionary programming, particle swarm optimization etc. This paper proposes an application of swarm intelligences to solve optimal power flow problems. The objective used here is to minimize the overall power transmission losses by optimizing the control variables within their limits. The proposed technique was tested on the IEEE 30 bus system and SVC and UPFC can be installed at any of the weakest voltage at load buses.

II. BASIC CIRCUIT OF SVC

Electrical loads both generate and absorb reactive power. Since the transmitted load varies considerably from one hour to another, the reactive power balance in a grid varies as well. The result can be unacceptable voltage amplitude variations, voltage depression, or even a voltage collapse. A rapidly operating SVC can continuously provide the reactive power required to control dynamic voltage swings under various system conditions and thereby improve the power system transmission and distribution performance. Installing an SVC at one or more suitable points in the network can increase transfer capability and reduce losses while maintaining a smooth voltage profile under different network conditions[5].In addition, SVC can mitigate active power oscillations through voltage amplitude modulation.Fig.1 shows the single line diagram of SVC.

SVC consists of a Thyristor Controlled Reactor (TCR) and a Fixed Capacitors(FC) banks. The TCR is a thyristor controlled inductor whose effective reactance varied in a continuous manner by partial conduction control of thyristor valve. The basic elements of a TCR are a reactor in series with a bidirectional thyristor switch as shown in figure 2.

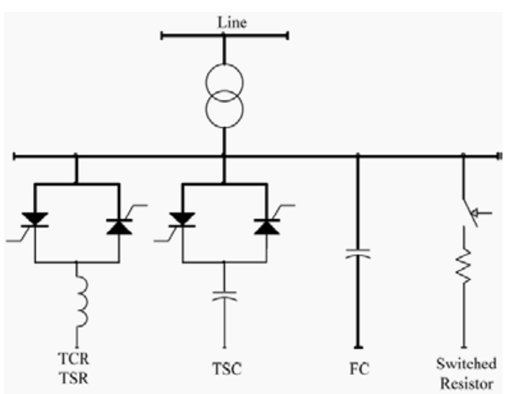

Fig. 1: Single Line Diagram of SVC

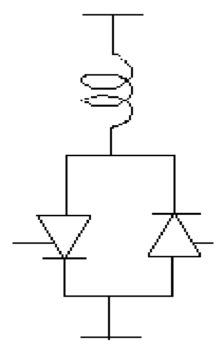

Fig. 2: Thyristor Controlled Reactor (TCR)

The thyristors conduct at alternate half-cycles of supply frequency depending of the firing angle α, which is measured from a zero crossing of voltage. Full conduction is obtained with a firing angle of 90°.The current is essentially reactive and sinusoidal. Partial conduction is obtained with firing angles between 90º and 180º.Firing angle between 0° and 90º are not allowed as they produce asymmetrical current with a dc component. The effect of increasing the firing angle is to reduce the fundamental harmonic component of the current. This is equivalent to an increase in the inductance of the reactor, reducing its reactive power as well as its current. So far as the fundamental component of current is concerned, the thyristor–controlled reactor (TCR) is a controllable susceptance, and can therefore be applied as a static compensator[1].The SVC regulates voltage at its terminals by controlling the amount of reactive power injected into or absorbed from the power system. When system voltage is low, the SVC generates reactive power (SVC capacitive). When system voltage is high, it absorbs reactive power (SVC inductive). The variation of reactive power is performed by switching three-phase capacitor banks and inductor banks connected on the secondary side of a coupling transformer. Each capacitor bank is switched on and off by three thyristor switches (Thyristor Switched Capacitor or TSC).Reactors are either switched on-off (Thyristor Switched Reactor or TSR) or phase-controlled (Thyristor Controlled Reactor or TCR)

A. Model of SVC

The static Var compensator is a shunt connected FACTS controller and is modeled as a variable reactive power connected to a bus in a power system. The effect of SVC is incorporated in power flow problem as reactive power generation/absorption. The range of reactive power generation is limited between maximum and minimum values of -30 MVAR to +30 MVAR to keep the size minimum for reducing the cost of SVC.

The reactive power generated by SVC is given by

$$Q^{min}_{SVC} \leq Q^{max}_{SVC} \leq Q_{SVC}1 \qquad (1)$$

III. STATIC MODEL OF UPFC

The UPFC consists of a shunt (exciting) and a series (boosting) transformers as shown in Fig 3.Converter-1 is primarily used to provide the real power demand of converter-2 at the common DC link terminal from the AC power system and can also generate or absorb reactive power, similar to the Static Compenstaor (STATCOM), at its AC terminal, which is independent of the active power transfer to (or from) the DC terminal.Converter-2 is used to generate a voltage source at the fundamental frequency with variable amplitude ($0 \leq V_T \leq V_{Tmax}$) and phase angle ($0 \leq \varphi_T \leq 2\pi$), which is added to the AC transmission line by the series connected boosting transformer[9].Thus, UPFC can be used for direct bus and line voltage control, series compensation, phase shifter, and their combinations. With these features, UPFC is probably the most powerful and versatile FACTS controller which combines the properties of TCSC, TCPAR and SVC[10].It is the only FACTS controller having the unique ability to simultaneously control all three parameters of power flow i.e. voltage, line impedance and phase angle.

Based on the basic principle of UPFC and network theory, the active and reactive power flows in the line, from bus-*i* to bus-*j*, having UPFC can be written as, for the series and shunt sources the power equations of UPFC can be written as:

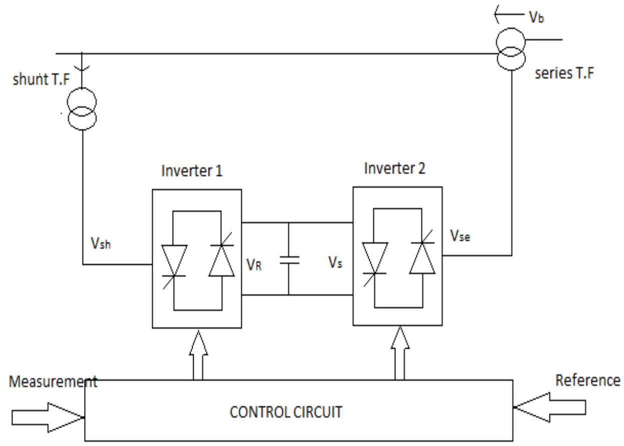

Fig. 3: Single Line Diagram of UPFC

$$P_{se} = V^2_{se}G_{mm}+V_{se}V_k(G_{km}\cos(\theta_{se}-\theta_k) + B_{km}\sin(\theta_{se}- \theta_k))+V_{se}V_m(G_{km}\cos(\theta_{se}- \theta_k) + B_{mm}\sin(\theta_{se}-\theta_k)) \quad (2)$$

$$P_{sh} = -V^2_{sh}G_{sh}+V_{sh}V_k(G_{sh}\cos(\theta_{sh}-\theta_k) +B_{sh}\sin(\theta_{sh}-\theta_k)) \quad (3)$$

IV. PARTICLE SWARM OPTIMIZATION TECHNIQUE

PSO is originally attributed to Kennedy, Eberhart and Shi and was first intended for simulating social behaviour, as a stylized representation of the movement of organisms in a bird flock or fish school.PSO is a computational method that optimizes a problem by iteratively trying to improve a candidate solution with regard to a given measure of quality. PSO optimizes a problem by having a population of candidate solutions, here dubbed particles, and moving these particles around in the search-space according to simple mathematical formulae over the particle's position and velocity. Each particle's movement is influenced by its local best known position and is also guided toward the best known positions in the search-space, which are updated as better positions are found by other particles. This is expected to move the swarm toward the best solutions[2].PSO is a meta heuristic as it makes few or no assumptions about the problem being optimized and can search very large spaces of candidate solutions. However, metaheuristics such as PSO do not guarantee an optimal solution is ever found. More specifically, PSO does not use the gradient of the problem being optimized, which means PSO does not require that the optimization problem be differentiable as is required by classic optimization methods such as gradient descent and quasi-newton methods.PSO can therefore also be used on optimization problems that are partially irregular, noisy, change over time, etc. The PSO approach utilizes a cooperative swarm of particles, where each particle represents a candidate solution, to explore the space of possible solutions to an optimization problem. Each particle is randomly or heuristically initialized and then allowed to ‘fly’. At each step of the optimization, each particle is allowed to evaluate its own fitness and the fitness of its neighboring particles. Each particle can keep track of its own solution, which resulted in the best fitness, as well as see the candidate solu-tion for the best performing particle in its neighborhood[3],[8].At each optimization step, indexed by *t*, each particle, indexed by *i*, adjusts its candidate solution (flies).

A. PSO Algorithm

Basic algorithm as proposed by Kennedy and Eberhart (1995)

x_k^i - Particle position

v_k^i - Particle velocity

p_k^i - Best "remembered" individual particle position

p_k^g - Best "remembered" swarm position

c1,c2- Cognitive and social parameters

r1,r2- Random numbers between 0 and 1

Position of individual particles updated as follows:

$$x_k^{i+1} = x_k^i + v_{k+1}^i \qquad (4)$$

with the velocity calculated as follows:

$$v_{k+1}^i = v_k^i + c1r1(p_k^i - x_k^i) + c2r2(p_k^g - x_k^i) \qquad (5)$$

B. PSO Algorithm Description and Flowchart

1. Initialize

(a) Set constants $k_{max,}$ c1,c

(b) Randomly initialize particle positions x_0^i € D R^n for i=1,2....p

(c) Randomly initialize particle velocities $0 \leq v_0^i \leq v_0^{max}$ for i= 1,2....p

(d) Set K=1

2. Optimize

(a) Evaluate function value f_k^i using design space co-ordinates x_k^i

(b) If $f_k^i \leq f_{best}^i$ then $f_{best}^i = f_k^i$, $p_k^i = x_k^i$

(c) If $f_k^i \leq f_{best}^g$ then $f_{best}^g = f_k^i$, $p_k^g = x_k^i$

(d) If stopping condition is reached go to step 3

(e) Update all particle velocities v_k^i for i=1,2....p with the equation (5)

(f) Update all particle positions x_k^i for i=1,2....p with the equation (4)

(g) Increment k

(h) Go to 2(a)

3. Terminate.

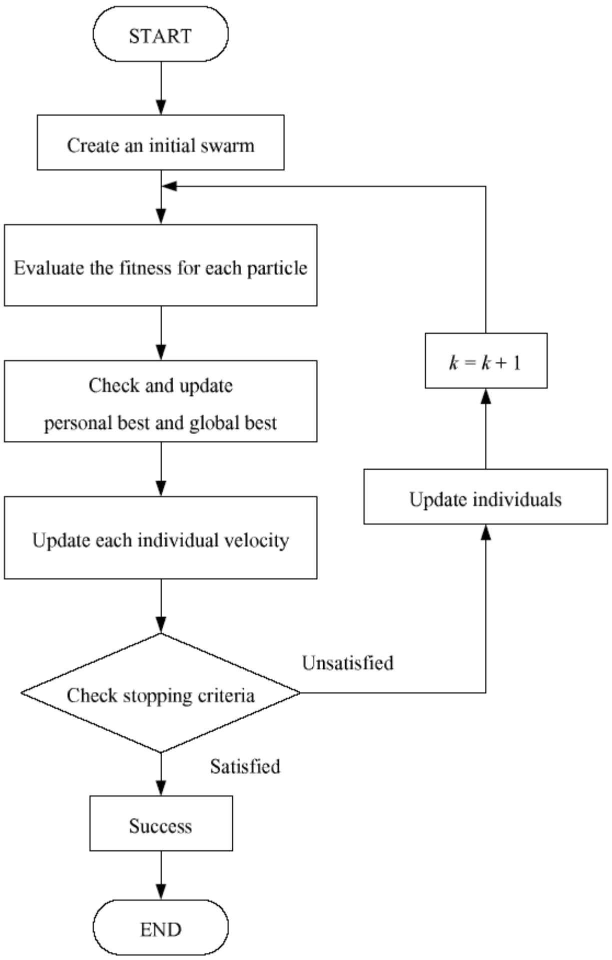

Fig. 4: Flowchart of PSO Algorithm

C. PSO Control Parameter

The following parameters are subjected to vary and their values are given in Table I.

Table 1: Various Parameters and their Values

Sl.No	Parameter	Value
1.	Number of particles	50
2	Number of iterations	200
3.	Dimension of particles	30
4.	Range of particles	0-1
5.	Velocity bounds	{-5,5}
6.	Learning factorsC1 & C2	1.4
7.	Inertia weight Wmin & Wmax	0.4,0.9

D. Fitness Function

The goal of optimal reactive power planning is to minimize the real power loss, reactive power generation and reactive power loss by optimal positioning of SVC and their corresponding parameters[7].

Hence, the objective function can be expressed as

F(i)=(Pgt-Pdt)/basemva;

In this, SVC is distributed in all buses and UPFC is distributed in 5 transmission lines and its optimal location is found by PSO iterative search.

V. RESULTS AND DISCUSSION

The optimal reactive power planning is formulated with the primary objective of minimization of reactive power generation and secondary objective of minimization of real power loss subject to voltage limit and reactive power limit constraints. The effectiveness of proposed approach has been illustrated using the medium size IEEE 30 bus test system shown in fig 5.The system has 6 generator buses, 24 load buses and 41 transmission lines. The possible location for installation of SVC is only the 24 load buses and UPFC is the 41 transmission lines.

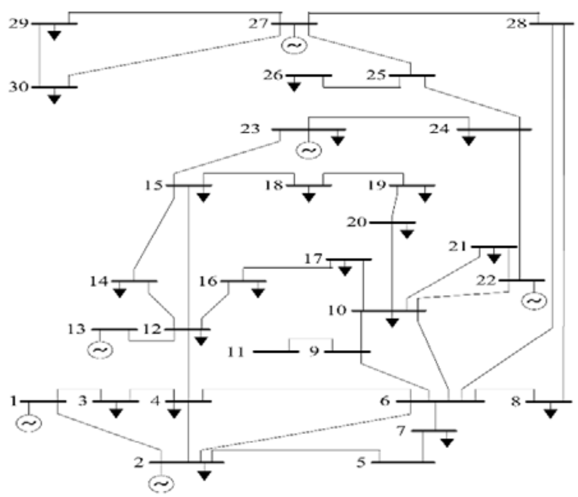

Fig. 5: Single Line Diagram of IEEE-30 Bus System

SVC and UPFC has been included in the buses to provide shunt reactive power compensation and is shown in table V for random increase in load in buses. Table II show the voltage profile results for 3 cases (i)without FACTS device (ii)with increase in load and (iii)with SVC&UPFC. Table III, IV, V shows the busdata of IEEE 30 bus system for 3 cases respectively. Table VI shows the series injection of reactive power between lines by means of UPFC. From the table II and V it is clear that it is not necessary to inject the reactive power at all affected buses.PSO algorithm searches for best possible location for reactive power injection/absorbtion by means of SVC and UPFC so that voltage at all affected buses will improve. Table VII shows the comparative results of proposed system. From the tables it is concluded that the system voltages have been improved and the losses are reduced when SVC and UPFC is installed.

Table II: Voltage Profile in 30 Buses

BUS NO.	VOLTAGE PROFILE		
	WITH BASE LOAD	WITH INCREASE IN LOAD	AFTER COMPENSATION BY SVC AND UPFC
1	1.0500	1.0500	1.0500
2	1.0438	1.0038	1.0238
3	1.0058	0.9558	0.9558
4	1.0230	0.9730	1.0130
5	1.0913	1.0913	1.0913
6	1.0883	1.0883	1.0883
7	1.0410	0.9933	1.0362
8	1.0380	0.9838	1.0285
9	1.0311	0.9744	1.0179
10	1.0131	0.9469	0.9809
11	1.0663	1.0148	1.0732
12	1.0770	1.0028	1.0995
13	1.0763	1.0383	1.1219
14	1.0748	1.0278	1.1286
15	1.0732	1.0161	1.1113
16	1.0748	1.0145	1.1055
17	1.0703	1.0014	1.0978
18	1.0689	1.0044	1.0992
19	1.0719	0.9995	1.0933
20	1.0709	1.0011	1.0937
21	1.0728	0.9805	1.0881
22	1.0731	0.9833	1.0911
23	1.0703	0.9910	1.0966
24	1.0702	0.9703	1.0862
25	1.0836	0.9491	1.0851
26	1.0792	0.9333	1.0722
27	1.0879	0.9401	1.0832
28	1.0307	0.9732	1.0108
29	1.0878	0.9265	1.0765
30	1.0777	0.9129	1.0650

Table III: Bus Data of Base Case

From Bus	To bus	Voltage mag	Angle	Load		Gen		Qmin	Qmax	Injected MVAR
				MW	MVAR	MW	MVAR			
1	1	1.0500	0	0	0	0	0	0	0	0
2	2	1.0438	-2.9166	21.7	12.7	57.56	0	0	60	0
3	2	1.0058	-8.9305	94.2	19.0	24.56	0	0	60	0
4	2	1.0230	-6.3379	30.0	30.0	35.0	0	0	62.5	0
5	2	1.0913	-7.2562	0	0	17.93	0	0	50	0
6	2	1.0883	-9.0927	0	0	16.91	0	0	40	0
7	0	1.0410	-4.8937	2.4	1.2	0	0	0	45	0
8	0	1.0380	-5.8656	7.6	1.6	0	0	0	0	0
9	0	1.0311	-6.5871	0	0	0	0	0	0	0
10	0	1.0131	-8.0747	22.8	10.9	0	0	0	0	0
11	0	1.0663	-9.0927	0	0	0	0	0	0	0
12	0	1.0770	-11.3261	5.8	2.0	0	0	0	0	0
13	0	1.0763	-10.2508	11.2	7.5	0	0	0	0	0

14	0	1.0748	-11.5603	6.2	1.6	0	0	0	0	0
15	0	1.0732	-11.9897	8.2	2.5	0	0	0	0	0
16	0	1.0748	-11.0979	3.5	1.8	0	0	0	0	0
17	0	1.0703	-11.5071	9.0	5.8	0	0	0	0	0
18	0	1.0689	-12.5898	3.2	0.9	0	0	0	0	0
19	0	1.0719	-12.6949	9.5	3.4	0	0	0	0	0
20	0	1.0709	-12.4459	2.2	0.7	0	0	0	0	0
21	0	1.0728	-12.2542	17.5	11.2	0	0	0	0	0
22	0	1.0731	-12.3942	0	0	0	0	0	0	0
23	0	1.0703	-13.4090	3.2	1.6	0	0	0	0	0
24	0	1.0702	-14.6775	8.7	6.7	0	0	0	0	0
25	0	1.0836	-18.8533	0	0	0	0	0	0	0
26	0	1.0792	-20.1289	3.5	2.3	0	0	0	0	0
27	0	1.0879	-20.4699	0	0	0	0	0	0	0
28	0	1.0307	-6.4885	0	0	0	0	0	0	0
29	0	1.0878	-22.0561	2.4	0.9	0	0	0	0	0
30	0	1.0777	-22.8223	10.6	1.9	0	0	0	0	0

Table: IV: Bus Data of Random Increase in Load

From Bus	To bus	Voltage mag	Angle	Load		Gen		Qmin	Qmax	Injected MVAR
				MW	MVAR	MW	MVAR			
1	1	1.0500	0	0	0	0	0	0	0	0
2	2	1.0038	-9.5926	32.55	19.05	57.56	0	0	60	0
3	2	0.9558	-29.4322	235.5	47.5	24.56	0	0	60	0
4	2	0.9730	-19.4532	60	60	35	0	0	62.5	0
5	2	1.0913	-21.4444	0	0	17.93	0	0	50	0
6	2	1.0883	-23.1130	0	0	16.91	0	0	40	0
7	0	0.9933	-13.1698	3.6	182	0	0	0	45	0
8	0	0.9838	-15.9715	7.6	1.6	0	0	0	0	0
9	0	0.9744	-18.8381	0	0	0	0	0	0	0
10	0	0.9469	-24.2936	45.6	21.8	0	0	0	0	0

11	0	1.0148	-23.3742	0	0	0	0	0	0	0
12	0	1.0028	-26.7796	11.6	4	0	0	0	0	0
13	0	1.0383	-24.3134	11.2	7.5	0	0	0	0	0
14	0	1.0278	-26.0295	6.2	1.6	0	0	0	0	0
15	0	1.0161	-26.6379	8.2	2.5	0	0	0	0	0
16	0	1.0145	-25.9768	7.7	3.9	0	0	0	0	0
17	0	1.0014	-26.6379	11	7.54	0	0	0	0	0
18	0	1.0044	-27.6919	4.48	1.26	0	0	0	0	0
19	0	0.9995	-27.9672	9.5	3.4	0	0	0	0	0
20	0	1.0011	-27.7696	2.2	0.7	0	0	0	0	0
21	0	0.9805	-28.2521	38.5	24.64	0	0	0	0	0
22	0	0.9833	-28.3378	0	0	0	0	0	0	0
23	0	0.9910	-28.9025	8	4.	0	0	0	0	0
24	0	0.9703	-30.7920	8.7	6.7	0	0	0	0	0
25	0	0.9491	-36.1187	0	0	0	0	0	0	0
26	0	0.9333	-37.8018	4.2	2.76	0	0	0	0	0
27	0	0.9401	-38.3876	0	0	0	0	0	0	0
28	0	0.9732	-19.2199	0	0	0	0	0	0	0
29	0	0.9265	-40.7904	3.84	1.44	0	0	0	0	0
30	0	0.9129	-41.9872	12.72	2.28	0	0	0	0	0

Table V: Busdata after Compensation (Shunt) By SVC+UPFC

From Bus	To bus	Voltage mag	Angle	Load		Gen		Qmin	Qmax	Injected MVAR
				MW	MVAR	MW	MVAR			
1	1	1.0500	0	0	0	0	0	0	0	10
2	2	1.0238	-9.9068	32.55	19.05	57.56	0	0	60	0
3	2	0.9558	-22.1912	235.5	47.5	24.56	0	0	62.5	0
4	2	1.0130	-18.8236	60	60	35	0	0	50	8
5	2	1.0913	-19.5531	0	0	17.93	0	0	40	1
6	2	1.0883	-23.1532	0	0	16.91	0	0	45	6
7	0	1.0362	-12.5490	3.6	18	0	0	0	45	18
8	0	1.0285	-15.0186	7.6	1.6	0	0	0	0	0
9	0	1.0179	-17.2336	0	0	0	0	0	0	0
10	0	0.9809	-20.4489	45.6	21.8	0	0	0	0	12
11	0	1.0732	-21.3779	0	0	0	0	0	0	0
12	0	1.0995	-24.3333	11.6	4	0	0	0	0	11
13	0	1.1219	-22.1953	11.2	7.5	0	0	0	0	5
14	0	1.1286	-24.1065	6.2	1.6	0	0	0	0	10
15	0	1.1113	-24.3293	8.2	2.5	0	0	0	0	0
16	0	1.1055	-23.6632	7.7	3.96	0	0	0	0	0
17	0	1.0978	-24.4355	11.7	7.54	0	0	0	0	1
18	0	1.0992	-25.1319	4.48	1.26	0	0	0	0	0
19	0	1.0933	-25.3026	9.5	3.4	0	0	0	0	0
20	0	1.0937	-25.0992	2.2	0.7	0	0	0	0	12
21	0	1.0881	-25.7585	38.5	24.64	0	0	0	0	10
22	0	1.0911	-25.8418	0	0	0	0	0	0	4
23	0	1.0966	-26.3609	8	4	0	0	0	0	0
24	0	1.0862	-28.0465	8.7	6.7	0	0	0	0	0

25	0	1.0851	-32.6935	0	0	0	0	0	0	0
26	0	1.0722	-33.7965	4.2	2.76	0	0	0	0	0
27	0	1.0832	-34.4308	0	0	0	0	0	0	0
28	0	1.0108	-18.0042	0	0	0	0	0	0	0
29	0	1.0765	-36.3590	3.84	1.44	0	0	0	0	0
30	0	1.0650	-37.2462	12.72	2.28	0	0	0	0	0

Table VI: Linedata after Compensation (Series) By UPFC

Bus n1	Bus nr	R p.u	X p.u	½ B p.u	Line code	Injected MVAR by UPFC
1	2	0.0192	0.0575	0.0264	1	0
1	7	0.0432	0.1852	0.0204	1	0
2	8	0.0570	0.1737	0.0184	1	0
7	8	0.0132	0.0379	0.0042	1	0
2	3	0.0472	0.1983	0.0209	1	4.5327
2	9	0.0581	0.1763	0.0187	1	0
8	9	0.0119	0.0414	0.0045	1	0
3	10	0.0460	0.116	0.0102	1	0
9	10	0.0267	0.082	0.0085	1	0
9	4	0.0120	0.042	0.0045	1	11.2047
9	11	0	0.208	0.01	1.0155	0
9	12	0	0.556	0.02	0.9629	0
11	5	0	0.208	0.02	1	0
11	12	0	0.11	0.01	1	0
8	13	0	0.256	0.02	1.0129	0
13	6	0	0.14	0.01	1	0
13	14	0.1231	0.2559	0.01	1	0

13	15	0.0662	0.1304	0.01	1	0
13	16	0.0945	0.1987	0.01	1	13.0695
14	15	0.221	0.1997	0.02	1	0
16	17	0.0824	0.1932	0.02	1	0
15	18	0.1070	0.2185	0.01	1	0
18	19	0.0639	0.1292	0.01	1	0
19	20	0.0340	0.0680	0.01	1	0
12	20	0.0936	0.2090	0.02	1	10.4111
12	17	0.0324	0.0845	0.02	1	0
12	21	0.0348	0.0749	0.01	1	0
12	22	0.0727	0.1499	0.01	1	0
21	22	0.0116	0.0236	0.01	1	0
15	23	0.1	0.2020	0.02	1	0
22	24	0.115	0.1790	0.02	1	0
23	24	0.132	0.27	0.02	1	0
24	25	0.1885	0.3292	0.02	1	0
25	26	0.2544	0.38	0.01	1	8.4170
25	27	0.1093	0.2087	0.01	1	0
26	27	0	0.396	0.01	1	0
27	29	0.2198	0.4153	0.02	1	0
27	30	0.3202	0.6027	0.01	1	0
29	30	0.2399	0.4533	0.02	1	0
4	28	0.0636	0.2	0.0214	1	0
9	28	0.169	0.0599	0.0065	1	0

Table VII: Power Loss for Various Cases (in p.u)

INCREASE IN LOAD	BEFORE COMPENSATION	AFTER SVC AND UPFC COMPENSATION
Random load change	0.581417	0.559931

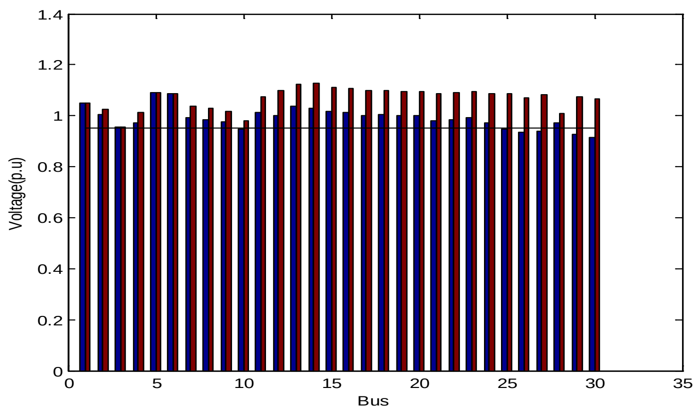

Fig. 6: Plot of Voltage Profile for Random Increase in load (SVC+UPFC)

VI. CONCLUSION

This paper presents the application of particle swarm optimization technique in power system state estimation without and with SVC together with UPFC. The effectiveness of the proposed method was demonstrated using an IEEE 30 bus system through the MatLab/Simulink simulation software package. Results show that the real power loss and voltage violation have been greatly reduced after optimization using the proposed method. From the results it is concluded that the system performs better when the SVC and UPFC is connected and the total losses are minimized.

REFERENCES

[1] A.S. Kannan and R. Kayalvizhi, "Utility of PSO for loss minimization and Enhancement of voltage profile using UPFC", International Journal of Scientific & Engineering Research, Volume 2, No. 2, February-2011.

[2] M.R AlRashidi and M.E El-Hawary, \Hybrid Particle Swarm Optimization Approach for Solving the Discrete OPF Problem Considering the Valve Loading E®ects," *IEEE Transactions on Power Systems*, Vol. 22, No. 4, Pp.2030 2038, 2007.

[3] B. Zhao, C.X. Guo and Y.J. Cao, \Improved particle swam optimization algorithm for OPF problems," *IEEE-PES Power Systems Conference and Exposition*, Vol. 1, Pp.233 - 238, 10-13 October 2004.

[4] C.A. Canizares, "Voltage stability assessment, procedures and guides", Technical Report, IEEE/PES Power System Stability Subcommittee, available at: http://www.power.uwaterloo.ca

[5] S. Jshak, A.F. Abidiii and T.K.A. Rahinan Static Var Compensator Planning Using Artificial Immune System For loss minimization And Voltage Improvement. *National Power & Energy Conrerelice (PECon) 2004*ES

[6] T. Van Cutsem, "Voltage instability: phenomena, countermeasures, and analysis methods", Proceedings of the IEEE, Vol.88, No.2, Pp.208-227, Feb.2000.

[7] C.A. Canizares, "Applications of Optimization to Voltage Collapse Analysis," IEEE/PES Summer Meeting, San Diego, July 14, 1998.

[8] R. Eberhart, and J. Kennedy, "Particle Swarm Optimization," Proc. Of IEEE International Conf. on Neural Networks, Vol. 4, Pp. 1942–1948, 1995.

[9] H. Sawhney and B. Jeyasurya, "Application of Unified Power Flow Controller for Available Transfer Capability Enhancement", *Electric Power Systems Research*, Vol. 69, No. 2-3, Pp.155-160, May 2004.

[10] K.S. Verma, S.N. Singh, and H.O. Gupda, "Location of Unified Power Flow Controller for Congestion Management", *Electric power system research*, 2001, Vol. 58, Pp. 89-96.