IMPLEMENTATION OF ADVANCED STATIC VAR COMPENSATOR (SVC) MODEL FOR MINIMIZING THE TRANSMISSION LOSSES AND IMPROVING THE VOLTAGE PROFILE USING NON-CONVENTIONAL ALGORITHMS

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Abstract: *In an electrical network, an optimal procedure is required for resolving the problems like voltage profile improvement and power losses reduction. Now a days, the condition for optimality can be attained by effective and efficient utilisation of available facilities with add on FACTS devices in the power systems. In practical applications, the choice of Static VAR Compensator (SVC) is better than other devices, as for the analysis and mitigation of problems due to its applicability and affordable costs. In this paper, for the selection of optimum location of SVC, determination of SVC's size and SVC's firing angle - three heuristic Optimization algorithms are proposed as non conventional optimizing algorithms for the same Objective function. Namely, this paper comprises of Genetic Algorithm, Particle Swarm Optimization and Dragonfly algorithm as three non conventional Algorithms. The proposed algorithms are validated for IEEE 30 and IEEE 118 bus test systems for analyzing the solution methodology for the improvements in voltage profile and reducing power losses in order to present its adaptability in power systems of higher dimensionality.*

Key words: *Flexible AC Transmission System (FACTS), Non Conventional Algorithms such as dragonfly Algorithm(DA), genetic algorithms (GA), particle swarm optimization (PSO), Power system, Static VAR Compensator (SVC) and Transmission system.*

1. Introduction

Flexible AC transmission system (FACTS) are widely utilized for improving system's power flow control and boosting capacity of transmission [1]. In power system networks, these devices are converters which are basic power electronics devices that are proficient to monitor and regulate various parameters in electrical transmission circuits which contributes a better control facility for steady state power flow & also control in dynamic stability. These FACTs devices in comprises of STATCOM (static compensator), TCSC (thyristor controlled series compensator), SVC (static VAR compensator), and UPFC (unified power flow controller) etc.

SVC (static VAR compensator) is the most generally employed shunt FACTS device in power system networks because of its availability, lower cost and good performance in system's function improvement. SVC when compared to STATCOM, with high accuracy it attains a well estimated voltage profile. It acts as a shunt assisted static VAR absorber or generator where the output can be modified by swapping inductive or capacitive current to the system for voltage support. The optimum location of SVC results significantly in reduced system power losses.

In this paper, the placement of FACTS device in the power system networks was designated as problem and this optimal placement is formulated and resolved by the help of the proposed novel Non - Conventional algorithm named "Dragon fly Algorithm". In the power system to determine the optimal location of static VAR compensator (SVC), this Dragonfly Algorithm is applicable as to attain minimum transmission line losses and also to regulate the voltage profile. Using MATLAB, the proposed Algorithm results are compared for IEEE 30 bus system with the results of the Genetic Algorithm (GA) and also with the Particle Swarm Optimization (PSO) techniques

2. Literature Survey

Many concepts were proposed by many authors regarding placement and sizing of SVC. The equations in polar form related to real and reactive power flow are represented by Hadi Saadat for 2 bus systems using Newton Raphson method with the help of a Jacobean matrix [1]. The initiation and development of FACTS devices from power electronics devices is referred by Hingorani N.G et.al. The improved stability, increased security, with the more heightened capability for power transferring and mitigated operation and transmission investment costs can be attained by using SVC's [2].

The combination of mechanically controlled and thyristor controlled shunt capacitors and reactors are named as SVC [3]-[4]. With reference to [5]-[6] papers, the combination of either thyristor controlled reactor & fixed capacitor or thyristor controlled reactor & thyristor switched capacitor is considered as the most popular model of SVC's. The novel firing angle model for Static VAR Compensator (SVC) FACTS devices is also designed as new SVC model [7]-[9]. As on development in the power electronic construction, the variable reactance reactive power compensator is placed instead of fixed capacitor and reactor reactive compensator. In multi machine power systems, Kumar G.R et.al discussed in brief regarding FACTS controllers with respect to of load flow analysis from various operational conditions [10]. B.Venkateswara rao et.al highlighted the Power System Stability management by introducing Static VAR Compensator in the system network [11]. The performance of the power system has been improved by Sahoo et.al by developing the basic modeling of the FACTS [12].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 [13]. The optimal placement of FACTS devices controls the power flows and losses in transmission losses has been detailed by Gotham.D.J and G.T Heydt to assure the power systems security and safety [14]. Povh.D justified the better modeling concepts of the transmission network in power systems with the inclusion of the FACTS devices [15]. The network's maximum power capability was tested by Ache et.al, using computer programming for the FACTS devices with various techniques [16].The multiplicity combinations of compensators and their stillness was proposed by Radman.G and R.S Raje [17]. Stagg.G.W et.al stated the multiple load flow analysis with preliminary perceptions of the power systems [18]. Tong Zhu and Gamg Haung conceptualised the FACTS devices installation to the buses which were suitable [19]. P.Kessal and H. Glavitsch recommended the installation of FACTS devices in transmission network raised capacity of transmission networks [20]. L.Jebaraj et al conferred that the transmission system with the FACTS devices action has been assessed with limited voltage stability for progressed levels of voltage and mitigated losses [21]. The optimal location of SVC with scheduled parameters Reza Sirjani et al explains the optimal placement and parameter settings of SVC FACTS devices [22]. M.L.Soni et al detailed the load demand, capacitor banks function etc with respect to SVC in a optimal way [23]. The optimal placement and setting of SVC's parameters by using genetic algorithm concepts [24]-[27].

The PSO concept for proper location and sizing of SVC device are analyzed [28]-[31]. The advancement in the techniques has been extended by S.Meerjalili as a novel technique named Dragon fly algorithm [32].

3. Power flow analysis

For numerical analysis of power flow, the basic tool that to be formulated is the load-flow study [33] in a power system. When compared to traditional circuit analysis, this study of power flow usually uses per unit system with simple one-line diagram, which targets on AC power's which comprises of reactive, apparent and real power forms instead of voltage and current. Determination of further extension and optimal operation of a power system can be planned and revealed by the analysis of load flow studies which is an added advantage. Power flow analysis is used to resolve by using Newton-Raphson method and Gauss Seidel method.

By using Newton–Raphson algorithm, the power flow equations are stated as, ΔP and ΔQ are power mismatch equations which expanded around base point (θ(0),V(0)) with the following relation expressed below:

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

Where

ΔP is the real power change at the bus

ΔQ is the reactive power change at the bus

$\frac{\partial P}{\partial \theta}$ is the real power change at the bus with respect to angles

$\frac{\partial P}{\partial V}V$ is the real power change at the bus with respect to change in voltage magnitude

$\frac{\partial Q}{\partial \theta}$ is the reactive power change at the bus with respect to angle

$\frac{\partial Q}{\partial V}V$ is the reactive power change at the bus with respect to change in Voltage magnitude

ΔV is the bus voltage change

$\Delta \theta$ is the bus angle change

4. Shunt compensation

As shown in figure 1, in electrical power systems, capacitors are connected in parallel with the transmission line or load in shunt compensation [34].whereas this type of compensation is highly used to shunt capacitive compensation for minimization of power losses i.e., both active and reactive power losses and also assures adequate voltage levels meanwhile extreme reactive loading conditions.

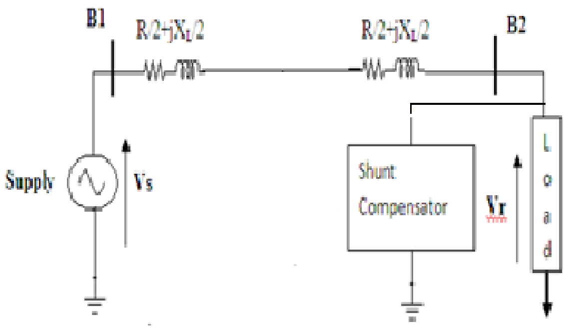

Fig.1. Single line diagram of shunt compensation

To minimize power losses and voltage drops in transmission and distribution systems, the Shunt capacitive compensation devices are dispersed. From the point of connection of shunt compensation in the system, a current is infused which can be carried out by changing the current source or voltage source and shunt impedance. The shunt compensator provides or consumes changed reactive power until unless the line voltage is in phase with the injected current. In general the common compensation techniques used in power system are shunt capacitor compensation or power factor.

In practice, for shunt compensation schemes the power factor may be corrected from 0.75 lagging to 0.9 lagging but it is not economical to afford required compensation to make the power factor to the range of 0.95 to 1.

Advantages

a) Inherent Ferro resonance risk is not seen.
b) Line fault current is not carried by capacitor.
c) Line currents are reduced.

Disadvantages

a) Expensive control gear is the only method for automatic regulation
b) Switchgear and control equipment is primarily needed.
c) In discrete steps, Voltage and VAR changes.
d) Response towards load fluctuations is incompetent.
e) From load generated harmonics there is risk of damage due to over current.

Thyristor controlled reactor (TCR), Static Synchronous Compensator (STATCOM), Thyristor Switched Capacitor (TSC), Thyristor Switched Reactor (TSR) and etc. are the examples of shunt compensation.

5. Static VAR Compensator (SVC)

A set of electrical devices which provides a rapid-acting reactive power in transmission networks with high voltage is named as static VAR compensator. These are one of the type of component in the FACTS (Flexible AC transmission system) device family that are meant to regulate voltage, power factor and stabilizing harmonics in the system , which is different from a rotating electrical machine i.e., a synchronous condenser but whereas a static VAR compensator do not have any rotating parts except an internal switchgear. The introduction of the SVC, highlighted compensation of power factor that reduced use of synchronous condensers or switched capacitor banks.

An automated impedance matching device, that designed to make the system closer to unity power factor is SVC, and is used at two main situations as:

- For Regulating voltage in transmission of power system Connected to the power system, to regulate the transmission voltage - Transmission SVC
- For improving power quality at large industrial loads -Industrial SVC

In the applications of transmission systems, the grid voltage is regulated by this SVC usage. If the load is capacitive i.e., leading, then the SVC will be used as thyristor controlled reactors which consumes VARs from the system there by decreasing the system voltage. Whereas if the load is inductive i.e., lagging conditions, the capacitor banks are switched on automatically, by providing a high voltage to the system. By the connection of the thyristor-controlled reactor, a continuous variable power, along with a capacitor bank, then the total resultant is varies power continuously either leading or lagging.

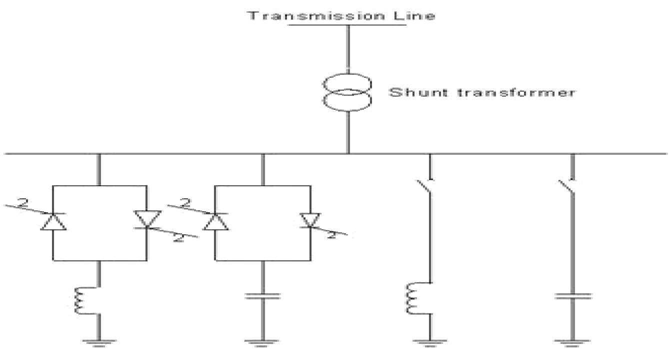

Fig. 2. The basic construction model of SVC device.

6. Firing angle model Static VAR Compensator (SVC)

In the power system, the SVC is a coordinated impedance identical device which is worked in transmission line for regulation of the voltage and to afford continuous VAR required. This modeling mitigates the additional iterative process handled by the Thyristor Controlled Reactor (TCR) 'α' firing angle in power flow formulation. The firing angle model for SVC is shown in figure 3.

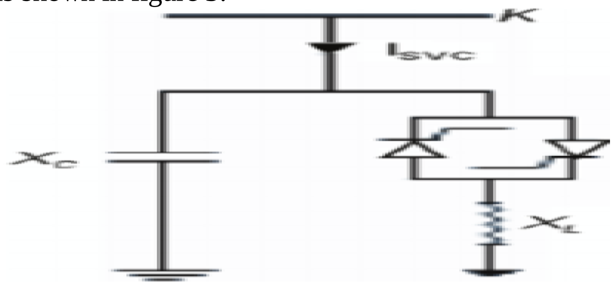

Fig. 3. The Firing angle model of SVC

SVC's unremarkably consists of a combination of mechanically controlled and thyristor controlled shunt capacitors and reactors [3], [4]. the foremost well known configuration for continuous controlled SVC's is that the combination of either fixed capacitance and thyristor controlled reactor or thyristor switched capacitance and thyristor controlled reactor [5], [6]. According to steady-stale analysis, every configuration is modelled on same lines. The SVC structure shown in Fig.3 is employed to derive a SVC model that considers the TCR firing angle α as state variable. This is often a brand new and additional advanced SVC illustration than those presently obtainable in open literature. The variable TCR equivalent electrical phenomenon, X_{Leq} , at harmonic, is given by [5] ,

$$X_{Leq} = X_L \cdot \frac{\pi}{2(\pi-\alpha)+\sin(2\alpha)} \quad (2)$$

Where α is the thyristor's firing angle.

The SVC effective reactance X_{eq} is determined by the parallel combination of X_C and X_{Leq},

$$X_{eq} = \frac{X_C.X_L}{\frac{X_C}{\pi}.(2(\pi-\alpha)+\sin(2\alpha))-X_L} \quad (3)$$

In general, the transfer admittance equation for the variable shunt compensator is,

$$I_{svc}(i) = jB_{svc}V(i) \quad (4)$$

Where

The SVC equivalent susceptance is given by (3) whilst its profile, as function of firing angle,

$$B_{svc} = -\frac{1}{X_c X_L}(X_L - \frac{X_c}{\pi}[2(\pi-\alpha)+\sin 2\alpha]) \quad (5)$$

$$X_L = wL.X_C = \frac{1}{wC} \quad (6)$$

and the reactive power equation is,

$$Q_k = \frac{-V_k^2}{X_c X_L}\{X_L - \frac{X_c}{\pi}[2(\pi-\alpha_{svc})+\sin 2\alpha_{svc}]\} \quad (7)$$

From the equation (7) , the linearized SVC equation is given by as

$$\begin{bmatrix}\Delta P_k \\ \Delta Q_k\end{bmatrix}^{(i)} = \begin{bmatrix}0 & 0 \\ 0 & \frac{2V_k^2}{\pi X_L}[\cos(2\alpha_{svc})-1]\end{bmatrix}\begin{bmatrix}\Delta\theta_k \\ \Delta\alpha_{svc}\end{bmatrix} \quad (8)$$

7. Genetic Algorithm (GA)

Genetic Algorithm [27] is one of the well accepted heuristic method and efficient tool for solving complex optimization problems. The structure of these methods is based on systems which work very closely to human reasoning; therefore it has been also called as intelligent. GA is global search technique which is capable to search for several solutions at the same time independent of prior knowledge or properties of solutions. The structure of GA basically includes three main steps: selection, crossover and mutation.

Selection: In this method tournament size is used for the selection.

Crossover: Cross over is the process of taking two parents and generating from them an offspring.

Mutation: It is performed after the crossover. It is used to prevent falling of all solutions into the local optimum.

In this paper, the formulation of SVC is described with some parameters including the location and size of the devices. Each individual is represented by a string that depends upon SVC parameter which is used for optimization. The first value of every string displays the location of SVC. It comprises the number of load buses where SVC may be placed. The rest of the values in the string indicate the possible sizing of device.

8. Particle Swarm Optimization (PSO)

Eberhart and Kennedy developed Particle Swarm Optimization in 1995 [28]. This algorithm starts by initializing a random swarm of M particles which consists R unknown parameters that to be optimized. Depending on selecting fitness function, in every iteration is evaluated for its fitness of each particle. This algorithm saves and incrementally change over's the best fitted parameters for each particle as P_{besti}, where i=1, 2, 3. . . M and the most fitted particle (g_{best}) among all the chooses particles in the group considered. The trajectory of each particle is determined in a direction by the previous velocity and the location of g_{best} and p_{besti}. Each particle's previous position (p_{besti}) and the swarm's overall best position (g_{best}) are meant to represent the notion of individual experience memory and group knowledge of a "ruler" respectively.

The parameters of each particle (pi) in the swarm are updated in each iteration (n) according to the following equations

$vel_i(n) = w \text{ X } vel_i (n-1) + acc_1 \text{ X } rand_1 \text{ X}(gbest-p_i(n-1)) + acc_2 rand_2 \text{X}(pbest_i-p_i(n-1))$ (9)

$p_i(n) = p_i(n-1)) + vel_i(n)$ (10)

Where, $vel_i(n)$ is the particle i's velocity.

acc_1, acc_2 are the coefficients of the acceleration which pulls each particle towards g_{best} and p_{besti} positions respectively

These acceleration coefficients are often set to be 2.0. w is the inertia weight of values∈ (0,1). Rand1 and Rand2 are two uniformly distributed random numbers in the ranges [0, 1].

9. Dragonfly Algorithm (DA)

DA is a random search optimization algorithm which replicating the flight movement of dragonfly swarm [32]. The swarming behaviours of dragonflies have two objective, which are hunting and migration. When they are in hunting mode, they form small groups and forage over an area repeatedly to find their prey. In migration mode, they form a big group that will travel in long distance with one destination place. These unique swarming behaviours become the inspiration of exploration and exploitation technique in DA. The swarm consists of N dragonflies as search agents. The location and step vector of a search agent is X and box respectively. With 1: s: I: s: N. The movement of a search agent is modeled after five individual behaviors in swarm, with explanation as follows:

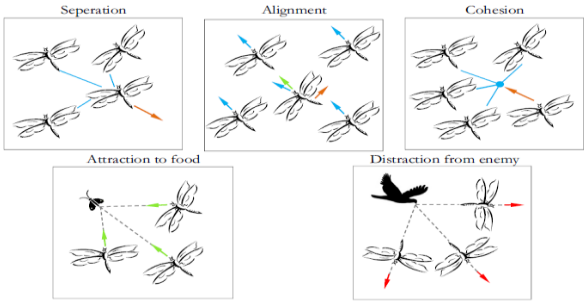

Fig. 4. Primitive behaviors of Dragonflies

Each of these behaviours is mathematically modeled as follows:

Separation is the tendency of an individual to keep a distance away from neighbouring search agents, with calculation as follows

$$S_i = -\sum_{j=1}^{N} X - X_j \quad (11)$$

where X is the position of the current individual,

Xj shows the position j-th neighbouring individual, and

N is the number of neighbouring individuals.

Alignment is the tendency of an individual to match its velocity with velocity of neighbouring search agents, with calculated as follows:

$$A_j = \frac{\sum_{j=1}^{N} V_j}{N} \quad (12)$$

where Vj shows the velocity of j-th neighbouring individual.

Cohesion is the tendency of an individual to fly toward the center of mass of neighboring search agents, with calculated as follows:

$$C_j = \frac{\sum_{j=1}^{N} X_j}{N} - X \quad (13)$$

where X is the position of the current individual, N is the number of neighbourhoods, and Xj shows the position j-th neighbouring individual

Attraction towards a food source is the tendency of an individual to fly toward a food source, with calculation as follows

$$F_i = X^+ - X \quad (14)$$

where X is the position of the current individual, and X^+ shows the position of the food source.

Distraction outwards an enemy is is the tendency of an individual to fly away from an enemy, with calculation as follows

$$E_i = X^- + X \quad (15)$$

where X is the position of the current individual, and X^- shows the position of the enemy.

$$\Delta X_{t+1} = (sS_i + cC_i + fF_i + aA_i + eE_i) + w\Delta X_t \quad (16)$$

where s shows the separation weight, Si indicates the separation of the i-th individual, a is the alignment weight,

A is the alignment of i-th individual, c indicates the cohesion weight, Ci is the cohesion of the i-th individual, f is the food factor, Fi is the food source of the i-th individual, e is the enemy factor, Ei is the position of enemy of the ith individual, w is the inertia weight, and t is the iteration counter. After calculating the step vector, the position vectors are calculated as follows:

$$X_{t+1} = X_t + \Delta X_{t+1} \quad (17)$$

To improve the randomness, stochastic behaviour, and exploration of the artificial dragonflies, they are required to fly around the search space using a random walk (Levy flight) when there is no neighbouring solutions. In this case, the position of dragonflies is updated using the following equation:

$$X_{t+1} = X_t + Levy(x)X_t \qquad (18)$$

The dragonflies are populated with the bus numbers of the system and the firing angles to the switching device of the SVC.

10. Results and Discussions

The proposed system is applied is IEEE 30 bus system by using MATLAB software.

10.1 Test case : IEEE 30 bus system

The single line diagram of IEEE 30 bus system is shown in the figure 5 and the voltage profile for IEEE 30 bus system without SVC is shown in figure 6.

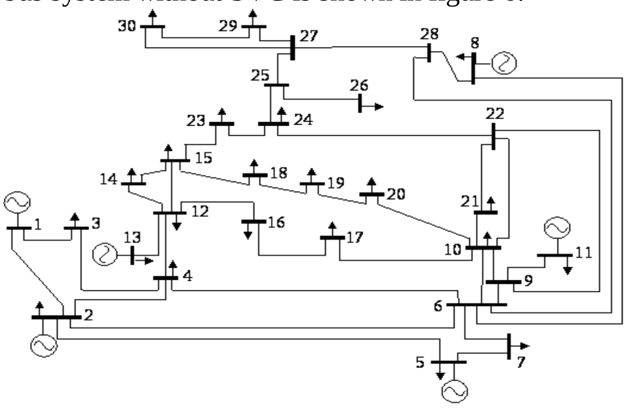

Fig.5. Single line diagram of IEEE 30 bus system.

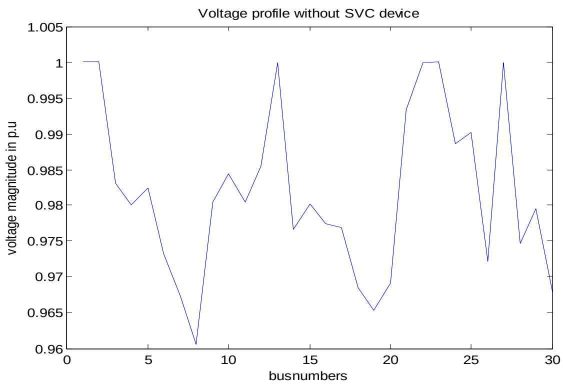

Fig. 6. Voltage profile of IEEE 30 bus system without SVC

10.1.1 Single SVC Placement

The placement of shunt compensating device which is SVC by using different optimizing techniques such as GA, PSO and DA is implemented on IEEE 30 bus system. The voltage profile, total real and reactive power losses without placing of SVC and with the placing of single SVC are shown in the figure 7,8 and 9 respectively.

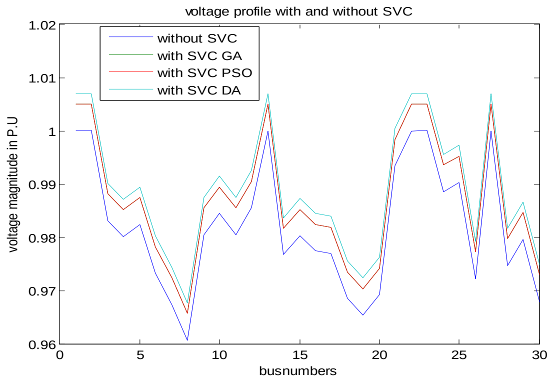

Fig. 7. Voltage profile of IEEE 30 bus with and without single SVC.

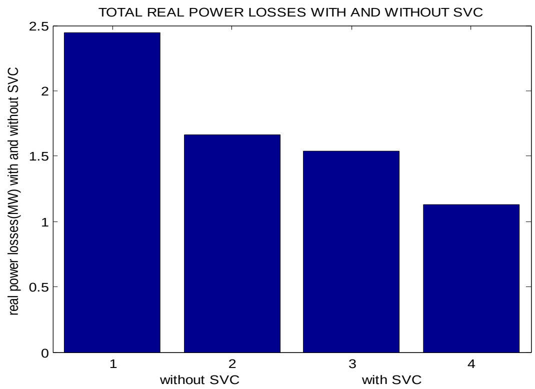

Fig. 8. Total Real power losses of IEEE 30 bus with and without single SVC.

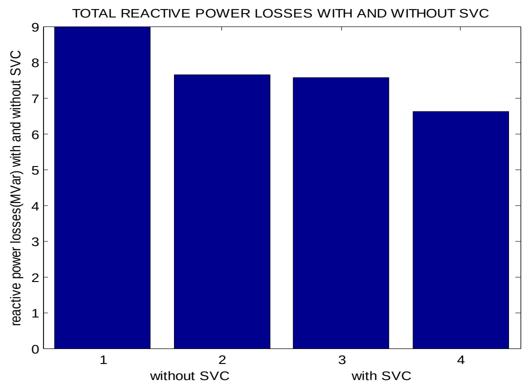

Fig. 9. Reactive power losses of IEEE 30 bus with and without single SVC.

10.1.2 Placement of Two SVC's

With the inclusion of two SVC's in the bus system then the power flows are further improved and losses further are reduced which is shown in the table 1. The voltage profile, total real and reactive power losses without placing of SVC and with the placing of two SVC's are shown in the figure 10,11 and 12 respectively.

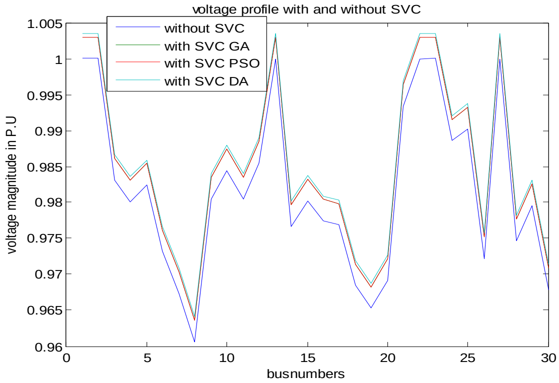

Fig. 10. Voltage profile of IEEE 30 bus with and without two SVCs

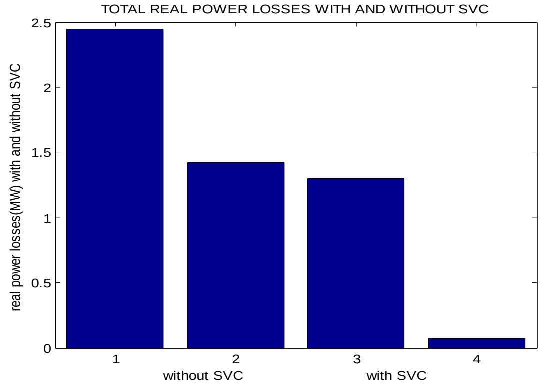

Fig.11. Total Real power losses of IEEE 30 bus with and without two SVCs

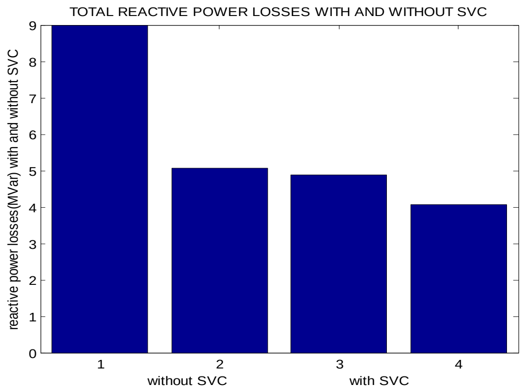

Fig. 12. Total Reactive power losses of IEEE 30 bus with and without two SVCs

Table 1 : Comparative system parameters of IEEE 30 bus with and without SVC by using GA PSO DA

Parameters	**Without SVC**	**With single SVC (GA)**	**With two SVC's (GA)**	**With single SVC (PSO)**	**With two SVC 's(PSO)**	**With single SVC (DA)**	**With two SVC 's(DA)**
Minimum Voltage (p.u)	0.966 at bus8	0.968 at bus 8	0.962 at bus 8	0.969 at bus 8	0.964 at bus 8	0.972 at bus 8	0.967 at bus 8
Maximum Voltage (p.u)	1.00 at bus1	1.006 at bus 1	1.002 at bus 1	1.008 at bus 1	1.004 at bus 1	1.016 at bus 1	1.009 at bus 1
Real power losses (MW)	2.44	1.665	1.414	1.542	1.296	1.132	0.806
Reactive power losses (MVar)	8.99	7.64	5.05	7.55	4.89	6.61	4.07
Location of SVC	----------	20th bus	9th bus, 16th bus	19th bus	20th bus, 11th bus	22nd bus	24th bus, 20th bus
SVC 1firing angle(deg)	----------	144.3	149.3	144.3	149.3	144.3	149.3
SVC2 firing angle(deg)	----------	-------	113.5	-------	114.3	-------	114.3
Size of SVC1 (kVar)	---------- -	2.72	1.94	2.72	1.94	2.72	1.94
Size of SVC2(KVar)	----------	-------	1.35	-------	1.35	-------	1.35

From the above table, it is shown that without SVC the Real and Reactive power losses are 2.44 MW and 8.99 MVar. In case of Genetic Algorithm for placing single SVC the losses are Reduced i.e Real and Reactive power losses are 1.665 MW and 7.64 MVar and for two SVC's 1.414 MW & 5.05 MVar. By applying Particle Swarm Optimization (PSO) for placing single SVC the Real and Reactive power losses are further reduced to 1.542 MW and 7.55 MVar and by using two SVC's the losses are 1.296 MW and 4.89 MVar. By applying Proposed method i.e Dragonfly Algorithm (DA) for placing single SVC, the Real and Reactive power losses are most further reduced to 1.132 MW and 6.61 MVar and by using two SVC's the losses are reduced to 0.806 MW and 4.07 MVar, So, The DA method gives better losses reduction as compared to GA and PSO.

10.2.Test case 2 : IEEE 118 bus

The single line diagram of the IEEE 118 bus system is shown in the figure 13. The improvement of voltage profile, the reduction of total real and reactive power losses, are shown in the figures 14 -19 respectively

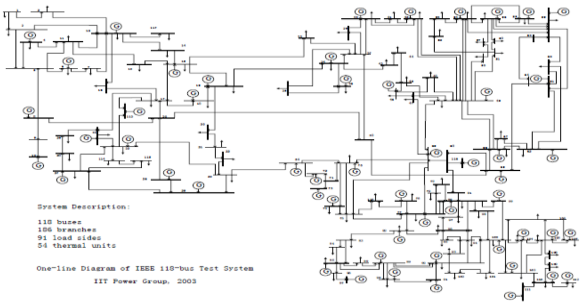

Fig.13. Single line diagram of the IEEE 118 bus system.

10.2.1. Single SVC Placement

The placement of single SVC by using different optimizing techniques such as GA, PSO and DA is implemented on IEEE 118 bus system. By placing single SVC at 98th bus location of the transmission network, the real and reactive power losses are reduced. The voltage profile, total real and reactive power losses without placing of SVC and with the placing of single SVC are shown in the figure 14,15 and 16 respectively.

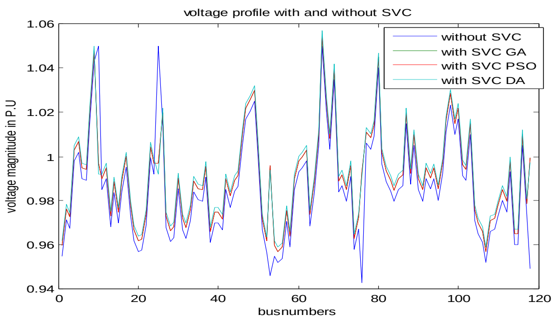

Fig.14. Voltage profile of IEEE 118 bus with and without single SVC

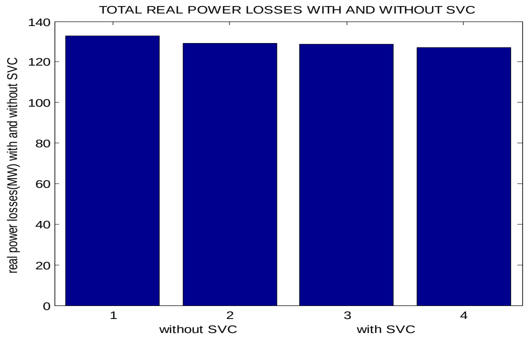

Fig. 15. Total Real power losses of IEEE 118 bus with and without single SVC

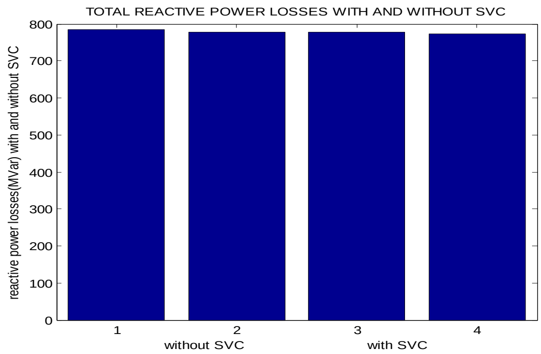

Fig.16. Total Reactive power losses of IEEE 118 bus with and without single SVC

10.2.2. Placement of Two SVC's

With the inclusion of two SVC's in the bus system i.e one SVC is locate at 96th bus and second SVC is locate at 101th bus 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 reactive power losses without placing of SVC and with the placing of two SVC's are shown in figures 17,18 and 19 respectively.

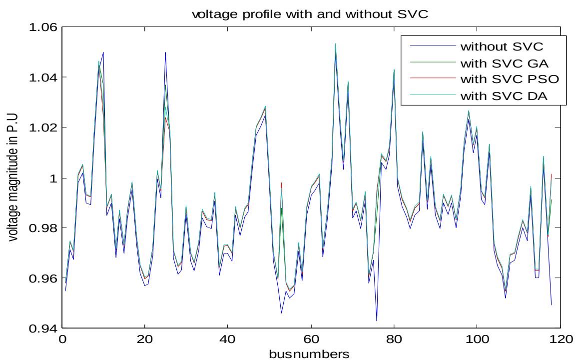

Fig.17. Voltage profile of IEEE 118 bus with and without two SVCs

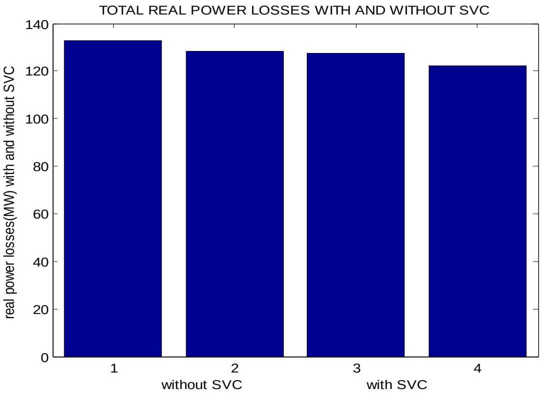

Fig. 18. Total Real power losses of IEEE 118 bus with and without two SVCs

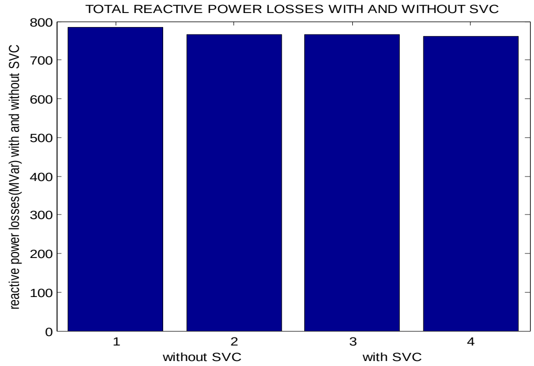

Fig. 19. Total Reactive power losses of IEEE 118bus with and without two SVCs

Table 2 Comparative system parameters of IEEE 118 bus with and without single & two SVCs by using GA PSO DA

Parameters	Without SVC	With SINGLE SVC (GA)	With TWO SVC's (GA)	With SINGLE SVC (PSO)	With TWO SVC 's(PSO)	With SINGLE T SVC (DA)	With TWO SVC 's(DA)
Minimum Voltage(p.u)	0.943 at bus 76	0.959 at bus 55	0.956 at bus 55	0.961 at bus 55	0.958 at bus 55	0.961 at bus 55	0.958 at bus 55
Maximum Voltage(p.u)	1.05 at bus10	1.047 at bus 9	1.045 at bus 9	1.048 at bus 9	1.046 at bus 9	1.048 at bus 9	1.046 at bus 9
Real power losses(MW)	132.83	129.329	128.213	128.771	127.655	126.911	122.075
Reactive power losses(MVar)	783.79	777.65	765.93	777.28	765.19	773.0	761.47
Location of SVC	----------	98th bus	96th bus, 101 bus	103rd bus	99th bus, 106th bus	110th bus	109th bus, 112st bus
SVC 1firing angle(deg)	----------	147.4	133.3	147.4	132	147.4	131
SVC2 firing angle(deg)	----------	-------	156.3	-------	156.3	-------	146.3
Size of SVC1(kVar)	-----------	4.672	2.74	4.672	2.74	4.672	2.74
Size of SVC2(KVar)	----------	-------	2.68	-------	2.68	-------	2.68

From the above table, it is shown that without SVC the Real and Reactive power losses are 132.83 MW and 783.79 MVar. In case of Genetic Algorithm for placing single SVC the losses are Reduced i.e Real and Reactive power losses are 129.329 MW and 777.65 MVar and for two SVC's 128.213 MW & 765.93 MVar. By applying Particle Swarm Optimization (PSO) for placing single SVC the Real and Reactive power losses are further reduced to 128.771 MW and 777.28 MVar and by using two SVC's the losses are 127.655 MW and 765.19 MVar. By applying Proposed method i.e Dragonfly Algorithm (DA) for placing single SVC, the Real and Reactive power losses are most further reduced to 126.911 MW and 773.0 MVar and by using two SVC's the losses are reduced to 122.075 MW and 761.47 MVar, So, The DA method gives better losses reduction as compared to GA and PSO.

11. Conclusion

The Firing Angle Model of Static VAR Compensator (SVC) using Non Conventional

Algorithms such as GA, PSO and DA methods has been implemented on IEEE 30 test system to investigate the performance of power transmission line in absence of SVC and presence of single and double SVC devices. In this paper, Dragonfly Algorithm has been proposed to analyze firing angle model of SVC .The results obtained for above bus system using proposed method with and without SVC compared and observations reveal that the Real and Reactive power losses are less with SVC. The obtained results are supportive, and show that the SVC 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 SVC 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 SVC's are placed in the IEEE 30 bus system, The Dragonfly algorithm gives better voltage profile improvement and better reduction in transmission line losses. Also the results indicate that the Dragonfly algorithm was an easy to use and best optimization technique compared with the Genetic algorithm (GA) and the Particle Swarm Optimization (PSO).

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