Analysis of Thyristor Controlled Series Compensator in Power Transmission Network by Using Bees Algorithm Technique

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Abstract— ***This paper presents Bees Algorithm (BA) technique to seek the optimum size of Flexible AC Transmission System (FACTS) device which is the Thyristor Controlled Series Compensator (TCSC) in a power transmission network. Fast Voltage Stability Index (FVSI) is used to designate the suitable line location of TCSC installation. Using these methods, the location and size of TCSC are optimized simultaneously and can be used to minimize loss in power transmission network. IEEE 26-bus Reliability Test System (RTS) will be use to investigate the effectiveness of the device. This research varies the loading conditions of the IEEE 26-bus system.***

Keywords-BA; FACTS; TCSC; FVSI; RTS; optimal location; loss minimization

I. INTRODUCTION

The problem lies when there are new of load that want to connect with national grid system which it already there for old load. This situation will make it required more load and the location of this plant on the outskirt of the city. So the problems are:

- Will there be enough power – handling capacity for this load?
- Will the additional load cause some components to be overloaded?
- Will it necessary to built new transmission lines or power plants?

Therefore, the best way to overcome this problem is by utilizing one of FACTS devices. In this paper will focus on the TCSC which it is one of the series compensator in FACTS devices.

The TCSC is an important component of FACTS devices. With the firing control of the thyristors, it can change its apparent reactance smoothly and rapidly [1]. The TCSC is able to directly schedule the real power flows through a typically selected line allow the system to operate closer to the line limits. More importantly because of its rapid and flexible regulation ability, it can improve transient stability and dynamic performance of the power system [2].

The analysis of FVSI developed by I.Musirin [3] is used to determining the location of the TCSC. While BA technique will be utilized as the optimization technique to optimum size of TCSC for minimize loss in power transmission network. Bees Algorithm is a novel optimization method developed by D.T.Pham in 2006 [4,5]. It is a kind of Swarm-based optimization algorithms that mimics nature's methods to drive the search towards the optimal solution.

This paper discusses the investigation of TCSC installed in power transmission network. There are objective to determine the suitable line location and optimum size of TCSC. So that it can controlling power flow in the line and minimize loss in power transmission network.

II. TCSC MODEL

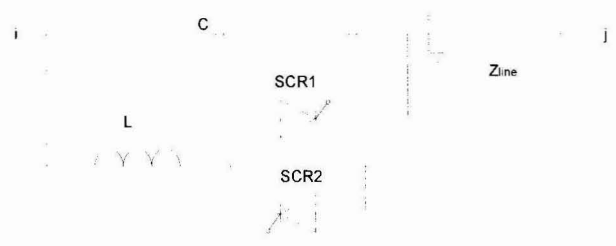

Figure 1. Installation TCSC in transmission line

Figure 1 represent the TCSC can change the line reactance so as to function as inductive or capacitive compensation. The reactance of TCSC is adjusted directly based on the reactance of the transmission line.

$$X_{ij} = X_{line} + X_{TCSC} \qquad \text{where } X_{TCSC} = r_{TCSC} \cdot X_{line}$$

Where X_{line} is the reactance of the transmission line, X_{TCSC} represents the reactance contributes by TCSC and r_{TCSC} represents the degree of compensation of TCSC. The working range of TCSC (X_{MIN} ~ X_{MAX}) is set between -0.7X_{line} and 0.2X_{line} [6].

III. METHODOLOGY

This section will discuss about analysis of FVSI concept and theory of BA. The analysis of FVSI and BA are in implementation to minimize loss in power transmission network. The data collection for optimun size of TCSC is done using simulation in MATLAB software.

A. *Fast Voltage Stability Index*

Figure 2 below shows FVSI flowchart that is used to determine line location of TCSC to be installed in the IEEE 26-bus system.

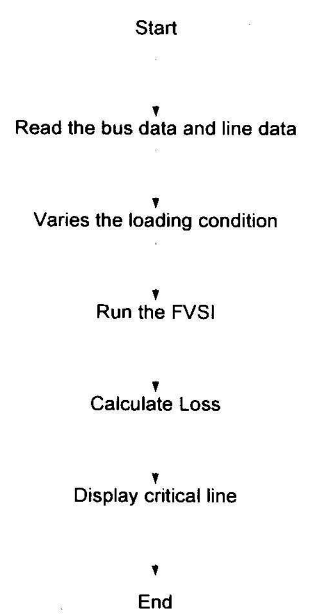

Figure 2. Flowchart of the FVSI technique

Firstly, the FVSI technique starts with read the bus data and line data in [7]. Then, run the load flow program using newton Raphson method for the base case and evaluate the FVSI value for every line in the system. After that, varies the reactive power loading at a chosen load bus and calculate FVSI values for every load variation. Repeat the step with gradually increase the reactive power loading until the load flow solution fails to give the results. Lastly, the highest FVSI value will be display on the most sensitive line in order.

B. *Bees Algorithm*

The foraging process begins in a colony by scout bees being sent to search for promising flower patches. Scout bees move randomly from one patch to another. Having found the patches which are rated above a certain quality threshold, these scout bees would then deposit their nectar or pollen and eventually perform a "waggle dance" when they return t the hive [8]. This dance is essential for colony communication. It is about the direction to the source, the distance from the hive, and the quality rating [8, 9]. This information helps the colony to send its bees to the flower patches precisely, without using guides or maps. While harvesting from a patch, the bees monitor its food level. This is necessary to decide upon the next waggle dance when they return to the hive [9]. If the patch is still good enough as a food source, then it will be advertised in the waggle dance and more bees will be recruited to the particular source [10].

C. *The Basic Bees Algorithm*

Figure 3 shows the flowchart of BA that is used to determine the optimum size of TCSC.

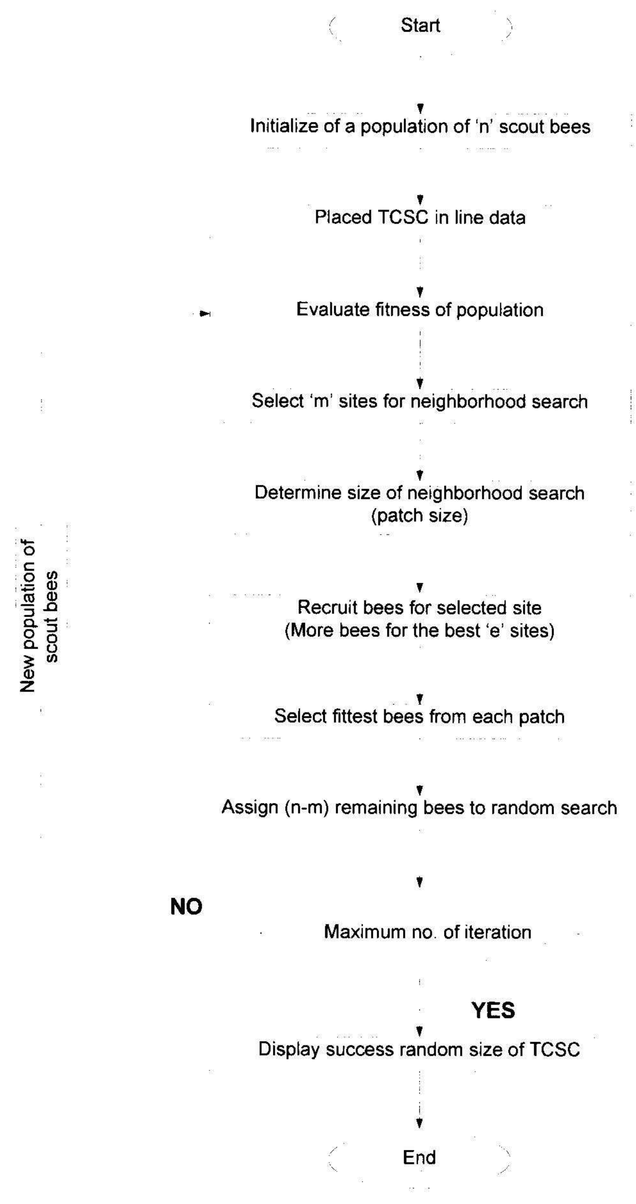

Figure 3. Flowchart of the Bees Algorithm technique

Step 1:
The algorithm starts with initial population of n scout bees.

Step 2:
Installation TCSC at sensitive line for minimizes the total losses transmission line.

Step 3:
The fitness computation process is carried out for each site visited by a bee by calculating the losses.

Step 4:
Repeat step 5-9 until stopping criteria is not met.

Step 5:
Bees that have the highest fitness are chosen as "selected bees" (m sites) and sites visited by them are chosen for neighborhood search. Best patches are set to be 20% of the population size.

Step 6:
It is required to determine the size of neighborhood search done by the bees in the "selected sites".

Step 7 & 8:
The algorithm conducts searches around the selected sites based on size determined in the step 5. More bees are assigned to search in the vicinity of the best e sites.

Step 9:
The remaining bees (n-m) are sent for random search to find other potential sites.

Step 10:
Randomly initialized a new population

Step 11:
Find the global best point.

Step 12:
The optimum size of TCSC was being display.

*** Steps 4-7**
Repeated until either the best fitness value has stabilized or the specified maximum number of iterations has been reached.

IV. Result and Discussion

This program was tested on the IEEE 26-bus Reliability Test System (RTS) which consists of one slack bus, five generator buses of PV bus, 20 load buses of PQ bus and 46 transmission lines by using MATLAB software.

TABLE I. The Parameters That be Set in BA Technique

Parameters	Definition
n=15	number of scout bees
itr=10	number of iterations
m=20	number of best selected patches
e=10	number of elite selected patches
n1=15	number of recruited bees around best selected patches
n2=30	number of recruited bees around elite selected patches
ngh=0.02	patch radius for neighborhood search

Based on the program designed, several buses are selected to conduct the optimization analysis with certain value of the loads. Five TCSCs are installed at line 14, 12, 26, 22 and 21 and assigned as X_1, X_2, X_3, X_4 and X_5. These lines were being chosen after done the FVSI technique that displays the most sensitive line. The loading condition will be set up between 10MVar until 50MVar to the selected load bus for optimization of TCSCs sizing. The results tabulated are obtained when the BA parameters are set to the following values at the initialization process at Table I.

A. *Effect of TCSCs Installation in Loss Reduction*

Three load buses were subjected to variation of loading conditions in this study which are buses 6, 10 and 19. Figure 4, 5 and 6 was shown the comparison between with and without installation of TCSCs at various loading condition. Line 14, 12, 26, 22 and 21 were chose to install TCSCs because these lines are the sensitive lines. By using FVSI technique, sensitive lines can be obtained.

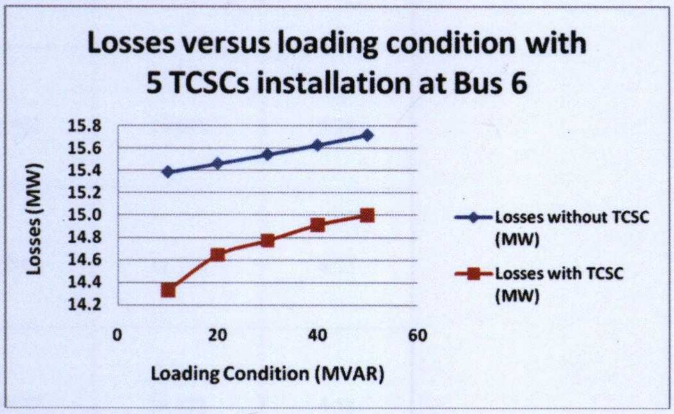

Figure 4. Effect of 5 TCSCs installation in the system with loading condition at bus 6

Theoretically, installation of TCSC will enhance voltage stability and reduce transmission losses. On the other hand, losses will increase proportionally with increase loading condition. It is observed that the losses at transmission line are reduced after the installation of TCSCs as illustrated in the Figure 4. From Table II, the higher percentage of loss reduction is 6.85% which total transmission losses reduce from 15.385MW to 14.330MW at 10MVar loading condition subjected to the system. The other results loading condition are also shown in Table II.

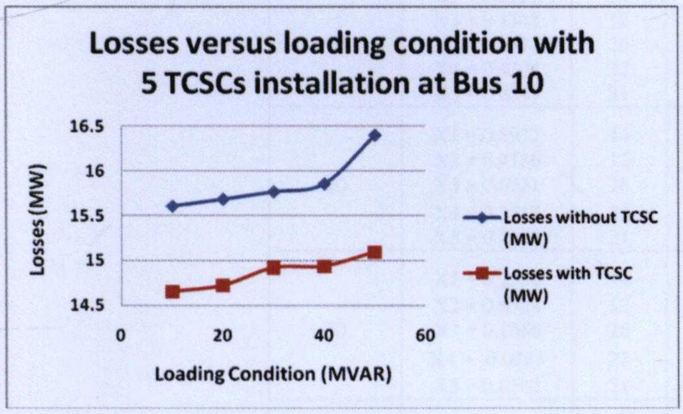

Figure 5. Effect of 5 TCSCs installation in the system with loading condition at bus 10

The same phenomena also can be observed in Figure 5 for load variations subjected to bus 10. The installation of TCSCs has also reduced the total transmission losses in whole system for all loading conditions. The results in Figure 5 shows the total losses transmission line with installation of TCSCs is start close to uniform compare the results in Figure 4. At 50MVar loading condition, the percentage of loss reduction is much larger as compared to other loading which is 7.98%. Table III shown all the data obtained.

Figure 6 represent the increasing of losses transmission line depend on the gradually increase of loading condition. It can be observed that losses increases until 20MVar loading condition and then the losses close to uniform until 40MVar but it increase rapidly after that. The details result for 5 TCSCs installations at bus 19 are tabulated in Table IV.

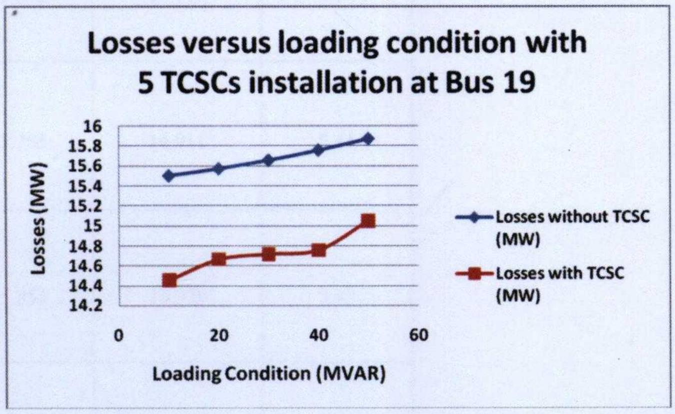

Figure 6. Effect of 5 TCSCs installation in the system with loading condition at bus 19

TABLE II. EFFECT OF 5 TCSC INSTALLATION WITH LOAD SUBJECTED TO BUS 6

Loading Condition (MVAR)	TCSC Installation	Line	Loss without TCSC (MW)	Loss with TCSC (MW)	% of Loss Reduction
10	X1 = 0.2249 X2 = 0.3365 X3 = 0.3837 X4 = -0.055 X5 = 0.6292	14 12 26 22 21	15.385	14.330	6.85
20	X1 = 0.7346 X2 = 0.5693 X3 = 0.5379 X4 = 0.6615 X5 = 0.7811	14 12 26 22 21	15.462	14.645	5.28
30	X1 = 0.2699 X2 = 0.7651 X3 = -0.0288 X4 = 0.6801 X5 = 0.5816	14 12 26 22 21	15.542	14.773	4.95
40	X1 = 0.5290 X2 = 0.7026 X3 = 0.0948 X4 = 0.0768 X5 = 0.6759	14 12 26 22 21	15.627	14.912	4.58
50	X1 = -0.1308 X2 = 0.4681 X3 = 0.5708 X4 = 0.4693 X5 = 0.6618	14 12 26 22 21	15.716	15.001	4.55

TABLE III. EFFECT OF 5 TCSC INSTALLATION WITH LOAD SUBJECTED TO BUS 10

Loading Condition (MVAR)	TCSC Installation	Line	Loss without TCSC (MW)	Loss with TCSC (MW)	% of Loss Reduction
10	X1 = 0.2132 X2 = 0.1748 X3 = 0.6372 X4 = 0.4304 X5 = 0.6847	14 12 26 22 21	15.605	14.648	6.13
20	X1 = 0.5977 X2 = 0.4186 X3 = 0.6231 X4 = 0.2717 X5 = 0.7115	14 12 26 22 21	15.682	14.716	6.16
30	X1 = 0.2598 X2 = 0.6534 X3 = 0.1566 X4 = -0.0783 X5 = 0.6562	14 12 26 22 21	15.765	14.911	5.41
40	X1 = 0.4903 X2 = 0.6340 X3 = 0.5682 X4 = -0.0136 X5 = 0.3683	14 12 26 22 21	15.854	14.929	5.83
50	X1 = -0.1048 X2 = 0.1486 X3 = 0.3824 X4 = -0.0380 X5 = 0.6630	14 12 26 22 21	16.394	15.086	7.98

TABLE IV. EFFECT OF 5 TCSC INSTALLATION WITH LOAD SUBJECTED TO BUS 19

Loading Condition (MVAR)	TCSC Installation	Line	Loss without TCSC (MW)	Loss with TCSC (MW)	% of Loss Reduction
10	X1 = 0.1951 X2 = 0.4162 X3 = 0.1143 X4 = -0.0819 X5 = 0.6335	14 12 26 22 21	15.502	14.451	6.78
20	X1 = 0.4737 X2 = 0.0068 X3 = 0.4512 X4 = -0.0060 X5 = 0.3561	14 12 26 22 21	15.570	14.662	5.83
30	X1 = 0.2719 X2 = 0.2022 X3 = -0.1397 X4 = 0.1546 X5 = 0.7496	14 12 26 22 21	15.654	14.715	6.00
40	X1 = 0.4820 X2 = 0.8160 X3 = 0.3249 X4 = 0.2419 X5 = 0.8234	14 12 26 22 21	15.753	14.755	6.33
50	X1 = 0.0973 X2 = 0.4247 X3 = 0.6593 X4 = -0.1158 X5 = 0.5484	14 12 26 22 21	15.867	15.047	5.17

B. *Effect of More TCSCs Installation*

Figure 7 shows the analysis of total losses transmission line with 6 TCSCs installation in the system. At all loading conditions the total losses transmission line reduced smoothly with installation for whole system and make improvement voltage stabilty. Table V shown the details result of total losses transmission line when additional one TCSC on the system. It can be see the different between Table II and Table V which there are subjected loading condition at same bus but data in Table V install more TCSCs at the system. At 10MVar loading condition, percentage of loss reduction with 6 TCSCs gives more reduction which 7.66% compared to 5 TCSCs which just reduce 6.85% only. This indicates that the additional of more TCSC can make larger reduction in total losses transmission line.

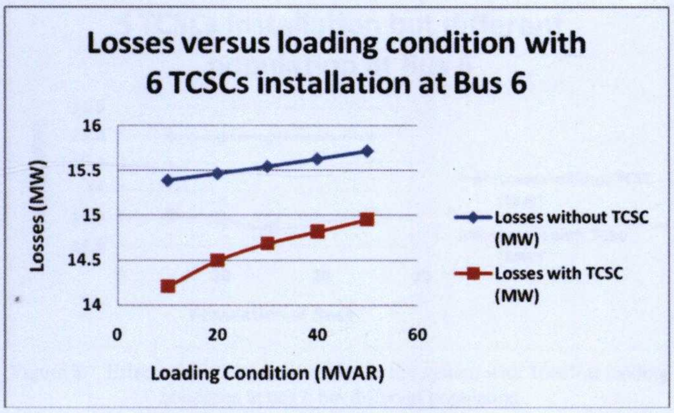

Figure 7. Effect of 6 TCSCs installation in the system with loading condition at bus 6

TABLE V. EFFECT OF 6 TCSC INSTALLATION WITH LOAD SUBJECTED TO BUS 6

Loading Condition (MVAR)	TCSC Installation	Line	Loss without TCSC (MW)	Loss with TCSC (MW)	% of Loss Reduction
10	X1 = 0.0049 X2 = -0.0232 X3 = 0.7757 X4 = -0.0412 X5 = 0.8421 X6 = 0.5267	14 12 26 22 21 39	15.385	14.206	7.66
20	X1 = 0.1285 X2 = 0.2619 X3 = 0.5266 X4 = 0.3440 X5 = 0.8348 X6 = 0.0078	14 12 26 22 21 39	15.462	14.496	6.25
30	X1 = 0.0400 X2 = 0.1986 X3 = 0.1114 X4 = 0.4084 X5 = 0.6867 X6 = -0.1524	14 12 26 22 21 39	15.542	14.686	5.51
40	X1 = 0.0124 X2 = 0.2091 X3 = 0.5776 X4 = 0.2667 X5 = 0.5435 X6 = 0.2417	14 12 26 22 21 39	15.627	14.820	5.17
50	X1 = 0.2207 X2 = 0.5324 X3 = 0.0857 X4 = 0.2469 X5 = 0.7094 X6 = 0.4750	14 12 26 22 21 39	15.716	14.954	4.85

C. *Effect on Number of Population*

Figure 8 shows the comparison of total losses transmission line with and without the installation of TCSC at various number of population. It was be tested when load subjected to bus 6 with regarding 4 different populations and the selected load value equals to 10MVar. From Table VI, a loading condition of 10Mvar has been subjected to the system with BA incurrently implemented. The percentage of loss reduction for every population quite similar with each other. In order to achieve reduction of 4.31%, the values of TCSCs are 0.5739, 0.1541, -0.0124, 0.3246 and 0.6674 which should be installed at line number 14, 12, 26, 22 and 21 respectively.

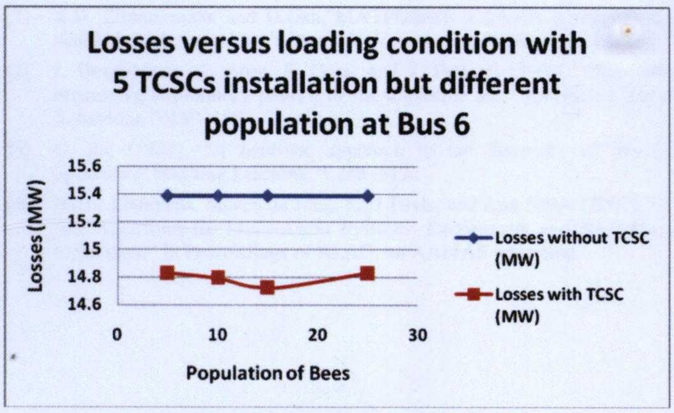

Figure 8. Effect of 5 TCSCs installation in the system with 10MVar loading condition at bus 6 but different population

TABLE VI. EFFECT OF 5 TCSC INSTALLATION WITH 10MVAR LOADING CONDITION AT BUS 6 BUT DIFFERENT POPULATION

Population	TCSC Installation	Line	Loss without TCSC (MW)	Loss with TCSC (MW)	% of Loss Reduction
15	X1 = -0.1380 X2 = 0.4681 X3 = 0.5708 X4 = 0.4693 X5 = 0.6618	14 12 26 22 21	15.385	14.825	3.64
20	X1 = -0.1048 X2 = 0.1486 X3 = 0.3824 X4 = -0.0380 X5 = 0.6630	14 12 26 22 21	15.385	14.790	3.87
25	X1 = 0.5739 X2 = 0.1541 X3 = -0.0124 X4 = 0.3246 X5 = 0.6674	14 12 26 22 21	15.385	14.721	4.31
35	X1 = 0.0613 X2 = 0.0193 X3 = 0.0870 X4 = 0.5387 X5 = 0.8032	14 12 26 22 21	15.385	14.825	3.64

V. CONCLUSION

This paper has presented the analysis of FVSI technique to determine the suitable line location of TCSC while application of BA technique to determine optimum size of TCSC to be installed in power transmission network. Tests were being conducted on IEEE 26-bus Reliability Test System (RTS) by using MATLAB software. The installation TCSC in the transmission line system will helps the system minimize loss in power transmission network to make improvement voltage stabilty. For future recommendation Bees Algorithm (BA) is also suitable for other FACTS device optimizations such as the Unified Power Flow Controller (UPFC). The implementation aims for loss minimization scheme. Moreover, other optimization techniques such as the Bacteria Foraging Optimization (BFO) technique.

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