International Journal of Advanced Computational Engineering and Networking, ISSN: 2320-2106, Volume-5, Issue-4, Aprl.-2017
http://iraj.in

OPTIMAL PLACEMENT OF UPFC AND SVC IN TRANSMISSION NETWORKS USING MOTH SWARM ALGORITHM (MSA)

[1]R. SWETHA, [2]M. LAXMI DEVIR, [3]M. DAMODAR REDDY

[1,2,3]S.V.University College of Engineering, Tirupathi , Andhra Pradesh, INDIA.
E-mail: [1]rswethareddy260@gmail.com, [2]m.laxmidevi@yahoo.com, [3]mdreddy999@rediffmail.com

Abstract-This paper gives an application of Moth Swarm Algorithm (MSA) in transmission networks by integrating UPFC and SVC devices for loss reduction and voltage profile enhancement. Power Loss Sensitivity Factors are used to find the optimal locations of UPFC and Fuzzy Approach is used for optimal locations of SVC.MSA is used to get the optimal control parameter settings of UPFC and optimal sizes of SVC in concern to the power loss minimization. The method proposed in this paper is tested on IEEE 14- bus system and the results are discussed.

Index terms-Optimal placement, Fuzzy approach, Power loss sensitivity factors, Transmission networks, MSA.

I. INTRODUCTION

Due to the expanded demands on transmission, absence of long –term planning and the need to provide open access to generating companies and customers, all together have created tendencies towards innovationof FACTS. Flexible Alternating Current Transmission Systems (FACTS) are ‘ac transmission systems incorporating power electronics based and other static controllers to enhance controllability and increase power transfer capability’.The main objectives of FACTS are to increase power transmission capability,voltage control, voltage stability enhancement and power system stability improvement.

FACTS include devices such as UPFC, SVC, TCSC, SSSC, STATCOM etc., among them UPFC is the most efficient device. Many researchers have proposed installing UPFC [1,2] and SVC [3,4, 5] in power systems when placed in optimal locations to reduce power losses.This leads to an idea of integrating both the devices UPFC and SVC to get results much better than the individual placement of them.In this paper, two FACTS devices Unified Power Flow Controller (UPFC) & Static VARCompensator (SVC) are used. The UPFC is one of the most versatile devices. The major role of UPFC is to control the flow of real and reactive power by injection of a voltage in series with the transmission line. Real and reactive power flow control can allow for power flow in specified routes. Various mathematical models of UPFC has been introduced rely on various purposes of application. Here in this paper, the power injection model of UPFC is used.SVC is used for Shunt Compensation. It is a shunt connected static VAR generator or absorber that minimises power loss and enhances voltage profile. Power loss sensitivity factors [6] &Fuzzy approach [4] are used to know the optimal locations of UPFC & SVC respectively in the transmission network. Optimal Placement of SVC and UPFC by using SFLA was proposed before for minimization of real power loss and improvement of voltage profile [6].

A new method Moth Swarm Algorithm (MSA), which is inspired by orientation of moths towards moonlight[7] is proposed in this paper to achieve the desired objective i.e., realpower loss minimization and enhancement of the voltage profile.The load flow method used here is Newton-Raphson method.

II. MODELLING OF UPFC & SVC

A. Modelling of UPFC

The UPFC is a device which can control simultaneously all three parameters of line power flow (line impedance, voltage and phase angle). The UPFC is a combination of static synchronous compensator (STATCOM) and static synchronous compensator (SSSC). Both converters are operated from a common dc link with a dc storage capacitor[6] as shown in below **Figure.1**.

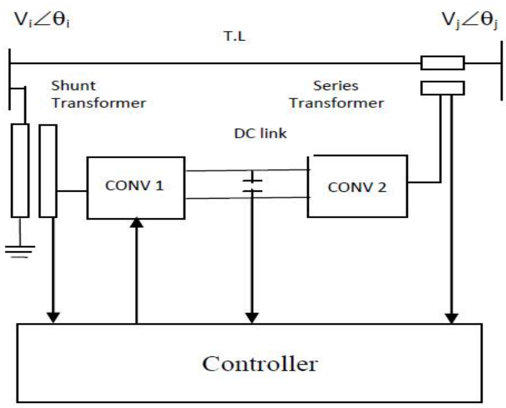

Figure.1UPFC Schematic Diagram

Converter 1 shall provide the shunt reactive compensation for the line either by generating or absorbing controllable reactive power. Converter 2 injects an AC voltage with controllable magnitude and phase angle in series with transmission line through a series transformer [2]. This is the fundamental function of UPFC, through which converter 2 either supplies or absorbs reactive power and active power is exchanged on the basis of series injected voltage.

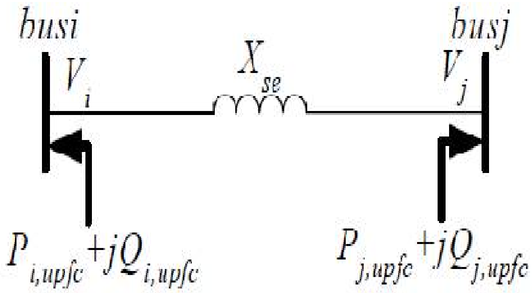

Figure.2.Steady-state UPFC power injection model

Here the power injection model of UPFC has been used which is simple and can be easily incorporated in load flow studies [1, 2]. The below **Figure.2** portrays the power injection model of UPFC.

The elements of the equivalent power injections [6] in **Figure.2** are

$$P_{i,UPFC} = 0.02rb_{se}V_i^2 Sin\gamma - 1.02rb_{se}V_iV_jSin(\theta_i - \theta_j + \gamma) \quad (1)$$

$$P_{j,UPFC} = rb_{se}V_iV_jSin(\theta_i - \theta_j + \gamma) \quad (2)$$

$$Q_{i,UPFC} = -rb_{se}V_i^2Cos\gamma \quad (3)$$

$$Q_{j,UPFC} = rb_{se}V_iV_jCos(\theta_i - \theta_j + \gamma) \quad (4)$$

In a power system where UPFC is placed between nodes i and j, the admittance matrix is altered by including a reactance X_s between the nodes. The Jacobian matrix is changed by addition of appropriate powers.

B. Modelling of SVC

Static VAR Compensator is a shunt connected FACTS device having the ability of supplying reactive power and thus could protect the system from voltage sags' potential threats[3,4,5].In the fundamental type of SVC, it is a thyristor controlled reactor which is a mix of capacitor connected in parallel. SVC resembles in the working perspective as a variable reactor which generates or absorbs the reactive power. It is mainly used for voltage regulation. It is an important component to control the voltage usually placed at the end of the transmission line. SVC is a shunt branch with a compensated reactive power Q_{SVC} shown in **Figure.3**which was set by available inductive and capacitive susceptance. On the other hand in SVC's working point of view, it is a shunt connected variable reactance, which either generates (or) absorbs reactive power in order to regulate the voltage magnitude. In this paper SVC model is acknowledged as an element which feeds a certain amount of reactive power at selected bus.

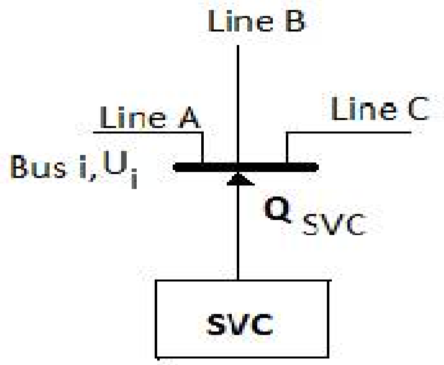

Figure.3. Injection model of SVC

III. OPTIMAL LOCATIONS OF UPFC & SVC

A. Optimal Location of UPFC using Power loss sensitivity indices:

To find the optimal locations of UPFC the most suitable line in the system need to be discovered. In such manner the power loss sensitivity factors are used [6].For UPFC placed between buses i and j the power loss sensitivity factors concerning to the parameters of the UPFC is given as

$$a_{ij} = \frac{\partial P_L}{\partial v_{ij}} \quad (5)$$

The power loss sensitivity factors is calculated with the assistance of the equation given below which is concluded from the equation below,

$$\frac{\partial P_L}{\partial v_{ij}} = 2V_iV_jcos(\delta_i-\delta_j) + 2V_iV_jsin(\delta_i-\delta_j) \quad (6)$$

B. Optimal Location of SVC using Fuzzy Approach

The optimal locations of SVC on load buses are known by using Fuzzy approach[4].Here Fuzzy logic is developed by taking two objective functions there by reducing real power losses and keeping up voltage profile within prescribed limits (0.9p.u-1.1p.u).

The Fuzzy rules are developed by using two inputs. Power loss index (PLI) and nodal voltages (p. u). Power loss index value for n^{th}node can be found by using the following equation

$$PLI_{(n)} = \frac{LR(n) - LR(min)}{LR(max) - LR(min)} \quad (7)$$

Where LR (n) is known as the loss reduction at n^{th}node and the minimum and maximum values of loss reduction are denoted by
LR (min) and LR (max) respectively. The fuzzy rules are taken from [4].The suitability index for the SVC placement is given by the output of fuzzy. The proper locations of the SVC will be the maximum values of the Fuzzy output. The following figures from **Figure.4** to **Figure.6** shows the membership function plot for power loss index, p.u.nodal voltage and SVC suitability respectively.

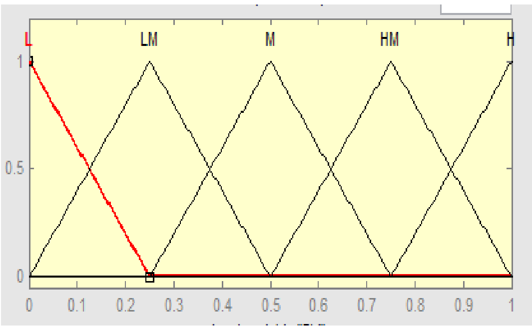

Figure.4. Membership function plot for power loss index

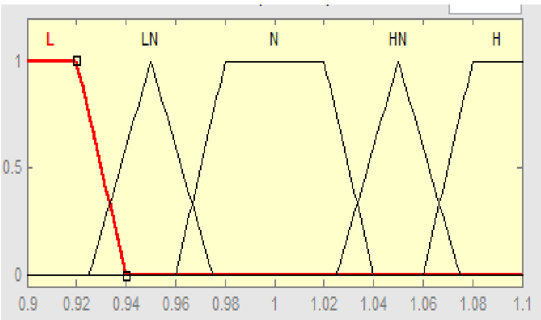

Figure.5. Membership function plot for p.u. nodal voltage

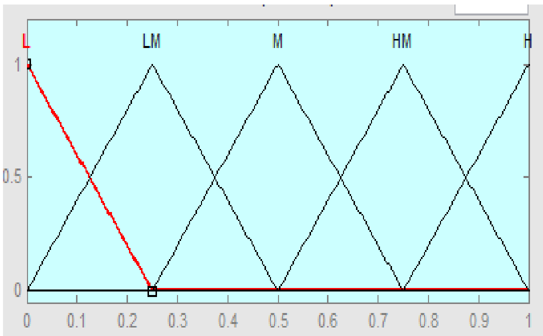

Figure.6.Membership function plot for SVC suitability

IV. MOTH SWARM ALGORITHM (MSA)

Moth Swarm Algorithm was developed by Al-Attar Mohamed [7]. This algorithm is based on moths' behaviour. Lepidoptera (butterflies and moths) is the second largest order in the insect class, which are more than 53% of all species on earth. Moths and other insects try to avoid themselves from predators during daylight, and at night they use the celestial navigation technique to adjust in the dark. The moths fly in a straight line over long distances in a constant angle relative to celestial far distant point light e.g., moonlight. In any case, such orientation suffers from a transverse direction motion due to spiral tracks around nearby artificial light sources.In MSA, the solution of optimization problem is represented by position of light source, and the fitness of this solution is considered as luminescence intensity of the light source. The proposed method consists of three groups of moths, which may be defined as follows:

Pathfinders: A small group of moths (n_p) that has ability to find the new areas over the optimization space with the principle of first in last out. The main function of this group is to separate the best positions as light sources to guide the movement of the main swarm.

Prospectors: This forms second group of moths which tends to move in a random spiral path within the neighbourhood of the light sources, which have been marked by the pathfinders.

Onlookers: This group of moths moves directly towards the best global solution (moonlight), which has been obtained by prospectors.

Initialization, Reconnaissance, TransverseOrientation and Celestial Navigation are the phases of moths occur in MSA.

In Initialization Phase, the positions of moths are randomly created.

In Reconnaissance Phase, to improve the diversity of solutions, the pathfinder moths update its positions by interacting with each other with an ability to fly for long distances using adaptive-crossover with levy-mutation. Here adaptive crossover is performed for first't'iterations, the normalised dispersal degreeρ_j^t in j[th] dimension is measured as

$$\rho_j^t = \frac{\sqrt{\frac{1}{n_p}\sum_{i=1}^{n_p}\left(x_{ij}^t - x_j^t\right)^2}}{x_j^t} \quad (8)$$

Where n_p is pathfinder moths and μ^t is variational coefficient given by

$$\mu^t = \frac{1}{d}\sum_{j=1}^{d} \rho_j^t \quad (9)$$

The pathfinder moths update their positions using adaptive crossover points group c_p with Levy-mutation as given below

$$j \epsilon c_p \text{ if } \rho_j^t \leq \mu^t (10)$$

The behaviour of Levy-Flights is as follows,

$$L_i \sim step \oplus \text{Levy}(\alpha) \sim 0.01 \frac{u}{|y|^{\frac{1}{\alpha}}} \quad (11)$$

Where *step*is the scaling size related to the scales of the interest problem, α is the entry wise multiplications, u =N $(0,\sigma_u^2)$ and y=N $(0,\sigma_y^2)$are two normal stochastic distributions.

Find sub-trail vectors with Levy-mutation using

$$v_i^t = x_{r1}^t + L_{i1}^t.(x_{r2}^t - x_{r3}^t) + L_{i2}^t.(x_{r4}^t - x_{r5}^t) \quad (12)$$

Build the trail solutions by using

$$V_{ij}^t = \begin{Bmatrix} v_{ij}^t if j \in c_p \\ x_{ij}^t if j \nexists c_p \end{Bmatrix} \quad (13)$$

Then fitness value of the completed trail solution is compared. If $f(v_i^t)$< f (x_i^t) then prefer V_i^t to x_i^t ,if not keep x_i^t in place of V_i^t.

In Transverse Orientation Phase, the prospectors which are the next best luminescence intensities are defined as

$n_f = round((n - n_p)*(1-\frac{t}{T}))$(14)

Where‘t’ is set of trajectories and ‘T’ is course of iterations.
Update the position of prospectors,

$$x_i^{t+1} = |x_i^t - x_p^t|.e^{bt}.Cos2\pi t + x_p^t \qquad (15)$$

In Celestial navigation phase, for each onlooker, if i∈ n_G then onlooker moths moves with Gaussian walks $x_i^{t+1} = x_i^t + \epsilon_1 + [\epsilon_2 * best_g^t - \epsilon_3 * x_i^t]$ (16)

If not it moves with ALIM, using

$$x_i^{t+1} = x_i^t + 0.001.N(x_i^{min} - x_i^t, x_i^{max} - x_i^t) + \left(1 - \frac{g}{G}\right).r_1.(best_g^t - x_i^t) + 2\frac{g}{G}.\ r_2.(best_g^t - x_i^t) \qquad (17)$$

Here $1 - \frac{g}{G}$ is cognitive factor and $2\frac{g}{G}$ is social factor. ϵ_1 is a random samples from Gaussian stochastic distribution go to the size of this group,$best_g^t$ is the global best solution obtained by the transverse orientation phase (both prospectors and pathfinders), ϵ_2 and ϵ_3 are random numbers distributed uniformly within the interval [0, 1].The Following **Figure.7**shows the flying of moths in spiral path and in a fixed angle.

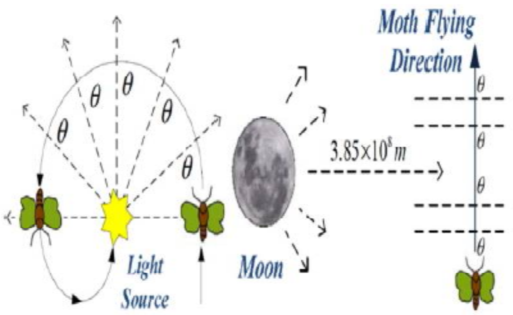

Figure 7: Flying of Moths in spiral path and in a fixed angle

V. ALGORITHM OF MSA TO DETERMINE SIZE OF SVC AND CONTROL PARAMETER SETTINGS OF UPFC

Step1: Identify the locations of SVC and UPFC by Fuzzy approach and Power loss sensitivity factors respectively.
Step2: Initialize the swarm size (n), number of light sourcesn_p, maximum number of iterations T, number of dimensions and limits of moth swarm variables.
Step3: For UPFC sizing the dimensions are 2 i.e., r which is series voltage coefficient and γ which is series voltage source angle should be in limits of 0 to 0.1 and 0 to 360° respectively. For two SVC’s, the dimensions are 2, i.e., shunt reactive power limits are from 0 to 30 MVAR. For simultaneous placement the dimensions are 3.
Step4: Generate the moth swarm randomly as [n*d] matrix within the limits. Run the load flow by placing UPFC & SVC and find the fitness. The fitness function is the real power loss minimization.
Step5: Sort the fitness functions in ascending order. The first $n_p$solutions are the solutions corresponding to pathfinder moths.
Step6: Update pathfinders using equation 10 and fitness of completed trail solution is compared using equations 11 to 13.
Step7: Thenfor selection of updating pathfinders, estimate the probability value of P_p $i.e.$, $P_p = \frac{fit_p}{\sum_{p=1}^{n_p} fit_p}$which is determined to be proportional to luminescence intensity.

$$fit_p = \begin{cases} \frac{1}{1+fit_p} for\ f_p \geq 0 \\ 1 + |f_p|\ for\ f_p < 0 \end{cases} \qquad (18)$$

Step8: Update the position of prospectors using equation 15. Calculate the fitness of prospector.
Step9: Thendefine next best solutions as onlookers. An Onlooker moth moves with Gaussian walks if not with Associative learning mechanism with immediate memory using equations 16 and 17.
Step10: Calculate the fitness of onlooker. Identify new light sources, moonlight, and type of each moth.
Step11: If maximum iterations are reached then display optimal solution (moonlight),else repeat the steps until solutions converge.
Step12: The solution vector gives optimal SVC sizes and optimal control parameters of UPFC and best fitness value gives minimum real power loss.

VI. RESULTS

The proposed method is tested on IEEE-14 bus system .The losses before and after the device placement is tabulated from **Table.1** to **Table. 2**and the results are shown as follows:

Losses Without UPFC (MW)	13.3938
UPFC Location	5-6
Dimensions	2
UPFC Parameters	γ = 170.9761° r=0.0669
Losses with UPFC (MW)	13.3136

Table.1 – Results for 14 bus system losses with and without UPFC (MSA)

Losses Without SVC (MW)	13.3938	
SVC Location	5,14	
Dimensions	2	
SVC Parameters	5thlocation 25.421	14thlocation 6.9909
Losses with SVC (MW)	13.2742	

Table.2 – Results for 14 bus system losses with and without SVC (MSA)

The results with the simultaneous placement of UPFC & SVC devices are tabulated below in **Table.3** as follows:

Losses Without UPFC (MW)	13.3938
UPFC Location	5-6
SVC Location	14
Dimensions	3
UPFC Parameters	$\gamma = 171.748°$ $r = 0.0626$
SVC Rating(MVAR)	6.9448
Losses With UPFC&SVC (MW)	13.2695

Table.3 – Results for 14 bus system losses with and without UPFC & SVC (MSA)

The voltages are enhanced with the individual placement of devices UPFC and SVC and also with the simultaneous placement of UPFC&SVC as tabulated in **Table.4**.

Bus no:	Without FACTS	UPFC inline 5-6	SVC at 5 & 14	UPFC inline 5-6& SVC at 14
1	1.0600	1.0600	1.0600	1.0600
2	1.0450	1.0450	1.0450	1.0450
3	1.0100	1.0100	1.0100	1.0100
4	1.0183	1.0253	1.0253	1.0255
5	1.0200	1.0314	1.0308	1.0312
6	1.0700	1.0700	1.0700	1.0700
7	1.0608	1.0639	1.0659	1.0659
8	1.0900	1.0900	1.0900	1.0900
9	1.0541	1.0569	1.0613	1.0612
10	1.0495	1.0517	1.0554	1.0554
11	1.0561	1.0573	1.0592	1.0591
12	1.0550	1.0553	1.0570	1.0570
13	1.0501	1.0505	1.0537	1.0537
14	1.0343	1.0361	1.0503	1.0502

Table.4-Voltages of 14 bus system for all the three cases

The loss reduction is morewith the simultaneous placement of UPFC and SVC devices as shown in**Table.3** than the individual placement of UPFC and SVC devices as shown in **Table.1**, **Table.2**respectively. The voltage profiles are enhanced with the placement of above FACTS devices as shown in **Table.4**.Hence MSA is proved in giving appreciable results.

CONCLUSION

In this paper, a two stage technique for knowing the optimal locations, the optimal control parameter settings of UPFC and sizes of SVC for active power loss minimization of standard IEEE-14 bus system is presented. By placing UPFC and SVC at optimal locations individually, the total real power loss of the system is minimised.The losses are reduced and voltage profile is enhanced by placing UPFC and SVC at optimal locations simultaneously.The results indicate the effectiveness of MSA for the optimal control parameter settings of UPFC and sizes of SVC.

REFERENCES

[1] S.V. Ravi Kumar and S. Siva Naga raju, ‘‘Loss Minimization by incorporation of UPFC in Load Flow Studies”, *International Journal of Electrical and power engineering*,1 (3): 321-327, 2007.

[2] A.MeteVural &Mehmat Tumay, ‘‘Mathematical modelling and analysis of a unified power flow controller: A comparison of two approaches in power flow studies and effects of UPFC location”, *Electrical Power and Energy Systems*,29 (2007),617-629.

[3] B.Venkateswara Rao, Dr.G.V.Nagesh Kumar, M.Ramya Priya &P.V.S.Sobhan, ‘‘Implementation of Static VAR Compensator for Improvement of Power System Stability”,*IEEE*-2009.

[4] Dr. M. Damodar Reddy andK.Dhanunjaya Babu ‘‘optimal placement of SVC using fuzzy and PSO algorithm”, *International journal of engineering research and applications*, ISSN: 2248-9622.vol.3,Issue1, 485-490, January-February 2013.

[5] Vinod.k.Shende, P. Jagtap“Optimal Location and sizing of SVC by PSO technique for Voltage Stability Enhancement and Power loss minimization”,*International journal of Engineering Trends and Technology*, *(IJETT)*, Volume 4, Issue 6, ISSN: 2231-5381, 2278-2282, June 2013.

[6] Dr.M.Damodar Reddy and Prasad krss “Optimal placement of SVC and UPFC by using SFLA”, *Discovery*,ISSN 2278 – 5469,45(210), 175-181, December 2015.

[7] Al-Attar-Ali Mohammad, Yahia Mohamed, Ahmed A.M. El-Gaafary, Ashraf M. Hemeida “Optimal power flow by using moth swarm algorithm” ,*Electric Power System Research*, 142(2017),190-206,September 2016.

★★★