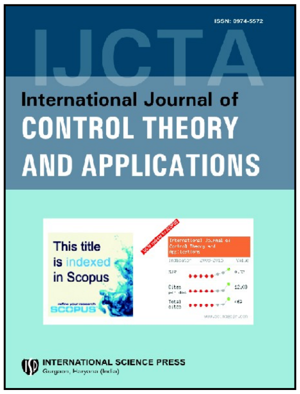

International Journal of Control Theory and Applications

ISSN : 0974-5572

Volume 10 • Number 22 • 2017

Optimal Location of Advanced Model of UPFC Device for Analyzing the Performance of Transmission System: A Hybrid DA-PSO Approach

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Abstract: Presently in the electrical systems, (FACTS) is the Flexible AC Transmission Systems is well known and prominent device. With the introduction of Flexible AC Transmission Systems knowledge, the flow of power in the power lines becomes additional stretchy and convenient. For different applications in the transmission network, many Flexible AC Transmission Systems have been well developed. Among all those different types of FACTS devices, UPFC is the mainly significant and adaptable device. This mechanism which controls the apparent power by the way of injection of a voltage in sequence with the power stripe. The degree and position of the voltage may be changed in an independent manner. This paper is aiming to enhance the profile of the voltage and to minimize losses in the electrical networks by placing power injection representation of UPFC as stated by conventional algorithm. The paper also highlights for the selection of optimum location and size of UPFC, optimization methods GA-PSO and DA-PSO which are proposed to determine the optimum setting and sizing of device. In that, the setting of the device is optimized by GA or DA and the optimized sizing is achieved with PSO. It is called Hybridization because of adoption of different optimizing techniques which are used to solve single objective function,. The stated optimization is an best method for decision the optimal setting of UPFC device and also improving the voltage profile and reducing the power system losses in the transmission line. This Hybrid GA-PSO and DA-PSO is well experienced on IEEE 57 test systems.

***Keywords*:** Power system, Transmission system, FACTS, UPFC, Power Injection Model, Hybrid GA-PSO and DA-PSO.

1. INTRODUCTION

FACTS is an emerging knowledge based result with good flexibility which can aid power spends to exploit in the transmission resources at maximum. Later many variety of FACTS devices have been opened and be a better substitute for decreasing the flows in deeply encumbered lines thus successive in improving weight ability, minimum power system loss and increased the voltage profile of the entire system. In order to achieve above mentioned benefits the UPFC is the mainly practical and perfect component [3]. At once the voltage magnitude, active and reactive power flows in the power transmission line can be accommodated by the familiar UPFC power system device. To effectively examine the consequence of above component on electric networks it is compulsory to put together its right and suitable representation. Different modellings of the components were available in studies of load flow [7]. Voltage source model is utilized to probe the performance of the UPFC in controlling the power flows and stabilities [4]. A.M. Vural [5] investigated the novel model for UPFC next to with NR method in load flow.

In this paper, the suitable settings for placement of FACTS device has been stated as a problem, and is solved using a innovative Hybrid Optimization algorithm called the Hybrid GA – PSO and DA - PSO Algorithm. The Hybrid Optimization Algorithm is functional for finding out the suitable settings of Power Injection Model of UPFC devices, to get less and less transmission line losses and better improved voltages in the power transmission system.

Good number of fundamentals were got introduced by many authors with regard to placement and sizing of UPFC. The equations in polar form in relation with real and reactive power flows are modelled by Hadi Saadat for 2 bus systems using Newton Raphson method supported by Jacobean matrix [1]. The instigation and improvement of FACTS devices from power electronics devices is enhanced by Hingorani N.G *et al.* attained making use of UPFCs with the increased security, the good stability with the more responsive and capacity for transferring the power and mitigated operation and transmission investment costs can be acheived[2]. The numerous types of power electronic devices have been introduced. The main aim of these devices can be reduction of power system losses and increases the voltage profiles of the power system network which was proposed by L. Gyugyi [3]. With reference to [4]-[5] papers, the combination of either STATCOM or SSSC are regarded as the most general model of UPFCs. The UPFC is a latest power electronics device for analysis the performance of conduction line [6] – [7]. Ishit Shah1 *et al* explains the theory of Power flow with UPFC controller for the purpose of improving the power transfer capability of the system and at the same time to maintain the system with stablility and reliability[8]. C. R. Foerte-Esquivel et.al well presented a set of analytical equations which are derived to present good UPFC [9]. M. Behshad et.al explains about to recognize the suitable settings of the UPFC[10]. Samina Elyas Mubeen et.al explains the functional performance of upfc which is made out to power flow control over the transmission line [11]. presentation of UPFC for analyzing the system as explained by Z.J. Meng et.al [12].The performance of the power system has been improved by Sahoo et.al by modifying the basic modelling of the FACTS [13].Zhang, X.P et.al mentioned Newton Raphson algorithm and Newton Raphson strong convergence characteristics with the help of Jacobian Matrix for power flow analysis [14]. The suitable position of combined series and shunt power electronic devices controls the power flows and losses in transmission losses which have been detailed by Gotham.D.J and G.T Heydt to assure the power systems security and safety [15]. Povh.D justified the better modelling concepts of the transmission network in power systems with the inclusion of the FACTS devices [16]. The network's maximum power capability was tested by Ache et.al, using computer programming for the FACTS devices with various techniques [17].The variety combinations of compensators and their stillness was proposed by Radman.G and R.S Raje [18]. Stagg. G.W *et.al* stated the multiple load flow analysis with preliminary perception of the power systems [19]. Tong Zhu and Gamg Haung conceptualized the FACTS devices installation to the buses which were suitable [20]. P.Kessal and H. Glavitsch recommended the installation of FACTS devices in transmission network raised capacity of transmission networks [21]. A novel and comprehensive load flow model for the unified power flow controller (UPFC) is presented by Fuerte-Esquivel C.R *et al.* [22], [25]. Abbate. L presents the new UPFC for load flow studies [23]. M.L.Soni et al detailed the load demand, capacitor banks function etc with respect to UPFC in a optimal way [24]. The optimal placement and setting of UPFC's parameters by using genetic algorithm concepts [26]-[28]. The PSO concept for exact location and sizing of UPFC device are analyzed [29]-[32]. The encroachment in the techniques has been extended by S.Meerjaali as a new technique named Dragonfly algorithm [33].

2. PROBLEM FORMULATION

The voltage steadiness of the arrangement is mainly dependent on the P, V and the delta, and hence it is maintained by controlling the P, V and the delta parameters.

The objective function and constraints are

$$\text{Min } S_L(\text{r,s}) \tag{1}$$

$$\text{Subject to } h(\text{r,s})=0 \tag{2}$$

$$p(r,\, s) \le 0 \tag{3}$$

Where, S_L is the objective function which minimizes the total losses in the system, h is the sameness constraint and p is the unfairness constraint wrt control variables r and s.

Sameness constraints

The real power is given by

$$Pinj,\, n = Pg,\, n + PL{,}n \tag{4}$$

The reactive power is furnished by

$$Qinj,\, n = Qg,\, n + Q\, L,\, n \tag{5}$$

Where, P*inj*, *n* is the real power injected into bus *n*, *Pg*, *n* is the real power produced by *nth* generator and P*L*, *n*, the real power of the *nth* load bus. Similarly, *Qinj*, *n*, represents the reactive power injected into bus *n*, *Qg*, *n*, the reactive power produced by *nth* generator and *QL*, *ni*, the reactive power of the *nth* load bus.

3. LOAD FLOW ANALYSIS

A mathematical cum systematic approach is revealed by the studies of load flow [34] to know many bus voltages and their respective parameters

Hence it is also beneficial to find the optimum size in addition to the v.ery favorable locations for power capacitors for the betterment of power factor and as well as improving voltages of the network.

Thus it is also beneficial to know the exact locations, optimal capability of proposed power generating stations, substations as well as new transmission lines. The load flow is a major and essential subject in the studies of power system. It too helps to calculate the losses of the lines for different conditions of power flow and help for analyzing the effect of temporary loss of power generating station or transmission on power flow.

just about a base position (θ(0),V(0)), ΔP and ΔQ are the power mismatch equations as well expanded and therefore the following relationship is uttered through power flow Newton–Raphson algorithm.

$$\begin{bmatrix} \Delta P \\ \Delta Q \end{bmatrix} = \begin{bmatrix} \frac{\partial P}{\partial \theta} & \frac{\partial P}{\partial V}V \\ \frac{\partial Q}{\partial \theta} & \frac{\partial Q}{\partial V}V \end{bmatrix} \begin{bmatrix} \Delta \theta \\ \frac{\Delta V}{V} \end{bmatrix} \tag{6}$$

Where

ΔP is the active power mismatches at the bus

ΔQ is the reactive power mismatches at the bus

ΔV is the bus voltage modify

$\Delta\theta$ is the bus angle change

4. COMBINED SERIES - SHUNT COMPENSATION

In this method, series controller is used to inject voltage in series with line and shunt device is used to inject current in parallel with point and P is exchange between those two.

Examples of combined series – shunt devices are TCPST and UPFC.

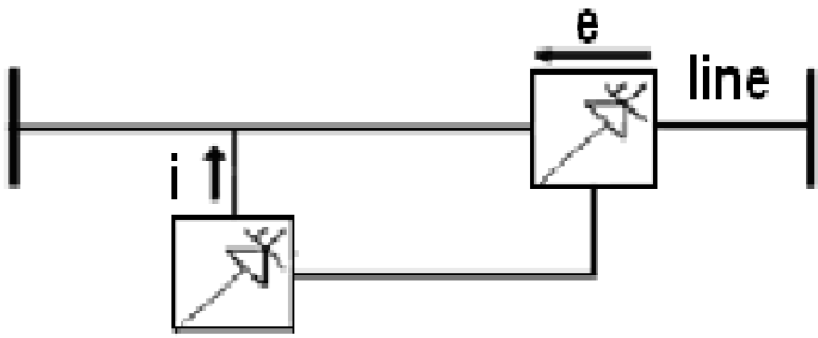

Figure 1: Single line diagram of combined series – shunt Compensation

5. UNIFIED POWER FLOW CONTROLLER (UPFC)

(A) Operating Principle of UPFC

The ideology of UPFC was revealed by Gyugyi [3] for compensating the AC transmission system and the more current FACTS component. This device is the combination of STATCOM and SSSC which is coupled with a common DC link. Hence, it has the capacity to control active and reactive power flows of the transmission line, and bus voltage at the same time.

In this there are two types of converters; these are converter 1 and converter 2. Converter1 is coupling with a transformer which is called as shun type and another one is converter 2 which is coupling with a transformer as series type and those two are combined with a common dc link for the purpose of P power is exchange between the two as shown in figure. Here the transformer and converter voltage levels are always coordinated with each other and also output voltage parameters of those converters are very synchronized efficiently. Between ac terminals of two converters, the P power flow in freely . Here the converter 1 is used to inject voltage in series with line and converter 2 is used to inject current in parallel with point and P is exchange between those two.

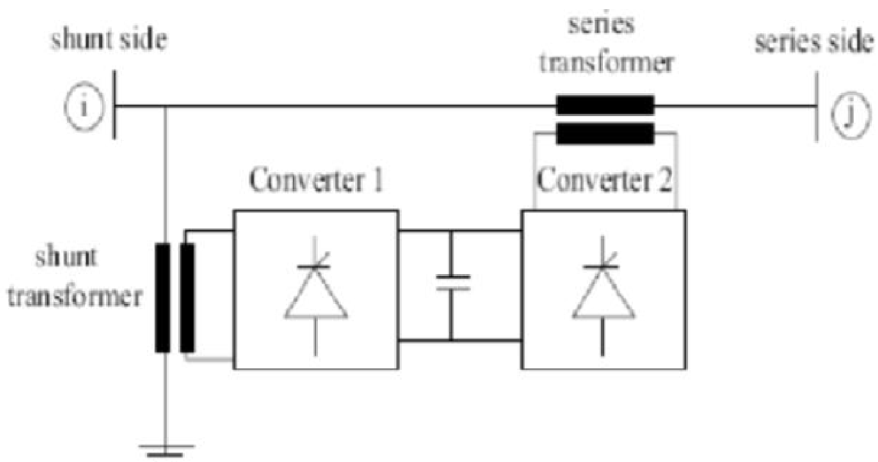

Figure 2: Single line diagram of UPFC Device

(B) Mathematical Modelling of UPFC

Figure 3 represents UPFC equivalent circuit. From the equivalent circuit, the equations for E_{rS}, E_{tS} are

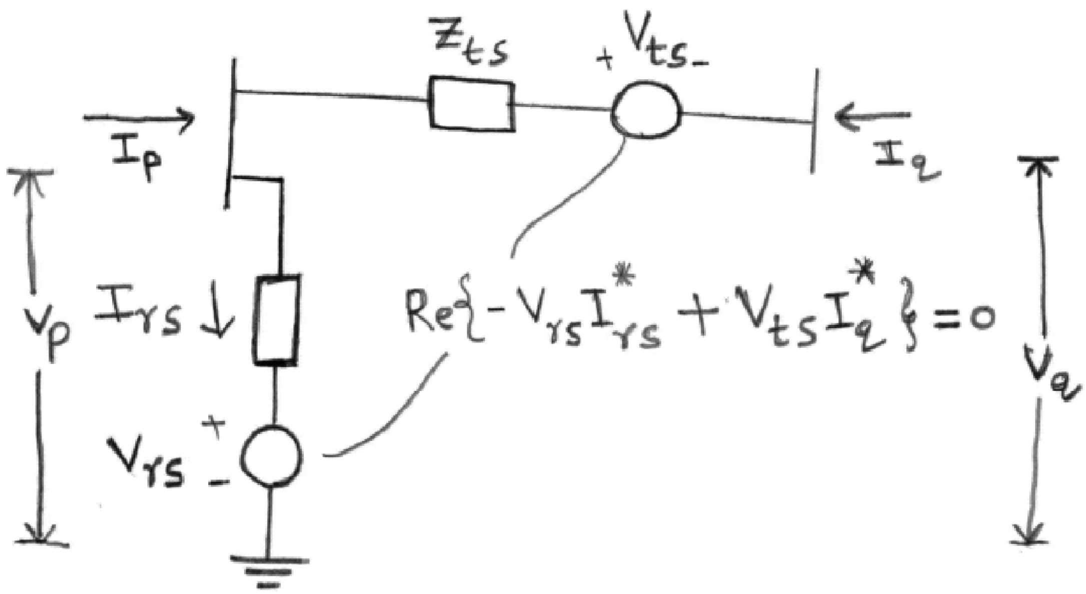

Figure 3: UPFC equivalent circuit

$$E_{rS} = V_{rS}\,(\cos\delta_{rS} + j\sin\delta_{rS}) \tag{7}$$

$$E_{tS} = V_{tS}\,(\cos\delta_{tS} + j\sin\delta_{tS}) \tag{8}$$

Where

V_{rS} and δ_{tS} are the controllable magnitudes $V_{rSqin} \le V_{rS} \le V_{rSqax}$ and phase angle $(0 \le \delta_{rS} \le 2\pi)$ of the voltage source representing the shunt converter.

The magnitude V_{tS} and phase angle δ_{tS} of the voltage source representing the series converter are controlled between limits

$V_{tSqax} \le V_{tS} \le V_{tSqax}$ and phase angle $(0 \le \delta_{tS} \le 2\pi)$ and respectively.

Based on the equivalent circuit shown in Figure 3, the active and reactive power equations are at bus p [4]:

$$P_p = V_p^2\,G_{pp} + V_pV_q\,[G_{pq}\cos(\theta_p - \theta q) + B_{pq}\sin(\theta_p - \theta q)]\;V_pV_{rS}[G_{pq}\cos(\theta_p - \theta_{rS}) + B_{pq}\sin(\theta_p - \theta_{rS})]\;V_pV_{tS}[G_{tS}\cos(\theta_p - \theta_{tS}) + B_{tS}\sin(\theta_p - \theta_{tS})] \tag{9}$$

$$Q_p = V_p^2\,B_{pp} + V_pV_q\,[G_{pq}\sin(\theta_p - \theta q) + B_{pq}\cos(\theta_p - \theta q)]\;V_pV_{rS}[G_{pq}\sin(\theta_p - \theta_{rS}) + B_{pq}\cos(\theta_p - \theta_{rS})]\;V_pV_{tS}[G_{tS}\cos(\theta_p - \theta_{tS}) + B_{tS}\sin(\theta_p - \theta_{tS})] \tag{10}$$

At bus q:

$$P_q = V_q^2\,G_{qq} + V_qV_p\,[G_{qp}\cos(\theta_q - \theta_p) + B_{qp}\sin(\theta_q - \theta_p)]\;V_qV_{rS}[G_{qq}\cos(\theta_q - \theta_{rS}) + B_{qq}\sin(\theta_q - \theta_{rS})]] \tag{11}$$

$$Q_q = -V_q^2\,B_{qq} + V_qV_p\,[G_{qp}\sin(\theta_q - \theta_p) + B_{qp}\cos(\theta_q - \theta_p)]\;V_qV_{rS}[G_{qq}\sin(\theta_q - \theta_{rS}) + B_{qq}\cos(\theta_q - \theta_{rS})]] \tag{12}$$

Series converter

$$P_{rS} = V_{rS}^2\,G_{qq} + V_{rS}V_p\,[G_{pq}\cos(\theta_{rS} - \theta_p) + B_{pq}\sin(\theta_{rS} - \theta_p)]\;V_qV_{rS}[G_{qq}\cos(\theta_{rS} - \theta_q) + B_{qq}\sin(\theta_{rS} - \theta_q)]] \tag{13}$$

$$P_{rS} = -V^2_{rS}\,B_{qq} + V_{rS}V_p\,[G_{pq}\sin(\delta_{rS} - \theta_p) - B_{pq}\cos(\delta_{rS} - \theta_p)]\;V_{rS}[G_{qq}\sin(\delta_{rS} - \theta_q) - B_{qq}\cos(\delta_{rS} - \theta_q)]] \tag{14}$$

Shunt converter

$$P_{tS} = -V_{tS}^2\,G_{tS} + V_{tS}V_p\,[G_{tS}\cos(\theta_{tS} - \theta_p) + B_{tS}\sin(\theta_{tS} - \theta_p)] \tag{15}$$

$$Q_{tS} = V_{tS}^{2} B_{tS} + V_{tS} V_{p} [G_{tS} \sin(\delta_{tS} - \theta_{p}) - \cos(\delta_{tS} - \theta_{p})] \quad (16)$$

6. HYBRIDIZATION

The important theme for the Hybridization of several algorithmic ideas is to exploit and combine the advantages of individual algorithm strategies i.e GA - PSO and DA - PSO. The Evolutionary such as Hybrid genetic – PSO and Hybrid Dragonfly - PSO algorithms emerges as an alternative for optimizing more effectively than the traditional methods.

Hybridization of the two algorithms i.e GA and PSO algorithm is necessary because Hybridization better than both standard algorithms which maximizes the optimization convergence and overcome local optimums efficiently

In this a paper hybrid optimizing techniques such as GA-PSO and DA-PSO are used to optimize the losses of the transmission system.

GA-PSO: In this optimization Genetic algorithm [28] is used to select the suitable location of the transmission network and PSO [29] is used to select the suitable firing angle of the internal device of power electronic of the system. The parameters of the Genetic Algorithm are shown below

Population=15.

Generations=30

Crossover=0.9.

Mutation=0.03

The initialization vector is randomized with the bus numbers of the system . Compensation device like UPFC is placed at bus number which generated at each iteration. By crossover and mutation the suitable location of the device is selected by optimizing the losses of the transmission network.

With PSO technique the suitable firing angles of the internal power electronic device is selected by considering the following parameters.

No of Particles=25

No.of Iterations=150

Internal weight (Wmax)= 0.9

Internal weight (Wmin)=0.4

Learning factor1=1.5

Learning factor2=1.5.

By using the GA-PSO algorithms the minimum losses are finding by optimal location of UPFC with Optimal size.

DA-PSO: In this hybrid optimization dragonfly algorithm (DA)[33] is used to find the suitable setting of UPFC by using the parameters of the DA which are mentioned below.

Number of searching Agents=40;

Iterations=500;

By considering the suitable line or branch from DA the PSO is used to find the best possible value of the firing angle for reducing the losses of the system. The parameters which are mentioned in GA-PSO.

7. RESULTS AND DISCUSSIONS

(A) IEEE 57 Bus System

The new hybrid optimization techniques are introduced in different test cases which are IEEE 57 bus systems The single diagrams and the effect of voltage profile for each system by installing single and two UPFC's with GA –PSO and DA-PSO are shown in the figures and Tabular columns respectively.

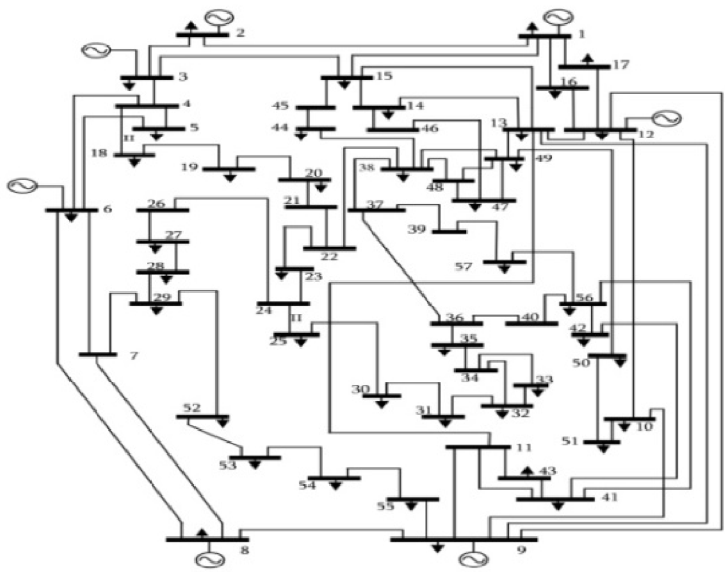

Figure 4: Single line diagram of IEEE 57 bus system

GA-PSO: GA-PSO technique is implemented to IEEE 57 bus system and the outcomes are tabulated as follows with the respective figures of change of voltage profiles.

(B) Single UPFC Placement

The placement of single UPFC by using hybrid optimization technique such as GA – PSO and DA - PSO are implemented on IEEE 57 bus system. By placing single UPFC at different locations of the conduction network losses are reduced. With the reference of the table.1.The losses are greatly reduced by DA – PSO as compared to GA-PSO. The voltage profile, total real and imprudent losses without placing of UPFC and with the placing of single UPFC are shown in the figure 5, 6 and 7 respectively.

DA-PSO: DA - PSO technique is implemented to IEEE 57 bus system and the results are tabulated as follows with the respective figures of change of voltage profiles.

Placement Two UPFC's

With the inclusion of two UPFC's in the IEEE 57 bus system then the power flows are further improved and losses further are reduced which is shown in the table 2. The voltage profile, total real and imprudent control losses without placing of UPFC and with the placing of two UPFC's are shown in the figure 11,12,13,14, 15 and 16 respectively.

GA-PSO: GA-PSO technique is implemented, then the outcomes are formated as follows with the respective figures of change of voltage profiles

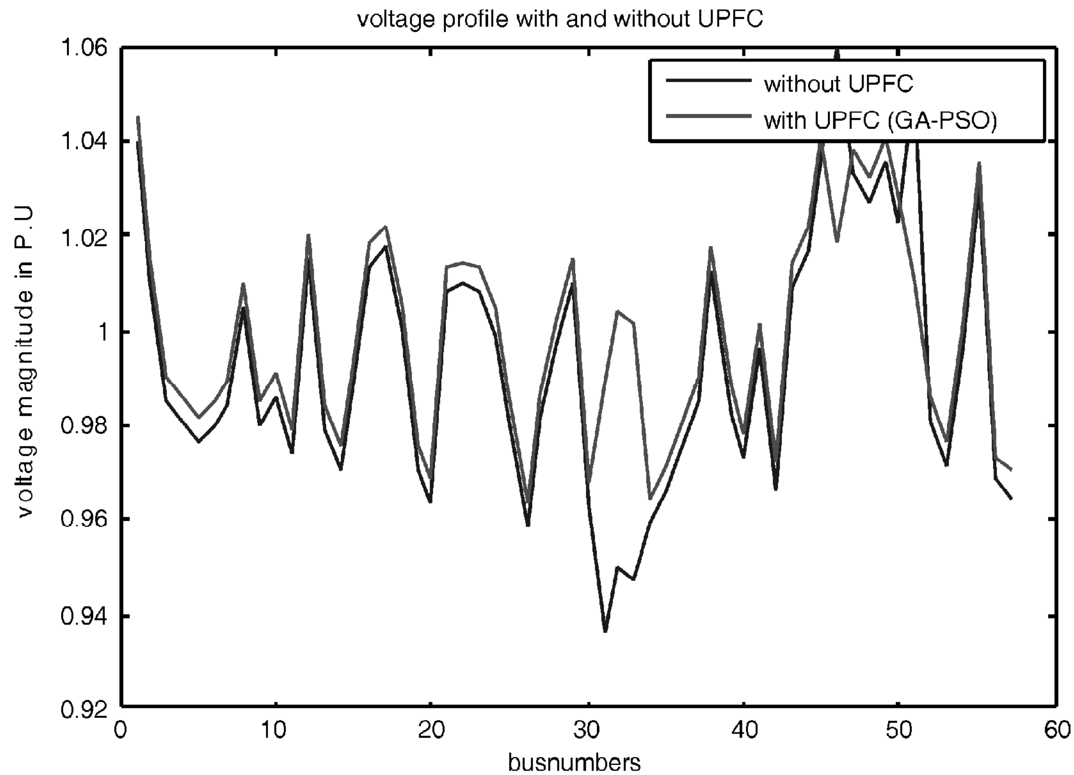

Figure 5: Comparative Voltage waveforms of IEEE 57 bus through and with no UPFC

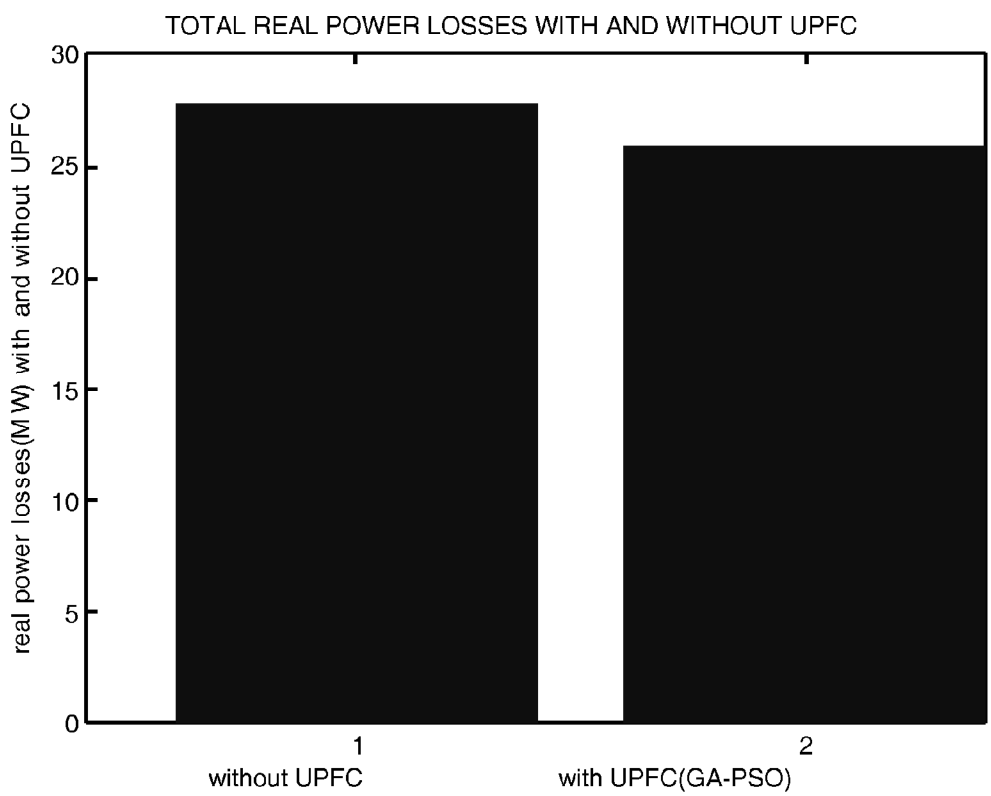

Figure 6: Total Real power losses of IEEE 57 bus through and with no UPFC(GA-PSO)

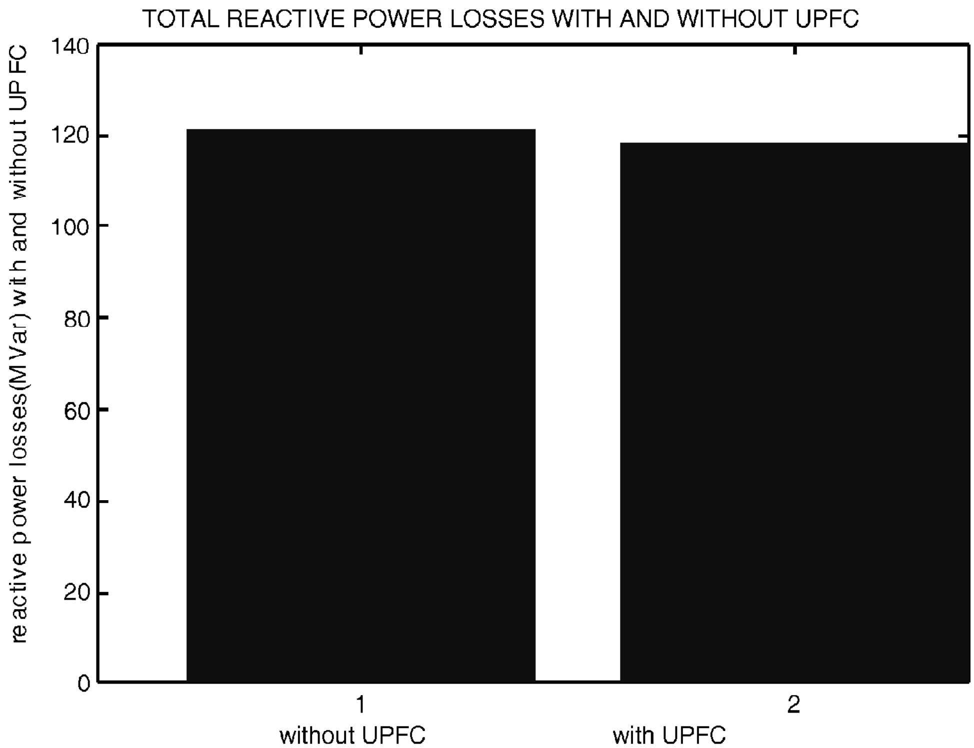

Figure 7: Total Reactive power losses of IEEE 57 bus through and with no UPFC (GA-PSO)

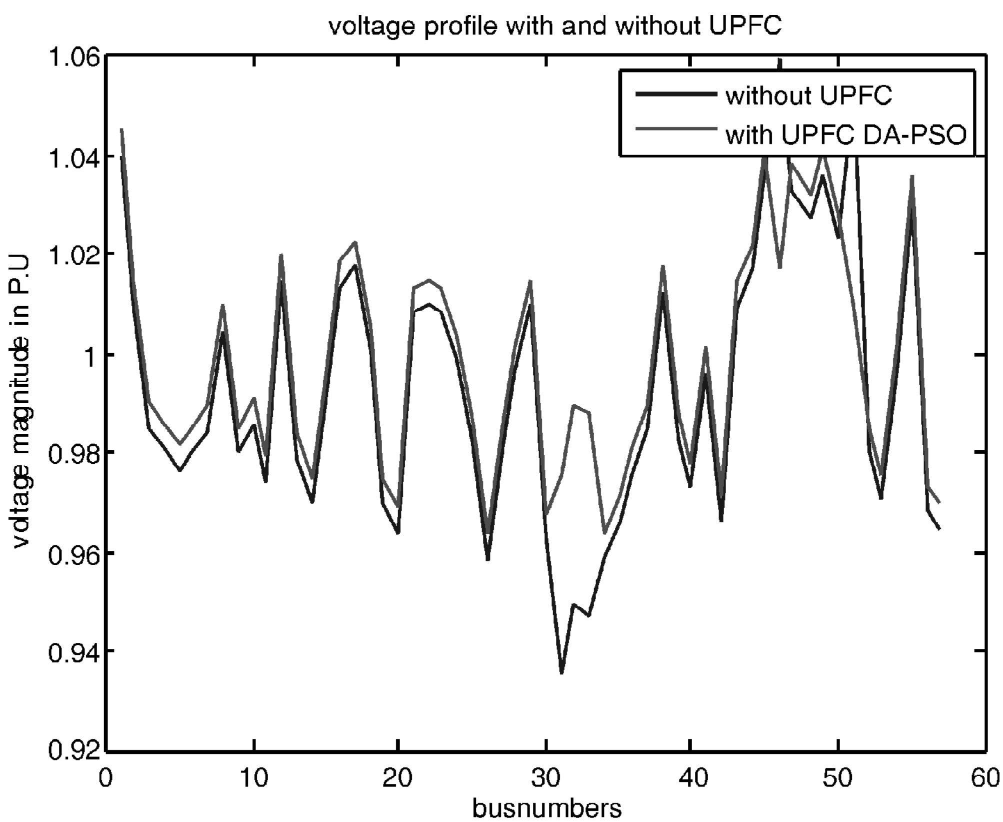

Figure 8: Comparative Voltage profile of IEEE 57 bus through and with no UPFC (DA-PSO)

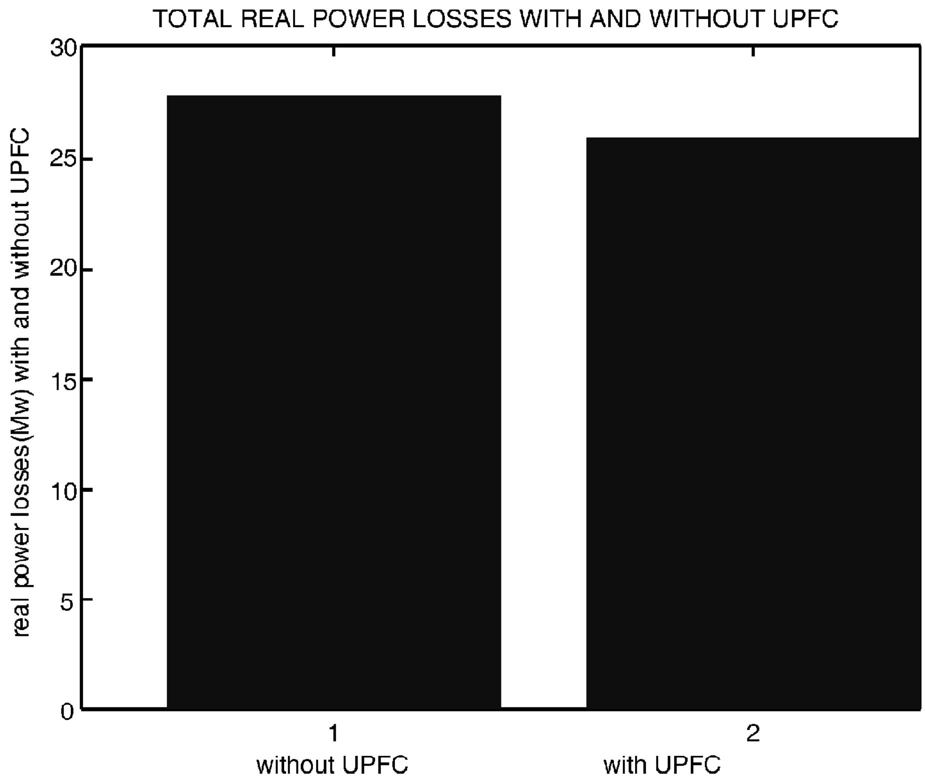

Figure 9: Total Real power losses of IEEE 57 bus through and with no UPFC

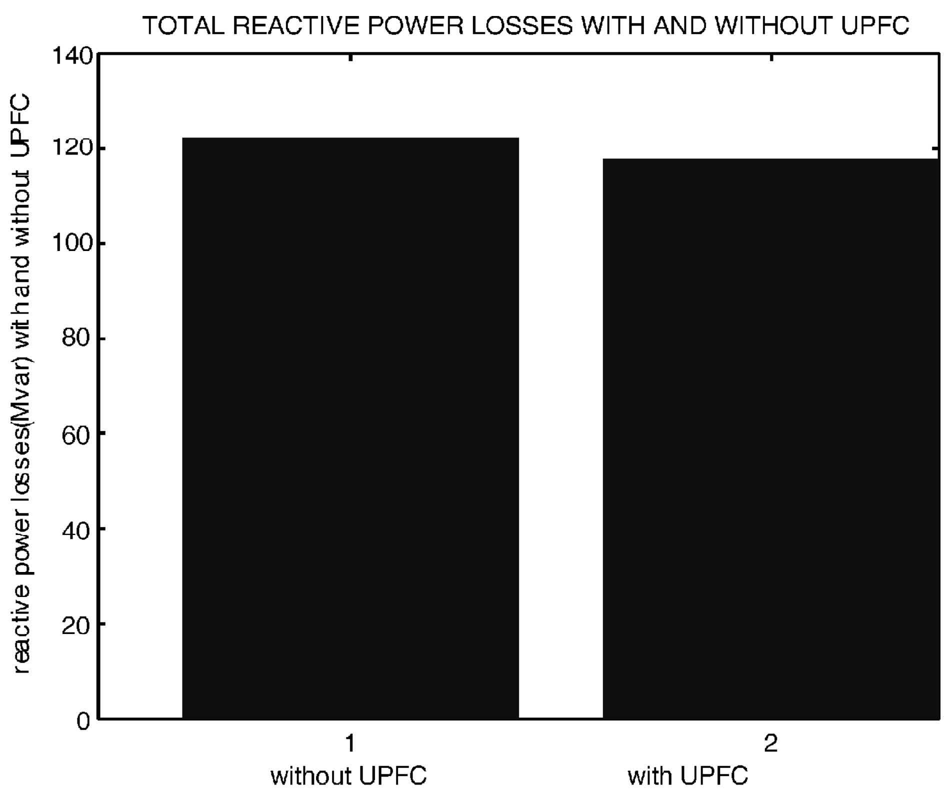

Figure 10: Total Reactive power losses of IEEE 57 bus through and with no UPFC (DA-PSO)

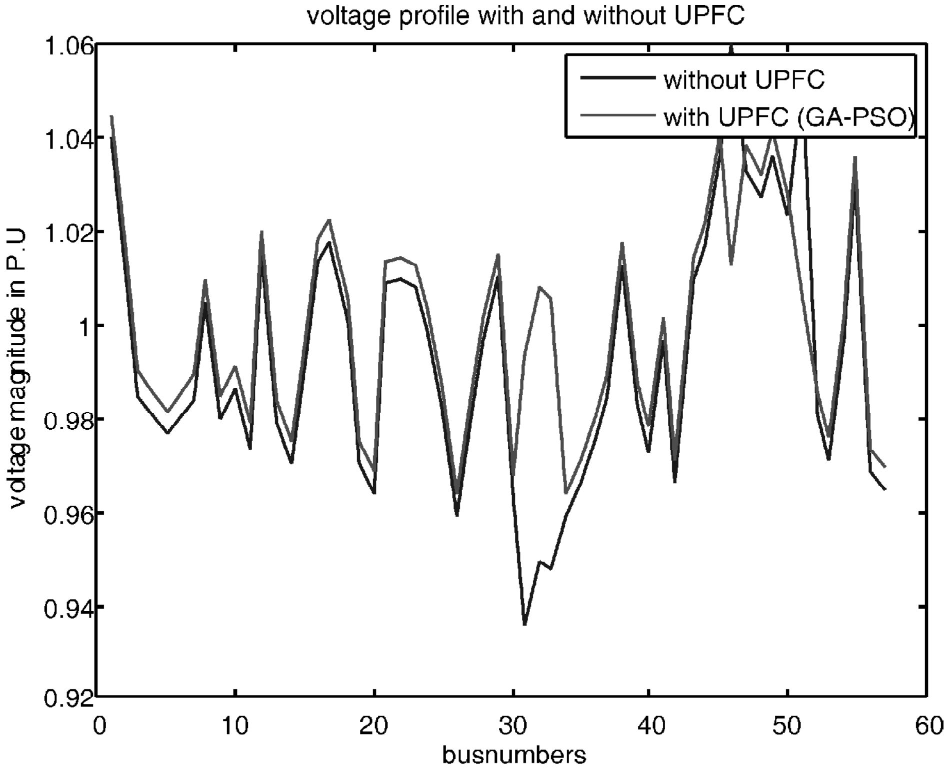

Figure 11: Comparative Voltage profile of IEEE 57 bus through and with no two UPFC's (GA-PSO)

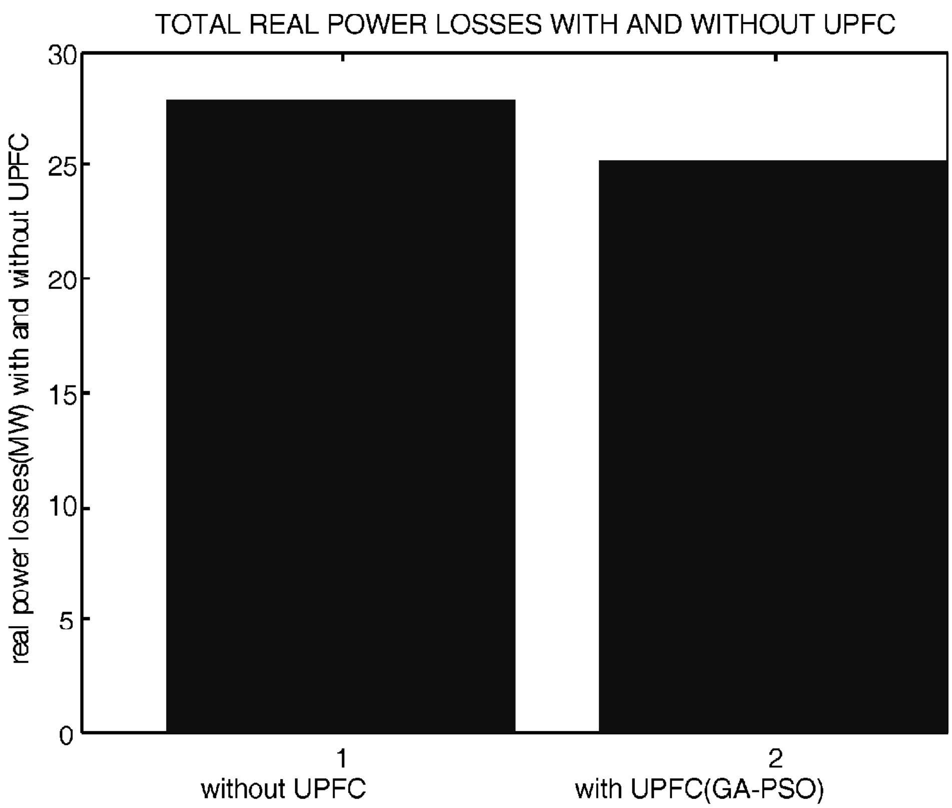

Figure 12: Total Real power losses of IEEE 57 bus through and with no two UPFC's (GA-PSO)

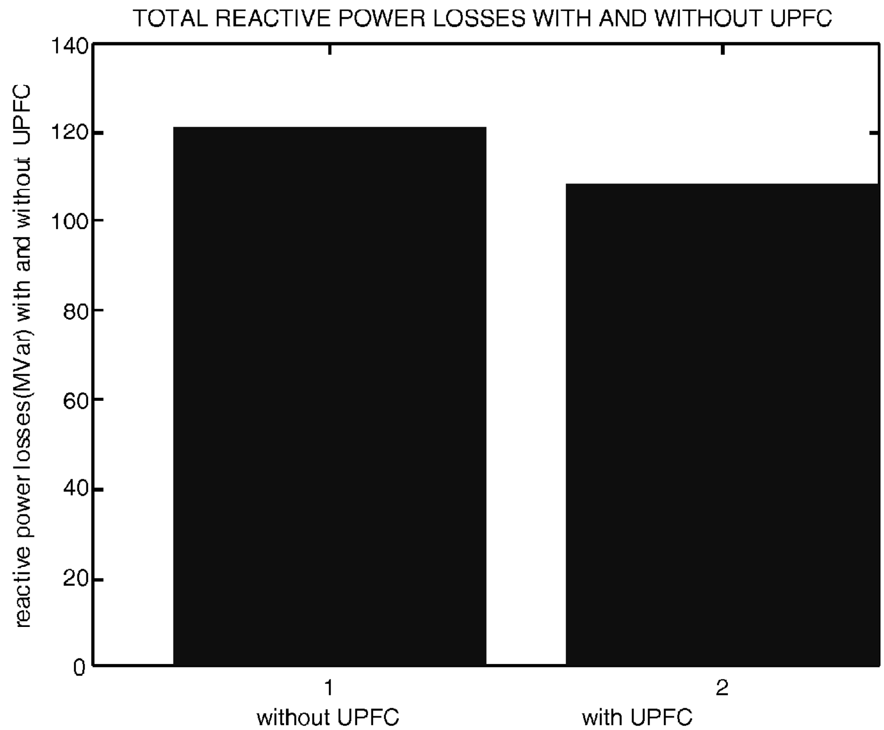

Figure 13: Total Reactive power losses of IEEE 57 bus through and with no two UPFC's (GA-PSO)

DA-PSO: DA - PSO technique is implemented to IEEE 57 bus system and the results are tabulated as follows with the respective figures of change of voltage profiles, total real and reactive power losses

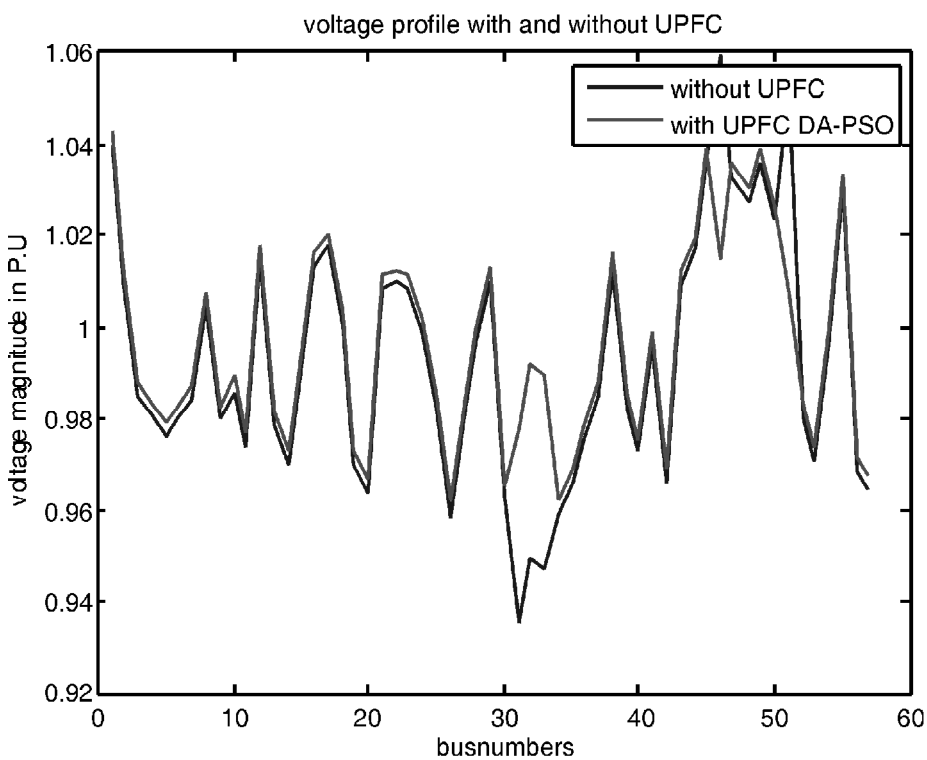

Figure 14: Comparative Voltage profile of IEEE 57 bus through and with no two UPFC's

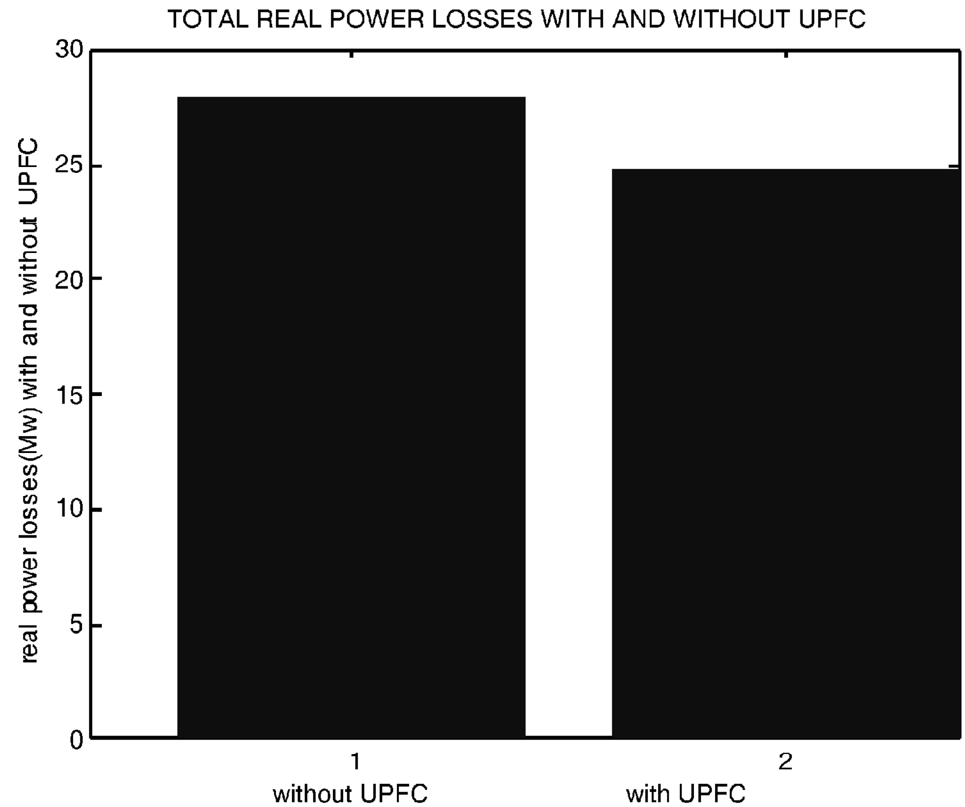

Figure 15: Total Real Power losses of IEEE 57 through and with no two UPFC's

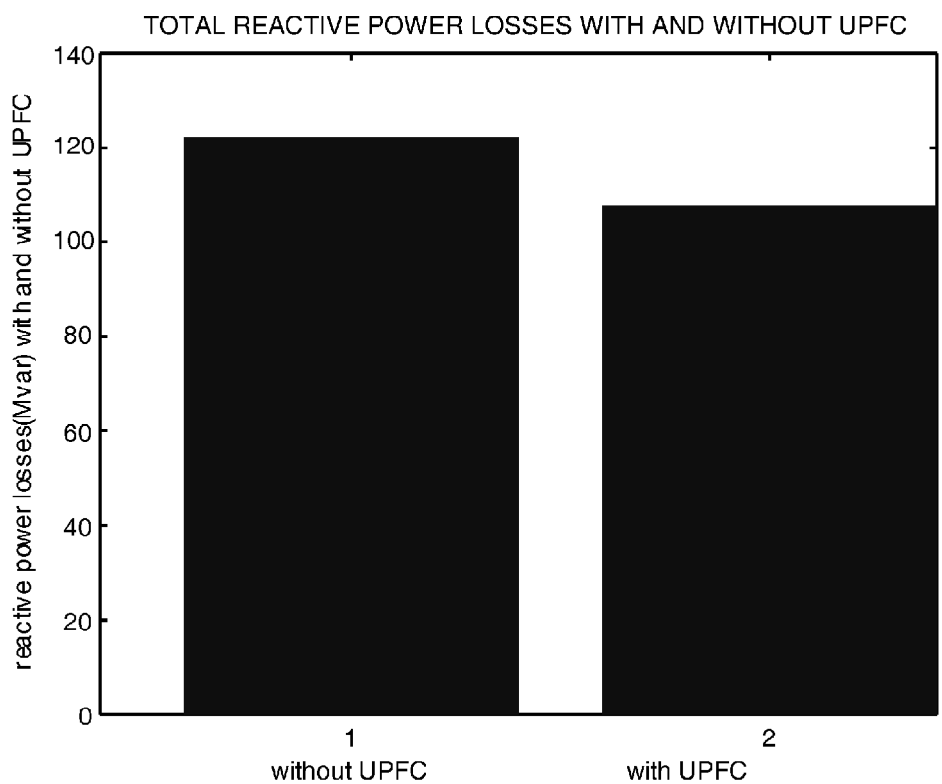

Figure 16: Total Reactive power losses of IEEE 57 bus through and with no two UPFC's

Table 1
Comparative system parameters of IEEE 57 bus with and without UPFC by using GA - PS0 and DA-PSO

Parameters	*Without UPFC*	*With single UPFC (GA- PSO)*	*With two UPFCs(GA PSO)*	*With single UPFC(DA PSO)*	*With two UPFCs(DA PSO)*
Minimum Voltage(p.u)	0.936 at bus 31	0.9638 at bus 26	0.9618 at bus 26	0.968 at bus 26	0.964 at bus 8
Maximum Voltage(p.u)	1.06 at bus1	1.0412 at bus 49	1.0392 at bus 49	1.045 at bus 1	1.003 at bus 1
Real power losses(MW)	27.864	25.920	25.224	25.832	24.752
Reactive power losses(MVar)	121.67	118.39	108.87	117.71	107.37
Location of UPFC	—————	45th bus	46th bus52nd bus	47th bus	46th bus41th bus
Size of UPFC1 (Kvar)	—————-	3.92	1.84	3.92	1.84
Size of UPFC2 (Kvar)	—————	———-	2.83	———-	2.95

From above table, the losses without UPFC are 27.864 MW and 121.67 MVar. The voltage profile of the system improved by installing of the single UPFC (DA-PSO) at 45th bus. The losses are reduced to 25.920 MW and 118.43 Mvar with UPFC size of 2.92 kVar. The voltage profile further improved by installing two UPFCs at the buses 46 and 52. The losses are further reduced to 25.224 MW and 108.87 MVar. By using GA-PSO optimization recital of the system are improved with the suitable location of the single UPFC and Double UPFC's at 47th bus and 46 and 41 buses respectively with the UPFC size of 3.72 kVar, 1.854 and 2.905 kVar respectively and with single UPFC the losses are further reduced to 25.832 MW and 117.71 MVar and by using two UPFC's the losses are 24.752 MW and 107.37 MVar

CONCLUSION

To determine the optimum position and suitable sizing of the UPFC Power Injection model using Hybrid Optimization i.e GA-PSO, DA-PSO methods have been executed on IEEE 57 bus examination method. The conduction losses are very less and voltage profiles are more with UPFC as per the results obtained for beyond bus method using Hybrid technique with and without UPFC estimated and remarks tell so as to the achieved outcomes are quite encouraging, and reveal that the UPFC as the best valuable combined series-shunt compensation devices with the purpose of may considerably raise the voltage profile of method. GA and PSO methods were also presented to analyze the impact of power injection model of UPFC and the results are compared with proposed method which is shown in tables 1. From this we can conclude that when the single and two UPFC's are placed in the IEEE 57 bus systems, The Hybrid DA – PSO gives better voltage profile improvement and optimum reduction in transmission line power losses as compared with standard GA, standard PSO and mixture GA – PSO.

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