International Journal of Engineering Research & Technology (IJERT)
ISSN: 2278-0181
Vol. 4 Issue 08, August-2015

Selection and Optimal Displacement of FACTS Equipments in order to Reduce the Loss of Power Network with the Help of PSO

Majid Payandehfar
Department of Electrical Engineering, Sanandaj Branch
Islamic Azad University,
Sanandaj, Iran

Goran Hasanifard
Department of Electrical Engineering, Sanandaj Branch
Islamic Azad University,
Sanandaj, Iran

***Abstract*— This article discusses how to correct placement of FACTS devices in the network using the IEEE standard PSO algorithm shows. In order to reduce losses and improve voltage profile in the network equipment is a static model to model equipped FACTS devices have been used. A suitable place to install the equipment and also to reduce losses and improve voltage profiles before and after the equipment is installed. The tested three types of devices used in the optimal location and size in order to increase the efficiency of the system is the objectives set out in the buses.**

***Keywords*— Location, Equipment FACTS, Algorithm PSO, Reduce losses, voltage profile.**

I. INTRODUCTION

Today, the power supply is One of the concerns of mankind. The electrical energy as the best and Most used form of energy, has a special place. The production and consumption of electric energy, is considered as an indicator of societies economic growth And a measurement of prosperity. The growth of power transfer facilities is limited due to the increasing transfer and use of power system in different places. Hence the development of the transmission line is necessary But it may not be easy to perform. There are important factors such as environmental diversity, land use, and regulations, which are imposed by the respective system. On the other hand, the power systems need to have sufficient reactive power with high reliability in order For the voltage to be suitable along the transmission path remain constant at all times. However, consumers are also looking for an uninterrupted and stable power supply as well. In this regard, in recent years with the development of power electronics industry Flexible Alternating Current Transmission Systems (FACTS) has been introduced to power networks system parameters can increase control of the system, and increase the reliability of the transmission line considerably[1].

Facts devices are consists of a series of controlled Thyristor Valve compensation (TCSC), static reactive power compensator (SVC), phase angle control Thyristor Valve Regulator(TCPST), static compensator (STATCOM), integrated flow controller (UPFC) etc. The Facts devices are widely used in power systems, to maintain the voltage profile and compensate reactive power. Due to their abundant capabilities and widespread use, they've been employed quickly in the power transmission and distribution networks, and have created a change in power systems. Facts device technology is an important tool to make full use of existing transmission facilities in emergency situations and without compromising the security of the system. An interesting feature of this equipment is allowing direct control of power transmission lines, by changing the parameters of the network structure, using high-gain controller based on the fast switching. Wide performance range, fast response and high reliability are of Characteristics of Facts devices.

II. FACTS DEVICES

Facts devices are defined by the IEEE standard as a system based on power electronics, which controls one or more ac transmission and distribution lines[1]. According to the standard IEEE, Facts devices bring about some advantages to the system , such as load voltage regulation control, minimizing the cost of production and utilization, increase dynamic stability, increase reliability and reduce the thermal load capacity of transmission lines with the necessary reactive power transmission system. in a number of studies the genetic algorithm have been used for the placement of Facts devices and to reduce production costs and investment In this paper, particle swarm optimization algorithm (PSO) is used to optimize the Nominal and location values. Facts elements based on placement in the network can be divided into three ategories[2]:

A. *Series FACTS Elements:*

These elements are placed in series with the transmission line, and usually with changing the reactance of the line, absorb reactive power, the TCSC is the most widely used member of this category.

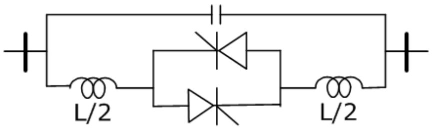

Fig 1. equivalent circuit TCSC

B. *Parallel FACTS Elements:*

These elements are placed in parallel on the network and are usually connected to one of the bus networks It controls the connection point by absorption or injection of reactive power to the network voltage the most famous member of this category is SVC.

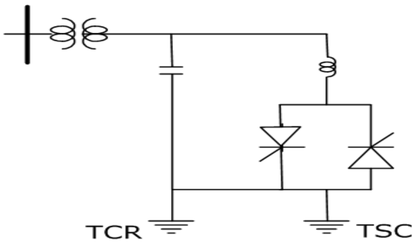

Fig 2. equivalent circuit SVC

C. Series–Parallel FACTS Elements:
These elements are a combination of two previous categories, and the UPFC is the most important member of this category, which is very powerful in terms of performance, and it's only limitation is the high cost.

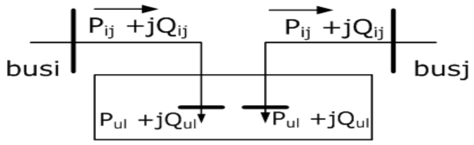

Fig 3. equivalent circuit UPFC

In this study, UPFC element was used because of the strong performance, fast response and high reliability. UPFC adjusts the power contribution of the two transmission lines which are parallel to each other. It also causes the maximum transmission power to be used. various lines of evidence show that UPFC significantly improves system reliability. This improvement can be measured with three reliable risk indicators, namely the loss of load expectation (LOLE), the expected loss of energy (LOEE), and Index System (SM). These algorithms are used to perform various calculations, including the placement of Facts devices in the transmission network. Among these algorithms, optimized ant colony[3,4], tabu search[5,6], genetic algorithms[7], simulated annealing[8,9], particle swarm optimization[10,11].

III. PARTICLE SWARM OPTIMIZATION [PSO]

The idea of Particle Swarm Optimization (PSO), was first introduced in 1995 by Kennedy Vabrhart. PSO is an evolutionary computation algorithms inspired by nature, and is based on repetition[12]. Source of inspiration of this algorithm is the social behaviour of animals such as a mass movement of fish and birds because PSO starts with an initial random population matrix. like continuous genetic algorithms. But unlike genetics, PSO has no evolution operators such as mutation and coupling. Each element of the population is called a particle (equivalent of chromosomes in genetics). The algorithm of PSO consists of certain number of particles. Which randomly. take initial value. for each particle two values are defined; position and velocity which are shown with position vector and velocity vector respectively. These particlesare move repeatedly in n-dimensional space, to calculate the amount of optimality as an evaluation criterion to search the new options. The space search dimension is equal to the number of parameters in the function to be optimized. one memory will be assigned to store the position of each particle in the past, and one memory to the best position among all the particles. With the experience gained from these memories, the particles decide how to move on the next turn. In each iteration, all particles move in n-dimensional space until the optimum point in general is found.

$$V_{i+1} = V_i + C_1 *rand_1 * (Pbest_i - X_i) + C_2 * rand_2 * (Gbest_i - X_i) \quad (1)$$

Particle velocity and their position gets updated according to the best local and absolute answer. That means:

$$V_i = (v_{i1}, v_{i2}, \ldots, v_{in}) \in \mathbb{R}^n \quad (2)$$

$$X_i = (x_{i1}, x_{i2}, \ldots, x_{in}) \in \mathbb{R}^n \quad (3)$$

In the Rapid changes formula, the parameters are C1 ,C2<4. Algorithm of PSO, updates each particle's velocity vector, and then adds the new speed, to the position or the amount of particle. Updating velocity, is affected both by the amount of the best local answer and absolute answer. The best local answer and The best absolute answer are The best answers that were obtained by a particle and in the total population respectively until the moment of the implementation of the algorithm. C1,C2 Constants are called, conceptual and social parameters respectively. The main advantage of PSO is that implementation of this algorithm is simple, and it needs to set only a few parameters. Moreover The PSO is able to the optimize the complicated cost functions.

IV. SIMULATION

It is clear, that power losses in a line depend on the current flowing and transmission line resistance Thereby reducing the amount of resistance or current, both leads to reduction in losses. Facts devices,reduce current Crossing the line, and network losses. To determine the extent of losses, it is important to calculate the load on the network, and specify all directories stream. Here, the Newton-Raphson load flow algorithm, is used to distribute the load on the network, and with a data network, and load flow results, losses of each branch is calculated by the well-known losses relation calculated.

$$P_{loss} = R_i I_i^2 \quad (4)$$

In this equation, Ri is the resistance of i-th branch, Ii is the current of i-th branch Modeling of Factc devices are classified by two methods. The first method isn't a separation method, in which all components are modeled as current sources and voltage sources. The second method is a separation method, here the elements are defined by the Jacobian matrix. In this matrix, the load flow matrix, and Facts devices, are modeled as elements of the matrix in a way that The impact of all this equipment, both on the network, and also on the results of the load flow, is quite clear.The resulting matrix is shown in the figure4.

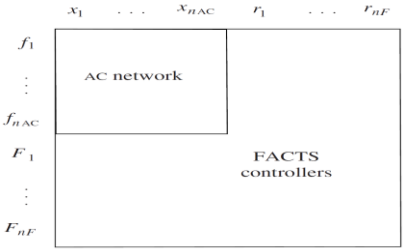

Fig. 4. Network load flow Jacobian matrix with FACTS

IEEE 6-bus network is a network used in this article. Single-line diagram of the network can be seen in Figure 5.

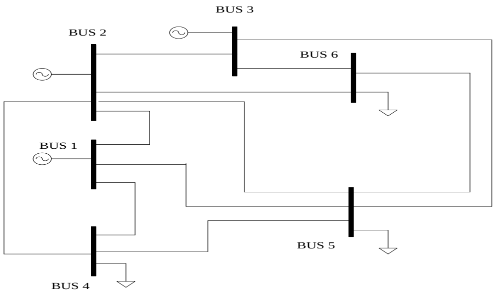

Fig 5. 6-bus IEEE test network

It has 6 buses which are connected by 11 transmission lines. In addition, the network has 3 manufacturing units. This network is a test network, which is mainly used for placement of Facts devices and equipment. The network information are shown in Tables 1 and 2.

TABLE I. DATA OF NETWORK LINES

From node	To node	R - p.u	X - p.u	B - p.u
1	2	0.1	0.2	0.04
1	4	0.05	0.2	0.04
1	5	0.08	0.3	0.06
2	3	0.05	0.25	0.06
2	4	0.05	0.1	0.02
2	5	0.1	0.3	0.04
2	6	0.07	0.2	0.05
3	5	0.12	0.26	0.05
3	6	0.02	0.1	0.02
4	5	0.2	0.4	0.08
5	6	0.1	0.3	0.06

TABLE II. BUSSES NETWORK INFORMATION

V_{max} **(pu)**	V_{min} **(pu)**	V_{int} **(pu)**	Q_{max} **(pu)**	Q_{min} **(pu)**	**Production (pu)**	**load (pu)**	**Bus**
1.05	0.95	1	1	-1	Bus slak	0	1
1.05	0.95	1.01	1	-1	0.5	0	2
1.05	0.95	1.01	0.6	-0.6	0.6	0	3
1.05	0.95	1	0	0	0	0.7	4
1.05	0.95	1	0	0	0	0.8	5
1.05	0.95	1	0	0	0	0.7	6

For the initial state of the network and devices without compensation, load flow results in the absence of Facts devices in the network test are provided in Table 4. Results of load flow include buses voltage and transfer power, from each of the lines.

TABLE III. VOLTAGE OF NETWORK BUS, FOR NORMAL MODE

Bus number	Voltage(p.u.)	Phase angle (degrees)
1	1	0
2	1.01	-4.2789
3	1.01	-4.74893
4	0.978723	-5.52675
5	0.971741	-7.01204
6	0.984765	-7.1515

Annual losses to the initial network, is equal to 52284/47 MWh.

TABLE IV. TRANSMISSION POWER AND LOSSES IN TRANSMISSION LINES

for bus	To bus	Current active power	Current reactive power	Losses
1	2	0.28706	0.199454	0.011461
1	4	0.473967	0.009357	0.011238
1	5	0.398658	0.017885	0.012726
2	3	0.032213	0.036908	5.28E-05
2	4	0.299516	-0.15829	0.005789
2	5	0.180159	-0.05207	0.003697
2	6	0.263713	-0.01589	0.00489
3	5	0.180555	-0.04273	0.004383
3	6	0.451605	-0.1631	0.004587
4	5	0.056457	0.048662	0.000688
5	6	0.00567	0.068616	0.000175

V. THE PROPOSED ALGORITHM

The following steps have been proposed to find the optimal point in different locations by using the algorithm

a) After the following steps, the optimal point is determined with respect to the required changes Estimation of PSO algorithm parameters, (population, number of variables, C1 and C2, etc.)

b) Position and initial velocity of the particles will be randomly determined in the d-dimensional search space.

c) the evaluation criteria for each of the particles, and calculation of the best personal experience of each particle (pbest), and calculation of the best experience of the particles (gbest).

d) Calculation of the particles velocity using equation (2) and updating the position of the particle in the equation (3)

e) calculation of the objective function for each particle and repeat steps (3)

f) Continue the implementation of the algorithm up to step (4) to achieve convergence.

VI. CONCLUSIONS AND RECOMMENDATIONS

In this study placement of Facts devices in the IEEE 6-bus network is analyzed using PSO algorithm. Function, have a goal of improving the losses of the network, by installing Facts devices in which the static model of the is used. The static model of the equipment is used alsi in studies of the system losses. In addition to considering the losses, voltage profile in the objective function is considered. A suitable place to install the equipment, and the improvement in losses and voltage profiles before and after the installation of this equipment is obtained. Table of improvement, with the installation of these devices is achieved.

Three types of Facts devices compensator have been examined, including SVC parallel compensator, TCSC series compensator, and UPFC series-parallel compensator, in order to compensate the reactive power, and improve the density of lines, with the aim of reducing losses and voltage profile also and the location and the optimal size of the device has been determined, in order to increase system efficiency by reducing losses and improving voltage buses. The obtained results for each of the devices is shown in the table below.

TABLE V. VOLTAGE VALUES AND VOLTAGE ANGLES IN EACH OF THE BUSSES, AFTER INSTALLATION SVC

Bus number	Voltage(p.u.)	Phase angle (degrees)
1	1	0
2	1.01	-0.0719
3	1.01	-0.08015
4	0.994817	-0.1002
5	0.990006	-0.12545
6	0.995734	-0.12443

TABLE VI. THE CURRENT POWER OF LINES AND LOSSES IN EACH LINE OF THE NETWORK, AFTER INSTALING SVC CANDIDATE

for bus	To bus	Current active power	Current reactive power	Losses
1	2	0.27861	0.27861	0.010859
1	4	0.484828	0.484828	0.012008
1	5	0.394261	0.394261	0.012437
2	3	0.032183	0.032183	5.27E-05
2	4	0.2912	0.2912	0.00416
2	5	0.180801	0.180801	0.003598
2	6	0.263566	0.263566	0.004871
3	5	0.180086	0.180086	0.004212
3	6	0.452044	0.452044	0.004561
4	5	0.059861	0.059861	0.000822
5	6	-0.00606	-0.00606	0.000119

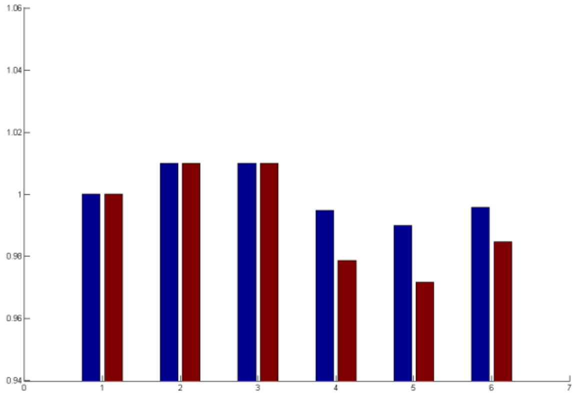

Fig. 6. Voltage than the previous buses (red curve) and after installation (blue curve)

TABLE VII. VOLTAGE VALUES, AND VOLTAGE ANGLE OF EACH OF THE BUSSES, AFTER INSTALLING TCSC CANDIDATE

Bus number	Voltage(p.u.)	Phase angle (degrees)
1	1	0
2	1.01	-4.58462
3	1.01	-4.94047
4	0.98534	-5.72082
5	0.976998	-7.16441
6	0.98578	-7.36101

TABLE VIII. THE CURRENT POWER OF LINES AND LOSSES IN EACH LINE OF THE NETWORK, AFTER INSTALLING TCSC CANDIDATE

for bus	To bus	Current active power	Current reactive power	Losses
1	2	0.209229	0.04283	0.00421
1	4	0.51577	-0.04231	0.013023
1	5	0.427287	-0.02049	0.014295
2	3	0.024383	0.035401	3.03E-05
2	4	0.25828	-0.11168	0.003998
2	5	0.167577	-0.03818	0.003089
2	6	0.254778	-0.01348	0.004559
3	5	0.171279	-0.0265	0.003769
3	6	0.453074	-0.15269	0.004545
4	5	0.05703	0.046038	0.000681
5	6	0.00134	0.057662	8.85E-05

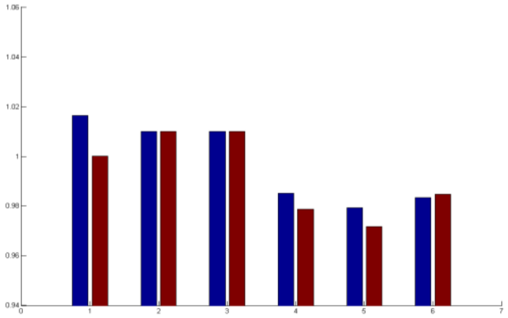

Fig. 7. Voltage than the previous buses (red curve) and after installation (blue curve)

TABLE IX. VOLTAGE VALUES, AND VOLTAGE ANGLE OF EACH OF THE BUSSES, AFTER INSTALLING UPFC CANDIDATE

Bus number	Voltage(p.u.)	Phase angle (degrees)
1	1	0
2	1.01	-4.163
3	1.01	-4.6326
4	0.995122	-5.79829
5	0.974444	-6.9531
6	0.985268	-7.04236

TABLE X. THE CURRENT POWER OF LINES AND LOSSES IN EACH LINE OF THE NETWORK, AFTER INSTALLING UPFC CANDIDATE

for bus	To bus	Current active power	Current reactive power	Losses
1	2	0.209229	0.04283	0.00421
1	4	0.51577	-0.04231	0.013023
1	5	0.427287	-0.02049	0.014295
2	3	0.024383	0.035401	3.03E-05
2	4	0.25828	-0.11168	0.003998
2	5	0.167577	-0.03818	0.003089
2	6	0.254778	-0.01348	0.004559
3	5	0.171279	-0.0265	0.003769
3	6	0.453074	-0.15269	0.004545
4	5	0.05703	0.046038	0.000681
5	6	0.00134	0.057662	8.85E-05

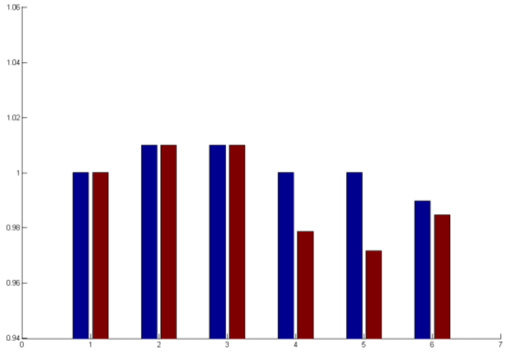

Fig. 8. Voltage than the previous buses (red curve) and after installation (blue curve)

The use of these elements in systems that have low consumption rates are not recommended. The main reason for this is the high cost of these elements. Our results show that the use of parallel elements (SVC) for networks with high reactive power consumption, is suitable. series (TCSC) and series-parallel (UPFC) Facts devices are suitable for balancing the network and improving losses networks with high density, on some lines The proposed algorithm and use of accurate models for these elements in the Jacobian matrix of power flow, show the suitability of this model for losses reduction studies. Using PSO algorithm to determine the location and the optimal size of the device indicate the efficiency of this optimization method for this purpose.On The other hand they show high performance and the speed of convergence is good.

REFERENCES

[1] L.J.Cai, I.Erlich, “optimal Choice and Allocation of FACTS Devices Using Genetic Algorithms”, ISAP Conference, Lemnos, Greece, August 31-Sept3, 2003
[2] Sutha, S., and N. Kamaraj. "Optimal Location of Multi Type Facts Devices for Multiple Contingencies Using Particle Swarm Optimization." International Journal of Electrical Systems Science & Engineering 1, no. 1 2008
[3] P. Bhasaputra, W. Ongaskul; “OptimalPlacement of Multi-Type FACTS Devices by Hybrid TS/SA Approach”, IndustrialTechnology, IEEE ICIT’02. IEEE International Conference, Vol. 1, 11-14 Dec.2002
[4] L.J.Cai, I.Erlich, “optimal Choice and Allocation of FACTS Devices Using Genetic Algorithms”, ISAP Conference, Lemnos, Greece, August 31-Sept3, 2003
[5] Sreenivasachar K. and etall, "Dynamic Stability Improvement of Multi Machine Power System with UPFC", Electric Power System Research 55, 2000
[6] Biansoongnern, S.; Chusanapiputt, S.; Phoomvuthisarn, S., "Optimal SVC and TCSC Placement for Minimization of Transmission Losses," Power System Technology, 2006. PowerCon 2006. International Conference on , vol., no., pp.1,5, 22-26 Oct. 2006
[7] Jumaat, S.A.; Musirin, I.; Othman, M.M.; Mokhlis, H., "Optimal placement and sizing of multiple FACTS devices installation," Power and Energy (PECon), 2012 IEEE International Conference on , vol., no., pp.145,150, 2-5 Dec. 2012
[8] Cai, L. J., István Erlich, and Georgios Stamtsis. "Optimal choice and allocation of FACTS devices in deregulated electricity market using genetic algorithms." In Power Systems Conference and Exposition, 2004. IEEE PES, pp. 201-207. IEEE, 2004
[9] S. Harison, And S. Ranga Raja, "PSO Based Solution for the Optimal Location and Control Parameter Settings of UPFC in a Restructured Power System," European Journal of Scientific Research, Vol.83 No.4, pp. 590 – 601. 2012
[10] A. Esmaeili Dahej, S. Esmaeili, And A. Goroohi, " Optimal Allocation of SVC AND TCSC for Improving Voltage Stability and Reducing Power System Losses using Hybrid Binary Genetic Algorithm and Particle Swarm Optimization," Canadian Journal On Electrical and Electronics Engineering, Vol. 3, No. 3, March 2012
[11] Momoh, J.A.; Zhu, J.Z., "A new approach to optimal power flow with phase shifter," Systems, Man, and Cybernetics, 1998. 1998 IEEE International Conference on , vol.5, no., pp.4794,4799 vol.5, 11-14 Oct 1998
[12] J. Kennedy, And R. Eberhart, "Particle Swarm Optimization," Proceedings of the IEEE International Conference on Neural Networks, Perth, Australia, pp. 1942-1945. 1995.