Optimal Location and Sizing of Thyristor Controlled Series Capacitor Using Particle Swarm Optimization Technique

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Abstract – Transmission loss minimization is a significant issue in Power System (PS). The power loss in Power System could be decreased by installing Flexible AC Transmission System (FACTS) devices. This paper described the application of Particle Swarm Optimization (PSO) for optimal placement and sizing of Thyristor Controlled Series Capacitor (TCSC) to minimize the power loss in the system. PSO is a naturally computational search and optimization technique invented by Eberhart and Kennedy in 1995 which focused on behavior of bird flocking or fish schooling. The objective for this study is to develope a PSO algorithm for loss minimization in power system. The impact of population size and weight coefficient throughout the optimization process is also tested. The technique is tested on IEEE 6 bus system.

Index Terms – FACTS devices, thyristor controlled series capacitor, particle swarm optimization

I. INTRODUCTION

FACTS device is a device proposed by N.G. Hingorani [1]; a well-known term for higher controllability in power systems by method for power electronics devices. FACTS devices can give benefits in term of increasing system transmission ability and power flow control flexibility and rapidity [2]. The connection of the FACTS device can be either in series or parallel compensation scheme. In series compensation, the FACTS device work as controllable voltage source when it is connected in series with transmission line of the system. In parallel compensation scheme, the FACTS devices work as current controller when it is connected in parallel with transmission line in the power system. One of the FACTS devices that can be used in power system is TCSC. This TCSC is used to control the transmission line reactance to give adequate load compensation. The aim of installing the TCSC is to decrease the power losses in the system. The advantages of TCSC is based on its capability to control the amount of transmission line compensation and it can operate in different modes.

In most recent decades, population based evolutionary computation methods have been examined and actualized to different optimization issues by using the collaboration among the potential solutions [3,4]. PSO technique was presented in 1995 by Kennedy and Eberhart [5,6]. It was one of the stochastic search techniques and developed via simulation of simplified system. This technique has been discovered to be strong in solving continuous non-linear optimization problems. The PSO take shorter time to make a calculation and have a stable convergence characteristics compared to other stochastic method. Other than that, PSO needs few parameters only. The following characteristics of PSO make it extremely appropriate for solving FACTS optimization problem.

- It has few parameters to be tuned
- It gives quick convergence
- Initial solutions do not impact its computational behavior
- Its behavior is not exceptionally impacted by increment in dimensionality

In this paper, the aim is to reduce the power losses in power system. PSO technique is proposed to find the optimal placement and sizing of FACTS devices. TCSC is chosen as the FACTS device for this study which can improved the transmission line reactance. The IEEE 6 bus system is used as the test specimen in this study.

II. THYRISTOR CONTROLLED SERIES CAPACITOR

In order to give adequate load compensation, Thyristor-Controlled Series Compensation (TCSC) is utilized within power system to control the reactance of a transmission line. The TCSC is used because of its capability to control the amount of transmission line compensation. Other advantages of TCSC is its capacity to work in distinctive modes. This characteristics are extremely important because the loads are always changing and cannot be predicted. TCSC is a capacitive reactance compensator made up of series capacitor bank parallel by a thyristor controlled reactor to give a smoothly variable series capacitive reactance [7]. To compensate for the inductive reactance of the line, the TCSC could be connected in series with the line conductors. It can operate in different mode which is in capacitive or inductive mode. The compensation ratio (TCSC) and the line reactance (X_L) influenced the TCSC (X_{TCSC}) reactance where it is spotted. The line impedance (Z_L) was changed by the value of X_{TCSC} when it is connected with the TCSC as TCSC introduces capacitive reactance to reduce the line reactance. The TCSC model is shown in Fig. 1.

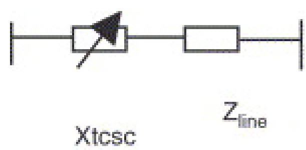

Fig.1: TCSC Model

III. PARTICLE SWARM OPTIMIZATION (PSO)

PSO gives a population based search method in which individuals called particles and changes their position. The position of each particle is laid in X-Y plane. By using velocity, every particle moves to the new position according to its own experience, called as P_{best}. The best value of all particle in the population are known as G_{best}. The PSO comprises of velocity change of every particles towards its P_{best} and G_{best} from time to time [8-9]. Every particle will attempt to alter its present position and velocity as indicated by the distance between its present position and P_{best} and the current position and G_{best}. The particles update its velocity and position after discovered the best values. Equation (1) is used to update the velocity of all particle in the system. Fig. 2 shows the flowchart of PSO.

$$v_i^{k+1} = wv_i^k + C1 \times rand1 \times \left(Pbesti - s_{i^k}\right) + c2 \times rand2 \times \left(Gbesti - s_{i^k}\right) \quad (1)$$

where

v_i^{k+1} : velocity of particle i at (k+1)th iteration
v_i^k : velocity of particle i at kth iterations
w : the inertia weight
c_1 and c_2 : weight coefficient (0-4)
s_i^k : current position of particle at kth iteration
$rand_q$ and $rand_2$: random number between 0 and 1
P_{best} : best position of particle i up to current position
G_{best} : overall best position of particles up to current iteration

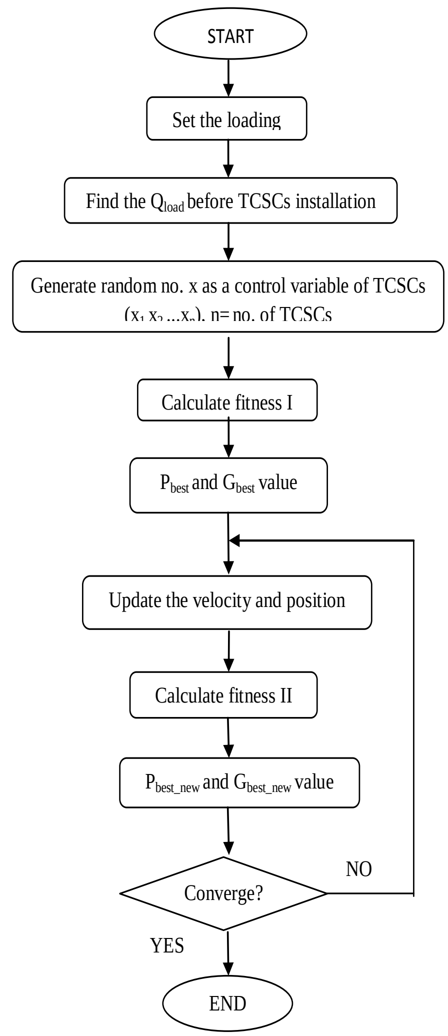

Fig. 2: Particle Swarm Optimization (PSO) Flowcharts

The position can be update by (2).

$$s_i^{k+1} = s_i^k + V_i^{k+1} \quad (2)$$

Where

s_i^k : current position of particle i at kth iteration
s_i^{k+1} : current position of particle i at (k+1)th iteration

IV. RESULTS AND DISCUSSION

As to find out its feasibility, the PSO technique is applied to find optimal placement and sizing of TCSC on the IEEE 6 bus system. The parameters of the optimization algorithms for this study are tabled in Table 1.

TABLE 1
PARTICLE SWARM OPTIMIZATION (PSO) PARAMETERS USED

Parameters	Value
Inertia Weight, w	0.9
Weight Coefficient, $c_1 = c_2$	1,2,3
Population Size	10,20,30,40
Number of iteration	1000
$Rand_1$ and $Rand_2$	0 to 1

A. Minimization of Power Loss using TCSC

Result for minimization of power loss are tabulated in Table 2. This table also show the results for the placement and sizing of TCSC in order to reduce the loss at few loading conditions. For instance, the loss has been reduced from 4.8246MW to 3.8399MW at 20MVar loading.

TABLE 2
LOSS MINIMIZATION AT SEVERAL LOAD CONDITION

Loading value Q_d (MVar)	Power loss (MW)		Location of TCSC			Sizing of TCSC		
	Without TCSC	With TCSC	Location 1	Location 2	Location 3	Size 1	Size 2	Size 3
5	4.2261	3.6810	3	1	3	1.3492	0.8670	0.8884
10	4.3706	3.7430	1	5	3	0.7917	0.9999	0.8316
15	4.5678	3.8063	3	6	1	0.8209	0.9623	0.7970
20	4.8246	3.8399	3	1	2	0.7637	0.7807	0.9137
25	5.1497	4.0664	1	2	6	0.8926	0.9228	0.8345
30	5.5544	4.1108	4	1	6	1.1204	0.8991	1.0291

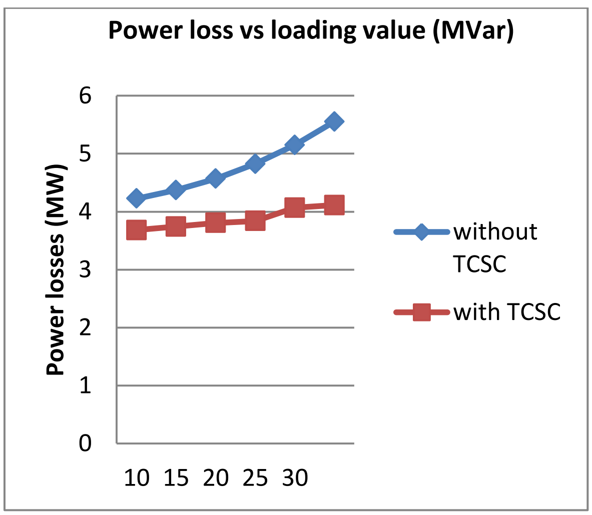

Fig. 3: Results for minimization of power loss

Based on the results obtained in the Table 2, it can be seen that the power loss of the system can be reduced by installing the TCSC at the transmission line when the loading is subjected to bus 3. For example, based on Table 2, the loss decreased from 5.5544MW to 4.1108MW at 30MVar loading. The location of TCSC1, TCSC2 and TCSC3 are lines 4, 1 and 6 and the sizing are 1.1204 p.u, 0.8991 p.u and 1.0291 p.u respectively in order to reduce these losses.

B. Impact of weight coefficient on power loss

TABLE 3
THE IMPACT OF WEIGHT COEFFICIENT ON DIFFERENT VARIATION OF LOAD

Weight coefficient C1 & C2	Power losses for different loading value (MW)		
	Q_d =10 MVar	Q_d =20 MVar	Q_d =30 MVar
1	3.9078	3.9781	4.0564
2	3.8369	4.0077	4.0686
3	3.7147	4.0647	4.1844

The result for impact of weight coefficient, c1 and c2 to the minimization of transmission loss are recorded in Table 3. The c_1 and c_2 values are set between 1 and 3. These data are recorded when the loading variation is tested at bus 3. Based on the Table 3 above, it indicate that as the reactive power loading rise, the transmission loss also rise. The bigger value of c1 and c2 provide the lowest reduction of transmission loss for the system. For example, after installation of TCSC at Q_d = 10MVar and the weight coefficient equal to 1, the losses is 3.9078MW, while when the weight coefficient equal to 3, the transmission losses is 3.7147MW. This means that bigger value of weight coefficients gives better results. Based on the results it is discovered that the bigger weight coefficients has a relevant effect in finishing process using the PSO method.

C. Impact of population size to the loss of the system

The impact of population size to the reduction of the transmission loss are tabulated in Table 4. Based on the table, it is examined that as the reactive power loading rise, transmission loss also rise. The bigger population size provides the least minimization of loss in the system. For example, with installation of TCSC at Q_d = 20MVar, the losses is 3.9380MW for size of population of 10, while when the size of population is changed up to 40, the transmission losses is 3.8261MW. This show that bigger population size give better results. The different values of loading will give about the same result as 20MVar loading. Based on the results, it is observed that the rising size of population has a correlated effect in exhibiting optimization process by using PSO method.

TABLE 4
THE IMPACT OF POPULATION SIZE ON DIFFERENT VARIATION OF LOAD

Population size	Power losses for different loading value (MW)		
	Q_d =10 (MVar)	Q_d =20 (MVar)	Q_d =30 (MVar)
10	3.6250	3.9380	4.5741
20	3.7768	3.9207	4.1035
30	3.8366	3.9441	4.2404
40	3.8514	3.8261	3.9612

V. CONCLUSION

This paper has presented the optimal location and sizing of thyristor controlled series capacitor using particle swarm optimization technique. Tests executed on the IEEE 6 bus system. Results indicates that the PSO technique had succeed to decrease the loss of the system. For the next time, this PSO technique could be modified to improve the result obtained.

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