Placement of TCSC for Analyzing the Performance of Transmission System by using Hybrid GA-PSO and DA-PSO

Mr.A.Hema Sekhar, Dr. A. Lakshmi Devi

Abstract --This paper investigates power flow analysis incorporating a firing angle model based TCSC. In this paper firing angle model of TCSC proposed to control the voltage at which it is connected. In same manner firing angle model for TCSC is used to control active power flow of the line to which TCSC is installed. The proposed models take firing angle as state variable in power flow formulation. In these paper optimization methods GA-PSO AND DA-PSO are proposed for finding the optimum location and firing angle of TCSC. In that, the location of the device is optimized by GA or DA and the optimized firing angle is done with PSO. Because of the two different Optimizing techniques are used to solve single objective function. The proposed optimization is an effective method for finding the optimal location of TCSC device and also increasing voltage profile and reducing the power system losses in the line. This Hybrid GA-PSO AND DA-PSO is tested on IEEE 14 and IEEE 118 bus test systems and simulation results are presented.

Keywords --- Power system, Transmission system, TCSC, Hybrid Optimization (GA-PSO, PSO-DA)

1 INTRODUCTION

With the rapid development of power system, especially the increased use of transmission facilities due to higher industrial output and deregulation, it becomes necessary to explore new ways of maximizing power transfer in existing transmission facilities, while at the same time maintaining the acceptable levels of the network reliability and stability. On the other hand, the fast development of power electronic technology has made FACTS (flexible AC Transmission system) promising solution of future power system. FACTS controllers like Thyristor Controlled Series Compensator (TCSC) is able to change the network parameters in a fast and effective way in order to achieve better system performance. These FACTS devices provide strategic benefits for improved transmission system management through: better utilization of existing transmission assets; increased transmission system reliability and availability; increased voltage profiles and reducing power system losses.

In the literature many people proposed different concepts about the placement and sizing of the TCSC by using hybrid GA-PSO and DA-PSO Algorithms.

Hadi Saadat Presented Real and Reactive Power flow equations in polar form by considering two bus power system. A Jacobean matrix is then constructed and Newton Raphson method is used to solve these equations [1].Ref.[2],[3],[4],[5],[6] Papers proposed in literatures for load flow analysis with incorporated FACTS controllers in multimachine power systems from different operating conditions viewpoint.

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There are different load flow analyses with incorporated FACTS controllers from different operating conditions in multimachine power systems for optimal power flow control. The Newton Raphson Methods have been proposed in literatures includes for different types of Modeling of Series FACTS controllers .Sahoo et.al (2007) proposed the basic modeling of the FACTS devices for improving the system performance[7].Zhang, X.P et.al explains Jacobian Matrix of Power flow Newton Raphson algorithm and Newton Raphson strong convergence characteristics [8 the facility to enhance the controllability and to improve the transmission system operation, stability limits wit h advanced control techniques in the existing power systems have been discussed by Gotham.D.J and G.T Heydt (1998) [9].Povh.D(2000) proposed the nice concepts of the modeling of the power systems and the impact of the FACTS devices on the transmission network [10].Modelling of the FACTS devices with various techniques with complete computer programming is proposed by Acha et.al. [11].The impact of multiple compensators in the system was proposed by Radman.G and R.S Raje [12].The important concepts of the power systems with different load flow was proposed by Stagg.G.W et.al(1968) [13]. Tong Zhu and Gamg Haung proposed(1999) the accurate points of the buses which were suitable for the FACTS devices installation [14].P.Kessal and H. Glavitsch(1986) proposed increase the transmission capability, improvement of stability by installing FACTS devices in transmission network [15].Hingorani N.G et.al presented about FACTS devices ,which are a family of high-speed electronic devices, which can significantly increase the power system performance by delivering or absorbing real and/or reactive power [16]. Hugo Ambriz-Perez et.al presented a novel power flow model for the Thyristor Controlled Series Compensator (TCSC).The model takes the form of a firing angle-dependant, nodal admittance matrix that is then incorporated in an existing Power flow algorithm [17]. Ref [18],[19] papers proposed on the placement of the TCSC by using genetic algorithm concepts. There are various stochastic search algorithms which have proved to be very efficient in solving complex power system problems. PSO is a novel population based method which utilizes the swarm intelligence generated by the cooperation and competition between the particle in a swarm and has emerged as a useful tool for engineering optimization.[20-21]. S.Meerjaali (2015) proposed a new approach of optimization by using Dragon fly algorithm [22].

2 POWER FLOW ANALYSIS

A power flow study (load-flow study)[4] is a steady-state analysis whose target is to determine the voltages, currents, and real and reactive power flows in a system under a given load conditions.

The purpose of power flow studies is to plan ahead and account for various hypothetical situations. For example, if a transmission line is be taken off line for maintenance, can the remaining lines in the system handle the required loads without exceeding their rated values.

The power mismatch equations ΔP and ΔQ are expanded around a base point (θ(0),V(0)) and, hence, the power flow Newton–Raphson algorithm is expressed by the following relationship.

$$\begin{bmatrix}\Delta P\\ \Delta Q\end{bmatrix}=\begin{bmatrix}\frac{\partial P}{\partial\theta} & \frac{\partial P}{\partial V}V\\ \frac{\partial Q}{\partial\theta} & \frac{\partial Q}{\partial V}V\end{bmatrix}\begin{bmatrix}\Delta\theta\\ \frac{\Delta V}{V}\end{bmatrix} \quad (1)$$

Where

ΔP is the change of real power at the bus.

ΔQ is the change of reactive power at the bus.

$\frac{\partial P}{\partial\theta}$ is the change in real power w.r.t angle at the buses

$\frac{\partial P}{\partial V}V$ is the change in real power w.r.t change in voltage magnitude at the buses

$\frac{\partial Q}{\partial\theta}$ is the change in reactive power w.r.t angle at the buses

$\frac{\partial Q}{\partial V}V$ is the change in reactive power w.r.t change in Voltage magnitude at the buses

Δ V is the change in voltage at the bus

$\Delta\theta$ is the change in angle at the bus

3 MODELING OF THE TCSC

3.1 Series Compensation

Series compensated transmission lines [23] utilize series capacitors to cancel a portion of the inductive reactance of the transmission line, So by means of compensation it can improve the power transmission capability of the line. Series compensation has been applied mostly to long transmission lines and other locations where the transmission distances, are great and where large power transfers over these distances are required. The transmission lines are series compensated to improve power system performance, to enhance power transfer capacity, to enhance power flow control and voltage control and to decrease capital investment.

The main effects of series compensated line of long EHV transmission line are discussed below

- The lower line impedance improves stability
- The lower line impedance improves voltage regulation.
- Adding series capacitance provides a method of Controlling the division of load among several lines.
- Increase power transfer capacity

As series compensated lines have reduced net transfer reactance, power transfer capability of system greatly increases compare to uncompensated line. This method of increasing power transfer capacity in the existing transmission system may eliminate the need of connecting parallel lines for increased load demand.

3.2 Thyristor Controlled Series Capacitor (TCSC)

The basic Thyristor-Controlled Series Capacitor (TCSC) [17] scheme was proposed in 1986 by Vithayathil with others as a method of "rapid adjustment of network impedance." It is a capacitive reactance compensator, which consists of a series capacitor bank shunted by a thyristor-controlled reactor in order to provide a smoothly variable series capacitive reactance. The basic TCSC module comprises a series capacitor C, in parallel with a thyristor-controlled reactor Ls as shown in Figure 1. However, a practical TCSC module also includes protective equipment normally installed with series capacitors. An actual TCSC system usually comprises a cascaded combination of many such TCSC modules, together with a fixed-series capacitor C_F. The modeling of this device is based on the idea of varying reactance. The reactance value of the TCSC is changed automatically to restrict the branch power at pre-defined value. The TCSC equivalent circuit is shown in Fig. 1.

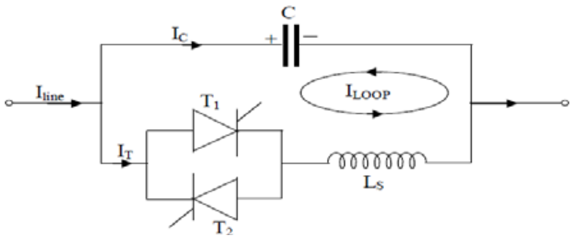

Fig. 1. A Basic Module of TCSC

3.3 Operation of the TCSC (Firing Angle Power Flow Model)

The model uses the concept of an equivalent series reactance to represent the TCSC. Once the value of reactance is determined using Newton's method then the associated firing angle TCSC can be calculated. However, such calculations involve an iterative solution since the TCSC reactance and the firing angle are nonlinearly related. The firing angles of the thyristors are controlled to adjust the TCSC reactance in accordance with a system control algorithm, normally in response to some system parameter variations. According to the operating principle of the TCSC, it can control the active power flow for the line l (between bus- f and bus- t where the TCSC is installed). The fundamental frequency of TCSC equivalent reactance as a function of the TCSC firing angle α is;

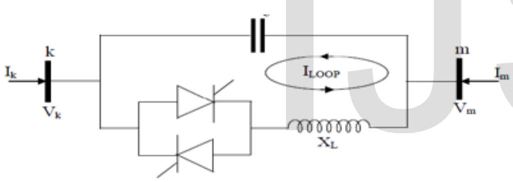

Fig. 2. TCSC Firing angle Power flow model.

$$X_{T\,csc(1)} = -X_c + C_1\{2(\pi-\alpha)+\sin[2(\pi-\alpha)]\} - C_2\cos^2(\pi-\alpha)\{\omega\tan[\omega(\pi-\alpha)]-\tan(\pi-\alpha)\} \quad (2)$$

Where

$$C_1 = \frac{X_c X_{Lc}}{\pi} \quad (3)$$

$$C_2 = \frac{4X_{LC}^2}{X_L\pi} \quad (4)$$

$$X_{LC} = \frac{X_c X_L}{X_c - X_L} \quad (5)$$

$$\omega = \left(\frac{X_c}{X_L}\right)^{\frac{1}{2}} \quad (6)$$

TCSC active and reactive power equations at bus k are

$$P_k = V_k V_m B_{km}\sin(\theta_k - \theta_m) \quad (7)$$

$$Q_k = -V_k^2 B_{kk} - V_k V_m B_{km}\cos(\theta_k - \theta_m) \quad (8)$$

Where

$$B_{kk} = B_{km} = B_{T\,csc(1)} \quad (9)$$

$$\begin{bmatrix}\Delta P_k\\ \Delta P_m\\ \Delta Q_k\\ \Delta Q_m\\ \Delta P_{km}^{\alpha_{Tcsc}}\end{bmatrix} = \begin{bmatrix} \frac{\partial P_k}{\partial\theta_k} & \frac{\partial P_k}{\partial\theta_m} & \frac{\partial P_k}{\partial V_k}V_k & \frac{\partial P_k}{\partial V_m}V_m & \frac{\partial P_k}{\partial\alpha_{TCSC}}\\ \frac{\partial P_m}{\partial\theta_k} & \frac{\partial P_m}{\partial\theta_m} & \frac{\partial P_m}{\partial V_k}V_k & \frac{\partial P_m}{\partial V_m}V_m & \frac{\partial P_m}{\partial\alpha_{TCSC}}\\ \frac{\partial Q_k}{\partial\theta_k} & \frac{\partial Q_k}{\partial\theta_m} & \frac{\partial Q_k}{\partial V_k}V_k & \frac{\partial Q_k}{\partial V_m}V_m & \frac{\partial Q_k}{\partial\alpha_{TCSC}}\\ \frac{\partial Q_m}{\partial\theta_k} & \frac{\partial Q_m}{\partial\theta_m} & \frac{\partial Q_m}{\partial V_k}V_k & \frac{\partial Q_m}{\partial V_m}V_m & \frac{\partial Q_m}{\partial\alpha_{TCSC}}\\ \frac{\partial P_{km}^{\alpha_{Tcsc}}}{\partial\theta_k} & \frac{\partial P_{km}^{\alpha_{Tcsc}}}{\partial\theta_m} & \frac{\partial P_{km}^{\alpha_{Tcsc}}}{\partial V_k}V_k & \frac{\partial P_{km}^{\alpha_{Tcsc}}}{\partial V_m}V_m & \frac{\partial P_{km}^{\alpha_{Tcsc}}}{\partial\alpha_{TCSC}} \end{bmatrix} \begin{bmatrix}\Delta\theta_k\\ \Delta\theta_m\\ \frac{\Delta V_k}{V_k}\\ \frac{\Delta V_m}{V_m}\\ \Delta\alpha_{TCSC}\end{bmatrix} \quad (10)$$

Where $\Delta P_{km}^{\alpha_{T\,csc}} = P_{km}^{reg} - P_{km}^{\alpha_{T\,csc}}$ is the active power mismatch for TCSC module. $\Delta\alpha_{T\,csc}$ is the incremental change in the TCSC firing angle.

4 HYBRID OPTIMIZATION

The different type of optimizing techniques which are used to solve the single objective function by sharing different parameters is called hybrid optimization. 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[19] is used to select the suitable location of the transmission network and PSO[20] is used to select the suitable firing angle of the internal power electronic device of the system. The parameters of the Genetic Algorithm are shown below

Population=10.
Generations=30
Crossover=0.9.
Mutation=0.03

The initialization vector is randomized with the bus numbers of the system . Compensation device like TCSC is placed at bus number which generated at each iteration .By

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crossover and mutation the suitable location of the device is selected by optimizing the losses of the transmission network. With Particle swarm Optimization technique the suitable firing angles of the internal power electronic device is selected by considering the following parameters.

No of Particles=30

Iterations=150

Wmax= 0.9

Wmin=0.4

C1=1.5

C2=1.5.

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

DA-PSO: In this hybrid optimization dragonfly algorithm (DA)[21] is used to find the optimal location of TCSC 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 particle swarm optimization is used to find the optimal value of the firing angle for reducing the losses of the system. The parameters which are mentioned in GA-PSO.

5 RESULTS

The proposed hybrid optimization techniques are implemented in different test cases which are IEEE 14 and IEEE 118 bus system The single diagrams and the effect of voltage profile for each system by installing single and two TCSC's with GA –PSO and DA-PSO are shown in the figures and Tabular columns respectively.

5.1 Test case 1: IEEE 14 bus system

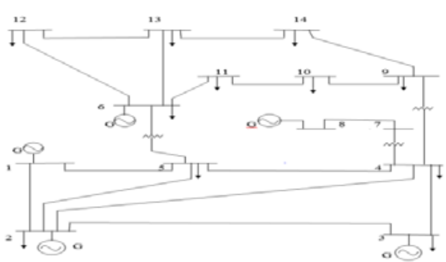


Fig. 3. Single line diagram IEEE 14 bus system.

GA-PSO: GA-PSO technique is implemented to IEEE 14 bus system and the results are tabulated as follows with the respective figures of change of voltage profiles.

5.1.1 Single TCSC Placement

The placement of single TCSC by using hybrid optimization technique such as GA - PSO and DA-PSO are implemented on IEEE 14 bus system. By placing single TCSC at different locations of the transmission network the real and reactive power losses are reduced. With the reference of the table.1.The losses are greatly reduced by GA – PSO as compared to DA – PSO. The real and reactive power losses are reduced to 9.222 MW and 49.28 MVar. The voltage profile, total real and reactive power losses without placing of TCSC and with the placing of single TCSC are shown in the figure 4,5,6,7,8and 9 respectively.

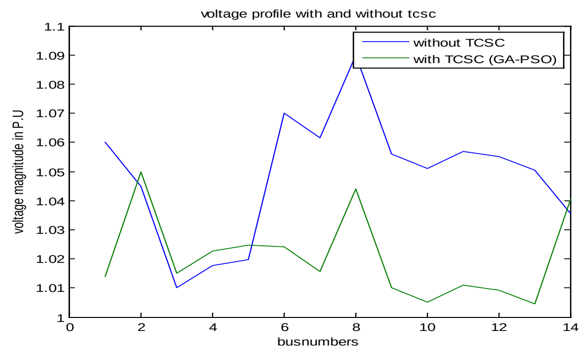


Fig. 4. Comparative Voltage profile of IEEE 14 bus with and without TCSC

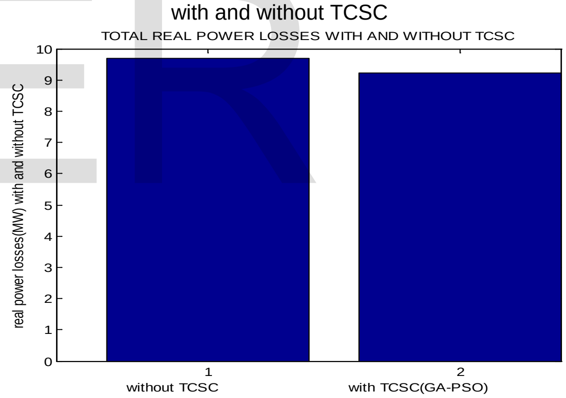


Fig. 5. Total Real power losses of IEEE 14 bus with and without TCSC

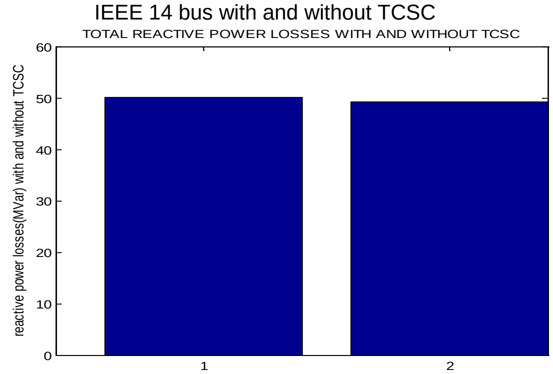


Fig. 6. Total Reactive power losses of IEEE 14 bus with and without TCSC

DA-PSO: DA - PSO technique is implemented to IEEE 14 bus system and the results are tabulated as follows with the respective figures of change of voltage profiles.

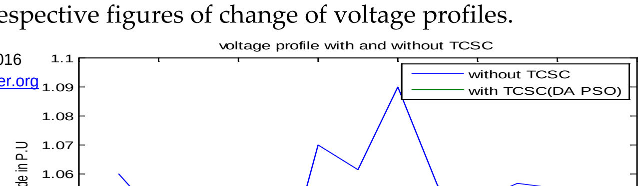


Fig. 7.. Comparative Voltage profile of IEEE 14 bus with and without TCSC

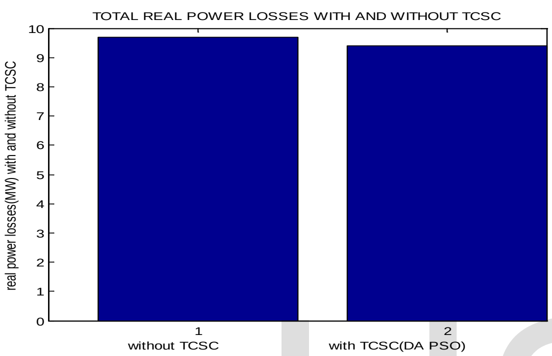


Fig. 8 Total Real power losses of IEEE 14 bus with and without TCSC

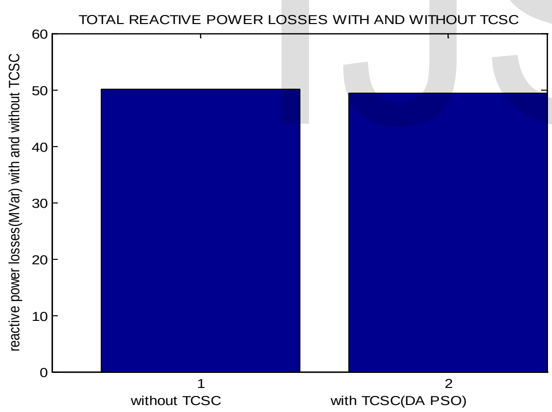


Fig. 9. Total Reactive power losses of IEEE 14 bus with and without TCSC

GA-PSO: GA-PSO technique is implemented to IEEE 14 bus system and the results are tabulated as follows with the respective figures of change of voltage profiles

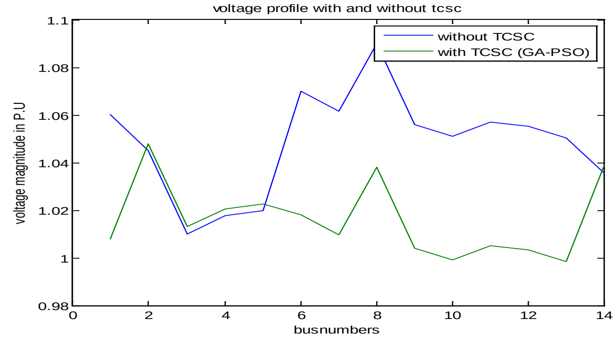


Fig. 10. Comparative Voltage profile of IEEE 14 bus with

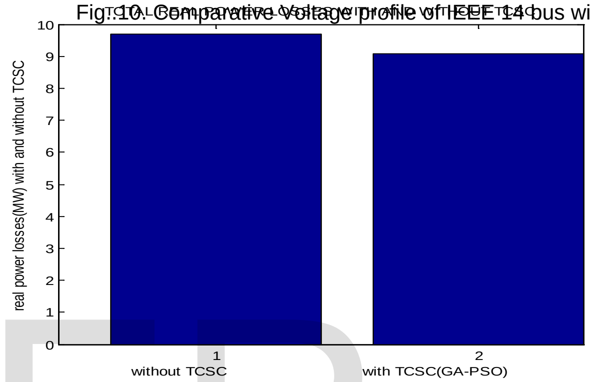


Fig. 11 Total Real power losses of IEEE 14 bus with and

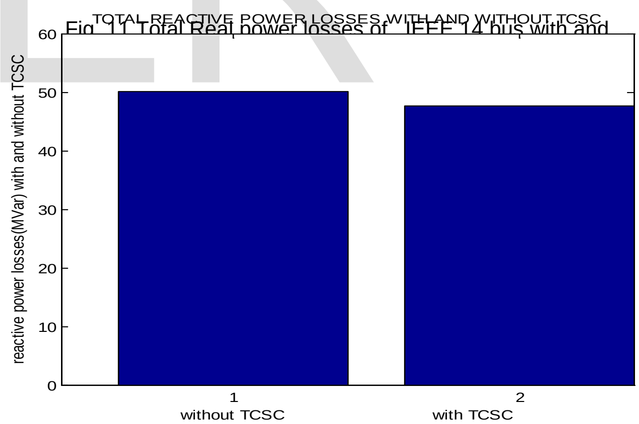


Fig. 12 Comparative analysis of Reactive power losses of IEEE 14 bus with and without two TCSC's

5.1.2 Placement Two TCSC's

With the inclusion of two TCSC's in the bus system i.e one TCSC is locate at 6-11 line and second TCSC is locate at 6-13 line (GA-PSO) then the power flows are further improved and losses further are reduced which are shown in the table 1. The voltage profile, total real and reactive power losses without placing of TCSC and with the placing of two TCSC's are shown in the figure 10,11,12,13,14and 15 respectively.

DA-PSO: DA - PSO technique is implemented to IEEE 14 bus system the respective figures of change of voltage profiles ,total real and reactive power losses

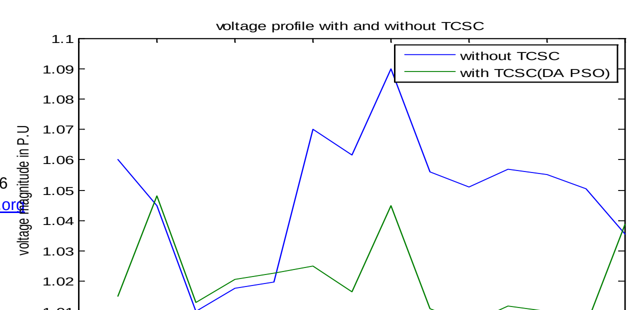
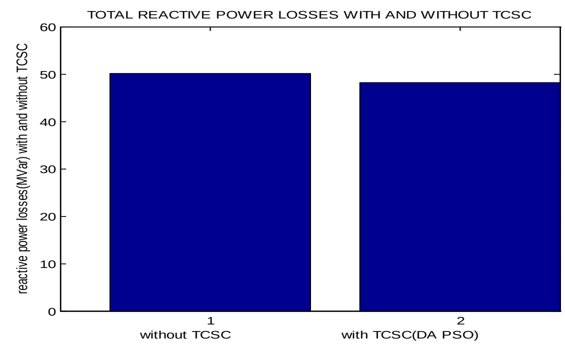
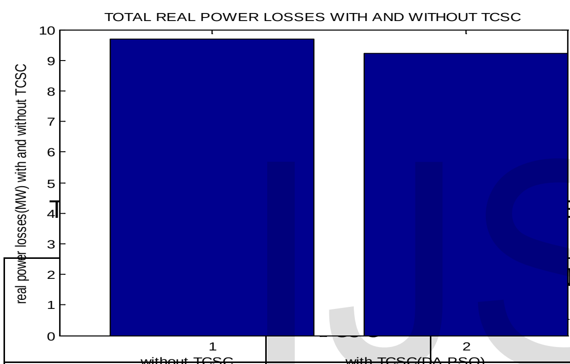


Fig. 13. Comparative Voltage profile of IEEE 14 bus with and without two TCSC's (DA-PSO)

Fig.14 Total Real power losses of IEEE 14 bus with and without two TCSC's



Fig, 15.Total Reactive power losses of IEEE 14 bus with and without two TCSC's



T[illegible]EEE 14 bus with and without TCSC by using GA - PS0 and DA-PSO

[illegible]	[illegible]	[illegible]GLE [illegible] PSO)	With TWO TCSC(GA PSO)	With SINGLE TCSC(DA PSO)	With TWO TCSC(DA PSO)
Minimum Voltage(p.u)	1.01 at bus 3	1.0044 at bus 13	0.998 at bus 13	1.0074 at bus 13	1.0054 at bus 13
Maximum Voltage(p.u)	1.09 at bus 8	1.049 at bus 2	1.047 at bus 2	1.049 at bus 2	1.0479 at bus 2
Real power losses(Mw)	9.682	9.222	9.082	9.402	9.222
Reactive power losses(Mvar)	50.04	49.28	47.64	49.44	48.14
Location of TCSC	----------	7-9 line	6-11 line 6-13 line	6-13 line	6-11 line 6-13 line
TCSC 1firing angle(deg)	----------	132.3	136.3	131.8	136.3
TCSC2 firing angle(deg)	----------	------	127.3	------	126.2
Size of TCSC1(Kvar)	-----------	2.38	1.410	2.36	1.42
Size of TCSC2(Kvar)	----------	------	0.983	------	0.973

The voltage profile of the system improved by installing of the TCSC between the buses 7 and 9. The losses are reduced to 9.222 MW and 49.28 Mvar with TCSC size of 2.38 Kvar. The voltage profile further improved by installing two TCSCs between the buses 6 and 11 and the buses 6-13. The losses are further reduced to 9.082 MW. By using DA-PSO, the voltage profiles of the system are improved with the suitable location of the single TCSC and Double TCSCS at 6-13 buses and 6-11 and 6-13 buses respectively with the TCSC size of 2.36 Kvar,1.42 Kvar and 0.973 Kvar respectively.and with single

TCSC the losses are further reduced to 9.402 MW and 49.44 Mvar and by using two TCSC's the losses are 9.222 MW and 48.14 MVar.

5.2 Test case 2: IEEE 118 bus system

The single line diagram IEEE 118 bus system and the voltage profile of IEEE 118 bus system without TCSC and with single TCSC are shown in the figure 16,17,18 ,19 and 20 and table 2.

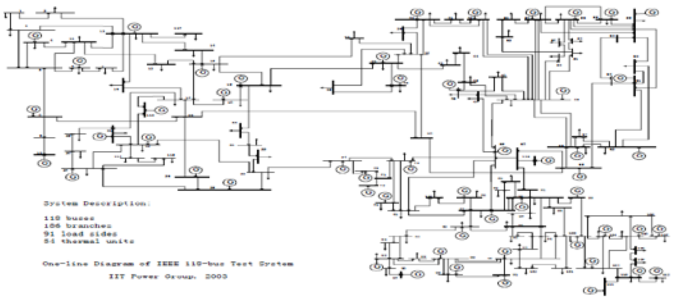


Fig.16. Single line diagram of IEEE 118 bus system.

5.2.1 Single TCSC Placement

The placement of single TCSC by using hybrid optimization technique such as GA - PSO and DA-PSO are implemented on IEEE 118 bus system. By placing single TCSC at different locations of the transmission network the real and reactive power losses are reduced. With the reference of the table.2.The losses are greatly reduced by GA – PSO as compared to DA-PSO .The comparative voltage profile without placing of TCSC and with the placing of single TCSC are shown in the figure 17 ,18,19,20 respectively.

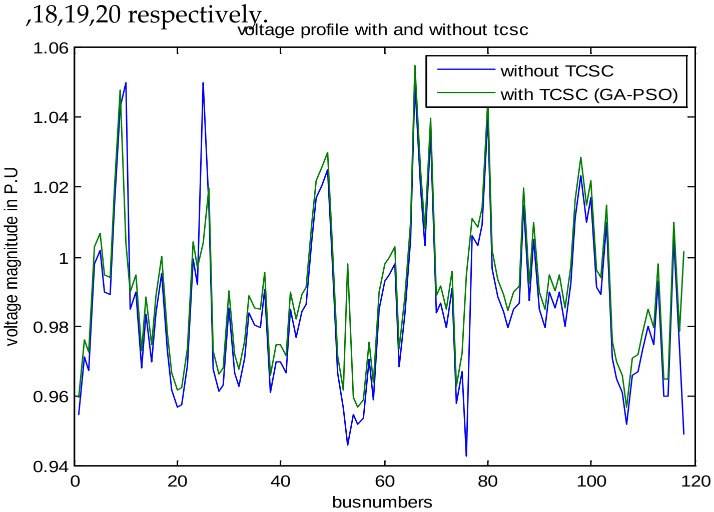
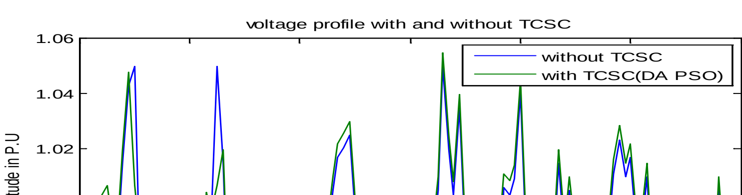


Fig. 17: comparative voltage profile of IEEE 118 bus with single TCSC and without TCSC (GA-PSO)



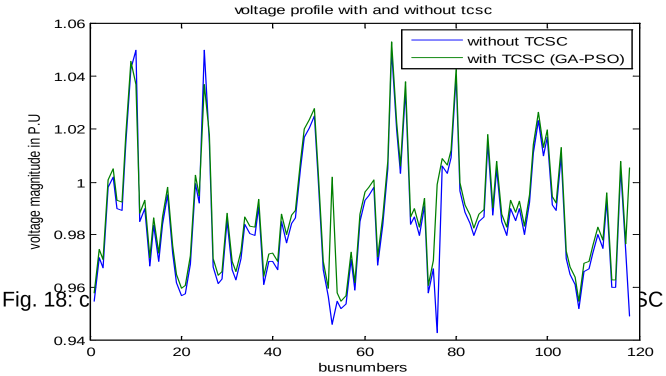
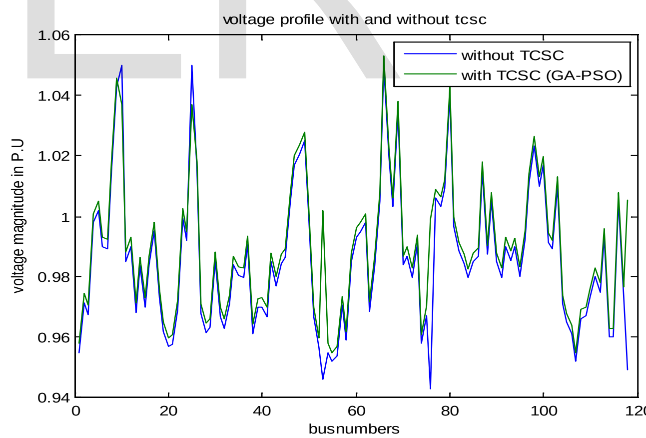


Fig. 18: c … SC and

5.2.2 Placement Two TCSC's

With the inclusion of two TCSC's in the bus system, the power flows are further improved and losses further are reduced which is shown in the table 2. The voltage profile without placing of TCSC and with the placing of two TCSC's is shown in the figure 13 and 14 respectively.



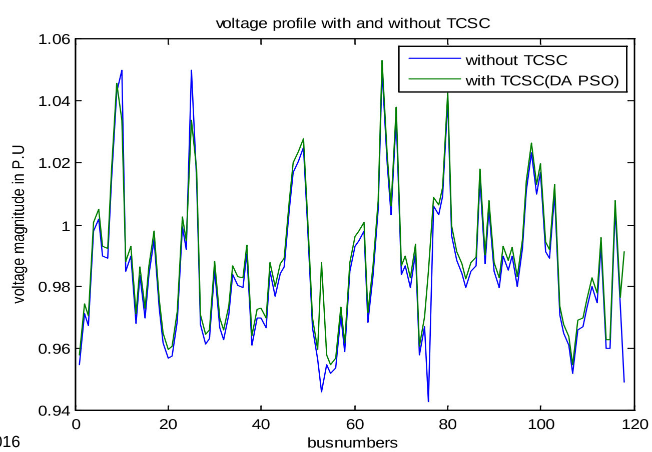


Fig. 20: comparative voltage profile of IEEE 118 bus with two TCSC's and without TCSC (DA-PSO)

Table 2: Comparative system parameters of IEEE 118 bus with and without TCSC by using GA - PS0 and DA-PSO

Parameters	Without TCSC	With SINGLE TCSC(GA PSO)	With TWO TCSC(GA PSO)	With SINGLE TCSC(DA PSO)	With TWO TCSC(DA PSO)
Minimum Voltage(p.u)	0.943 at bus 76	0.957 at bus 55	0.955at bus 55	0.957 at bus 55	0.955at bus 55
Maximum Voltage(p.u)	1.05 at bus10	1.055 at bus 66	1.053 at bus 66	1.055 at bus 66	1.053 at bus 66
Real power losses(Mw)	132.83	128.585	127.283	130.259	128.52
Reactive power losses(Mvar)	783.79	776.52	761.47	778.21	766.12
Location of TCSC	----------	76-77 line	105 -107 line 106-107 line	105-107 line	106 -107 line 92-94 line
TCSC 1firing angle(deg)	----------	143.4	132.6	147.3	133.3
TCSC2 firing angle(deg)	----------	-------	146.3	-------	116.3
Size of TCSC1(Kvar)	-----------	4.472	2.72	4.672	2.14
Size of TCSC2(Kvar)	----------	-------	2.58	-------	2.58

6 CONCLUSION

Thyristor controlled series capacitor (TCSC) firing angle control model using Hybrid GA-PSO, Hybrid DA-PSO methods have been implemented on IEEE 14 and 118 bus test system to determine the optimum location and suitable firing angle of the TCSC..The results obtained for above bus system using proposed method with and without TCSC compared and observations reveal that the Real and Reactive power losses are very less and voltage profiles are more with TCSC using Hybrid GA-PSO. The obtained results are shows that the TCSC is one of the most effective series compensation devices that can significantly increase the voltage profile of the system. GA and PSO methods were also presented to analyze the firing angle model of TCSC and the results are compared with proposed method which are shown in tables 1 and 2. From this we can conclude that when the single and two TCSC's are placed in the IEEE 14 and 118 bus systems, The Hybrid GA – PSO gives better voltage profile improvement and better reduction in transmission line losses as compared to GA, PSO, Hybrid DA-PSO .

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