Optima] Sizing of TCSC Using Ant Colony Optimization (ACO) Technique for Loss Minimization

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Abstract: - This paper present finds optimal location of Thyristor Controlled Series Capacitor (TCSC) using Ant Colony Optimization (ACO) technique in loss power minimization at transmission line (used 57 bus system). Recent year, TCSC has been increasingly installed in transmission line system in many part of the world. The installation based on the location and size of the capacitor. Power transmission loss of grid can be improve be improved by upgrading or adding of new transmission circuit TCSC offer a strong alternative for optimizing of transmission over power link, existing as well as new, by means intended for the control of power flow, improvement of stability, voltage profile management, power factor correction, and power losses. The optimal TCSC placement has been implemented by using MA TLAB programming.

Keywords: - Thyristor Controlled Series Capacitor (TCSC), Ant Colony Optimization (ACO), 57-bus system.

1. INTRODUCTION

In recent years, with the deregulation of the electricity market, the traditional concepts and practices of power systems have changed. Better utilization of the existing power system to increase power transfer capability by installing FACTS (Flexible AC Transmission Systems) devices becomes imperative **[3].** The problem of voltage collapse in power system is now becoming one of the most important predicaments to resolve, as several major blackouts throughout the world have been directly associated to this phenomenon [1].

TCSC is a one of the FACTS device. Other devices of FACTS devices are TCPST (Thyristor Controlled Phase Shifting Transformer), UPFC (Unified Power Flow Controller) and SVC (Static Var Compensation). The parameter and variable of the transmission line, for example line impedance, terminal voltage, and voltage angles can be can be controlled by FACTS devices in a fast effective way. The benefit brought about by FACTS includes improvement of system dynamic behavior and thus enhancement of system reliability [3]. However, their main function is to control power flow provided that that they are placed at optimal location. FACTS devices are capability of increasing the loadability.

TCSC used for improve stability limits and increase transfer capabilities. The transmitted power through a line is inversely proportional to the transfer impedance. For example, considering other parameters constants, 50 % series compensation approximately doubles the steady-state transmitted power, whereas 75 % series compensation would increase the transferred power to about four times the original value [1].

ACO is multi-agent system in which the behavior of each single agent, called artificial ant or ant is inspired by the behavior of real ant [2]. Optimal placement of TCSC has been implemented using MATLAB and genetic algorithms recently the ACO was applied to this problem. Above mentioned method has been used for TCSC allocated on an individual line in transmission line, while only real power losses are considered [4]. Some optimization problem has been solved by using ACO such as unit commitment, optimal placement of capacitor in distribution system, economic generator scheduling and load dispatch, and multi-state electrical power system problems [2].

In this paper present ACO based optimization technique for reduce power loss in transmission line at 57-bus system. In this study, loss reduction, and computation time has been added criteria monitored. Main expected result must consider before doing this study is the result of power losses after added TCSC must smaller than power losses before adding TCSC.

2. TCSC **THEORY**

Several studies on the use of controllable devices connected in series with the line (TCSC, UPFC) show that they have some advantageous control properties when compared with shunt devices. The control offered by TCSC is an 'impedance' type control, for example the inserted voltage is proportional to line current. This type of control normally is best suited to applications in power flow corridors, where a well defined phase angle difference exists between the ends of the transmission line to be compensated and controlled [7]. A TCSC can control the power transmission line reactance at high speed. TCSC compensation ratio is defined as 's' and value of V must less then 1 (|s|<l). The impedance of line A-B is assumed to be R+jX. If the TCSC is installed at a line A-B in the power system, the impedance of the line A-B changes to R+jX(l-s)[10].

TCSC consists of a fixed value of capacitance connected in series with the transmission line and in parallel with this fixed capacitance is connected a thyristor controlled reactance (TCR) which comprises an inductor and a pair of back-to-back thyristors. TCSC also used metal oxide varistor to protect the capacitor against overvoltage. TCSC typically requires a step-down transformer [1,5, and 6].

Basic construction of TCSC:

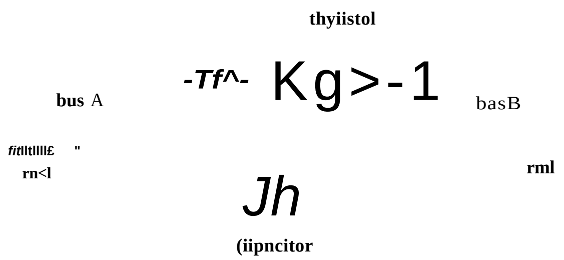


Figure 1: TCSC

The TCSC features four different modes of operation:

- CAP (capacitive voltage boost)
- BLK (thyristor valve blocked)
- CBP (controlled valve bypass)
- PBP (protective bypass)

The theory of operation of the TCSC needs to be understood from two different perspectives, firstly in terms of the 50 Hz reactance of its sub-elements and secondly in terms of the detailed, time-domain behavior of its circuitry at different thyristor delay angles [5].

To determine the suitable placement of the TCSC, an algorithm was created that would be appropriate given the particular constraints on operations. Thus, a line-based voltage stability index termed as Fast Voltage Stability Index (FVSI), based on the quadratic equation of voltage at the receiving end of a 2 bus system was adopted as the fitness function. Numerous line indices were computed at all lines or buses in the system considering a particular loading condition [12]. The mathematical equation for FVSI is given as follows:-

onl

$$FVShj = \frac{4Zi,^{2}<2y}{Vi^{2}Xij}$$

= line impedance
= line reactance
$V,$ = voltage at the sending end
Qj = reactive power at the receiving end

The greatest value of FVSI should be selected first for place TCSC. That means TCSC should be placed in that line when SI value in that line is largest then other lines [12].

3. ACO THEORY

ACO is a class of algorithms, whose first member, called Ant System, was initially proposed by Colorni, Dorigo and Maniezzo [9]. Many researchers have shown that insect colonies behavior can be seen as a natural model of collective problem solving. The analogy between the way ants look for food and combinatorial optimization problems has given rise to a new computational paradigm, which is called ant colony meta-heuristic [4].

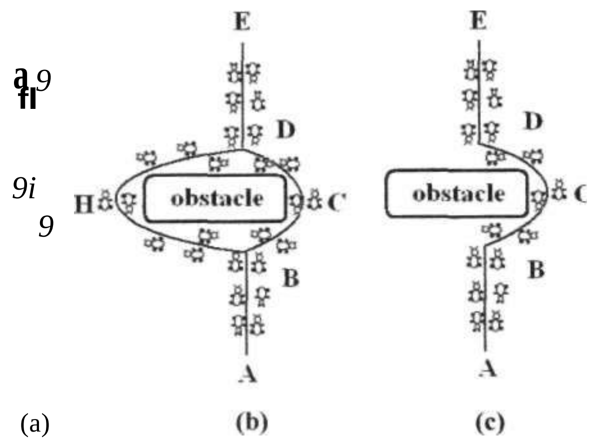


Figure 2: Ant Behavior

(a) Point E is the food source while A is the nest.
(b) When an obstacle is placed in between nest and the food source, the ant will initially choose either path B-H-D or B-C-D to get to food source.
(c) Since path B-C-D is shorter, the ants choosing this path will reach the food source and back to the nest.

Therefore, there will be more ants depositing pheromones on the trail. The amount of pheromone on the path B-C-D will be increase faster than those on path B-H-D. This will encourage more ants to choose the shortest path. At one point, all the ants will be choosing the only shortest path [8].

Ants lay down in some quantity an aromatic substance, known as pheromone, in their way to food. The pheromone quantity depends on the length of the path and the quality of the discovered food source. An ant chooses a specific path in correlation with the intensity of the pheromone. The pheromone trail evaporates over time if no more pheromone is laid down. Other ants can observe the pheromone trail and are attracted to follow it. Thus, the path will be marked again and will therefore attract more ants. The pheromone trail on paths leading to rich food sources close to the nest will be more frequented and will therefore grow faster. In that way, the best solution has more intensive pheromone and higher probability to be chosen. The described behavior of real ant colonies can be used to solve combinatorial optimization problems by simulation: artificial ants searching the solution space simulate real ants searching their environment. The objective values correspond to the quality of the food sources. The ant system approach associates pheromone trails to features of the solutions of a combinatorial problem, which can be seen as a kind of adaptive memory of the previous solutions [4].

4. PLACEMENT OF TCSC

Figure 3 was described general process to find loss and optimal placement of TCSC. In this paper, Newton-Rapshon method was used to solve power flow problem [11]. The process involves initialization, data bus system, power flow solution, placement solution. Below is the step to find loss and placement for TCSC.

Step:

1) **Initialization:**
   Bus no and bus values were specified.

Bus no.	: no. of bus test
Bus value	: value at bus test

2) **Read data:**
   Apply bus data system. In this paper was used 57-bus system.

3) **Apply power flow** solution:
   The purpose of this step is to find total loss in the system (57-bus system). Implement Newton-Rapshon method to solve power flow problem. In this step involve *Ifybus, Ifnewton, busout* and *line/low* program [11].

Ifybus	*:* Convert impedances to admittances & obtains the bus admittance matrix
Lfnewton	: Newton-Rapshon method
busout	: Produces the bus output result in a tabulated form
lineflow	: Produces the line output data and total losses in the system

4) **Apply placement solution:**
   The purpose of this step is to find optimal placement for TCSC. FVSI equation **(equation 1)** was applied in this step. The following steps are being implemented in order to produce the FVSI:

   1. Run the load flow program using Newton Raphson method for the base case.
   2. Evaluate the FVSI value for every line in the system.
   3. Gradually increase the reactive power loading at a chosen load bus until the load flow solution fails to give the results. Calculate FVSI values for every load variation.

Start

Read data

f

Annlv nower flow solution

4

ADtilv olacement solution

Calculate Loss

Figure 3: Flow Chart for Placement TCSC

After run the program above, we can get the power losses without TCSC and suitable place for locate TCSC in the line 57-bus system.

5. REDUCE LOSS USING ACO ALGORITHM

Figure 3 was described about general process of algorithm ACO. In this section, ACO responsible to reduces loss in transmission line. Before running this ACO, the placement of TCSC must find first. The ACO process involves initialization, state transition rule, local updating rule, fitness evaluation and global updating rule [2]. Below is the step of ACO process.

Step:

1) **Initialization:**

n, m, tmax, dmax, P, p, «. *%* and T_0 are specified

n	: no. of node
m	: no. of ants
tmax	: maximum iteration
dmax	: maximum distance for every ants
fi	: parameter which determine the

relative importance of pheromone versus distance ((J>0)

p : heuristically defined coefficient (0<p<l)

a : pheromone decay parameter (0<a<l)

q_n : parameter of the algorithm (0<qO<l)

r_0 : initial pheromone level

The limitation range is to avoid large computation time. d_{max} can be calculated by using following formula:

Equation 2:

$$d_{max} = \max 2> \quad rn-1$$

$$di = \mathbf{r} - \max(u)$$

Where: ***r*** current node
u unvisited node

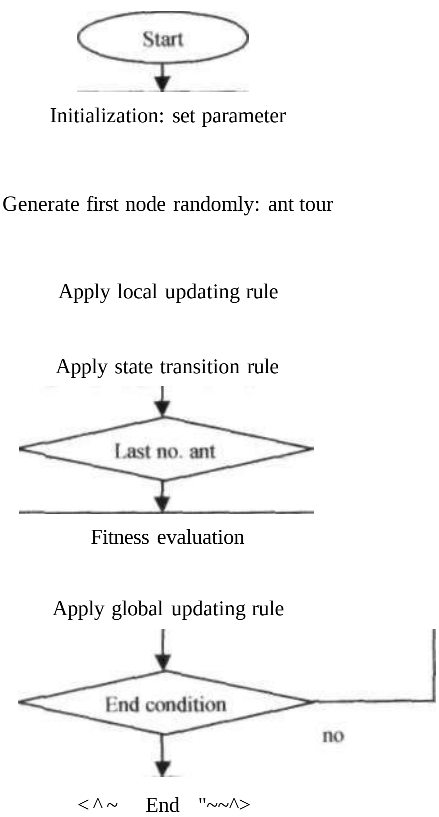


Figure 4: Ant Colony Optimization flow chart

2) Generate first node randomly:
The first will be selected by generating a random number according to a uniform distribution, ranging 1 ton.

3) Apply state transition rule:
The ant located at node *r* (current mode) will be choosing the node s (next node) based on the following rule.

Equation 3:

$$s = \begin{cases} (argmax_u J_{Kr})\{[r(r,y.)\}.\ [i?(r,u)"]\},i/ & q < q_a \\ S, & otherwise \end{cases}$$

Where: *q* random number uniformly distributed in [0...1]
s random variable selected according to the probability distribution given in equation below.

The probability ant *k* at node *r* to choose the next node *s*. it can be calculated by using the following equation

Equation 4:

$$Pk(r,s) = \begin{cases} \frac{[T(r,s)].[7j(r,s)<^{l}]}{\mathbf{Iu_{\xi}/_{t(r)}[T(r,u)].[7,(r,u)P]}} & (if\ s\ \epsilon J_{k(r)}) \\ 0, & otherwise \end{cases}$$

Where: *T* pheromone
Jk(r) set of node that remain to be visited by ant k positioned on node (to make the solution feasible)
1/8, as the inverse of the distance *§(r,s)*

4) Apply local updating rule:
Ants visit edges and change their pheromone level by applying the local updating rule of equation below

Equation 5:
r(r,s)<-(1 -p)t(r,s)+p.AT(r,s)

5) Fitness evaluation:
It is performed after all ants have completed their tours. In this step, the control variable is computed using the following equation:-

Where: $AT(r,s) = T_0$

$$X = \frac{XX}{\mathbf{dr,}} \quad max$$

Where: ***d*** distance foe every ant tour
Xmax maximum x

6) Apply global updating rule:

This step applied to edges belonging to the best ant tour which give the best fitness among all ants. The pheromone level is updated by applying the global updating global updating rule in following equation:

Equation 6:

$$x(r,s) \leftarrow (1-a)T(r,s)+a.At(r,s)$$

Where

$$Mr.s) - \begin{cases} UL_{gb})^{l}, lf\ (r,s)\ sglobal\ —\ best\ tour \\ 0,\ otherwise \end{cases}$$

a = pheromone decay parameter ($0 < a < 1$)

L_{gb}= length of the global best tour from the

L_{gb} length of the global best tour from the beginning of the trail.

7) End condition:

The algorithm stops the iteration when a maximum number of iterations have been performed otherwise, repeat step 2. Every tour that was visited by ant should be evaluated. If a better path is discovered in the process, it will keep to the next reference.

Since the impedance of line after locate TCSC was changed to R+jX(l-s). The equation for TCSC itself is Xs. Where's' is compensation ratio of TCSC. The purpose of ACO is responsible to find the value of s'. After the value of s' was found,'s' will multiply by X. 'X' is value of reactance in the line. By multiply both values's' and 'X', we can get the value of TCSC in per unit. Thus, the power losses after locate TCSC can occur after ACO found the best value of s'.

6. RESULT

6.1. Effect of loading conditions to losses:

In this section show result placement of TCSC and power losses after locate TCSC in the transmission at 57-bus system. Total losses will increase proportional to loading condition (Qd). P, Q, R, S are placement of TCSC in transmission line. Table 1 until table 6 represents the total losses without TCSC, total losses with TCSC, placement of TCSC, improvement of power losses and value of TCSC.

6.1.1 Result 1:

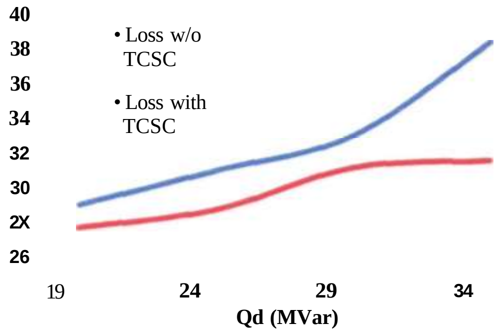
No ant=3
Node=10
Bus no= 20

Tablet:

No.	Qd (MVar)	Loss w/o TCSC (MW)	Placement TCSQno line)			
			P	0	R	S
1	20	28.9189	31	29	30	66
2	25	30 8805	31	29	30	66
3	30	32.8947	31	29	30	32
4	35	38.2647	31	29	30	32

Table2:

No.	Loss with TCSC (MW)	Improve (kW)	Value of TCSC (p.u)			
			P	Q	R	S
1	27.6040	1.3149	0.0982	0.0743	0.1964	0.0491
2	28.6430	2.2375	0.4584	0.5820	0.2789	0.0238
3	31.0399	1.8548	0.0163	0.0032	0.2386	0.0130
4	31.4619	6.8028	0.1880	0.7087	0.1853	0.0640



6.1.2 Result 2:

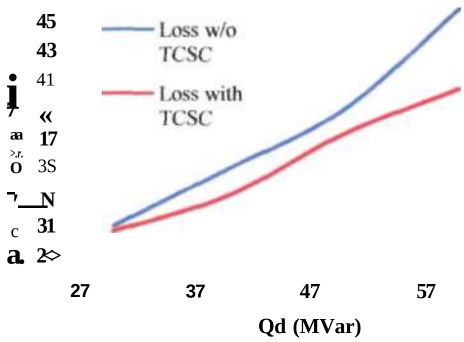
No ant=3
Node=10
Bus no= 40

Table3:

No.	Qd (MVar)	Loss w/o TCSC (MW)	Placement TCSQno line)			
			P	Q	R	S
1	30	30.9906	50	74	73	54
2	40	34.8823	50	73	74	•54
3	50	38.8838	73	50	74	54
4	60	45.7609	73	50	74	54

Table4:

No.	Loss with TCSC (MW)	Improvement (MW)	Value of TCSC (p.u)			
			P	Q	R	S
1	30.6338	0.3568	0.0964	0.1246	0.7093	0.1268
2	33.0312	1.8511	0.0069	0.6956	0.0800	0.6097
3	37.2126	1.6712	0 3169	0.0416	0.0175	0.0637
4	40.2782	5.4827	0.4384	0.0356	0.2087	0.3397



6.1.3 Result 3:

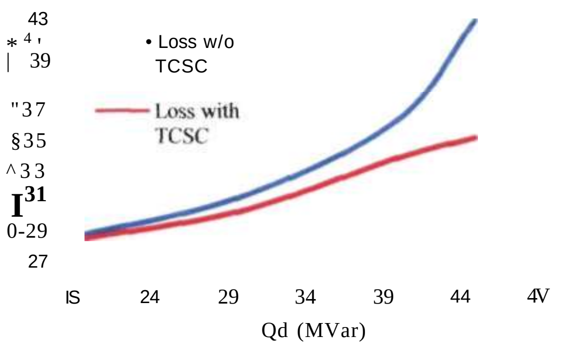
No ant=3
Node=10
Bus no= 56

Table?:

No.	Qd (MVar)	Loss Wo TCSC (MW)	Placement TCSC(no. line)			
			P	0	R	S
1	20	28.7883	74	76	73	54
2	30	31.2340	74	73	76	56
3	40	36.2230	74	73	76	56
4	45	42.7489	74	75	56	73

Table*:

No.	Loss with TCSC (MW)	Improvement (MW)	Value of TCSC (p.u)			
			P	Q	R	S
1	28.4986	0.2897	0.1328	0.0508	0.5904	0.1653
2	30.2972	0.9368	0 1699	0.3562	0.5297	0.1947
3	33.7428	2.4802	0.1494	0.3172	0.3834	00399
4	350516	7.6973	0.2058	0 1666	0.0251	0.3218



6.2. Effect of no. of ants to accuracy:

6.2.1 Result 1:

No bus=20

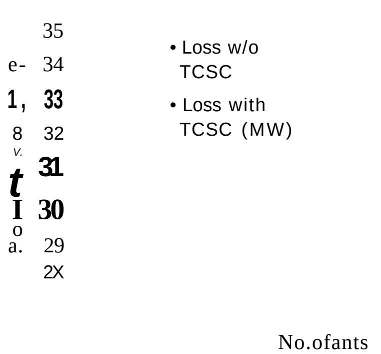
Qd (MVar)=25

Loss without TCSC (MW) = 30.8805

No node= 10

Table7:

No. of ants	Loss with TCSC (MW)	Improvement (MW)	Value of TCSC at line (p.u)			
			P	Q	R	S
3	28.6430	2.2375	0.4584	0.5820	0.2789	0.0238
4	28.8107	2.0698	0.1211	0.1104	0.2506	0.0572
5	28.8275	2,0530	0.1008	0.2040	0.2517	0.0173
6	28.7280	2.1525	0.4574	0.6871	0.3255	0.0288



6.2.1 Result 2:

No bus=40

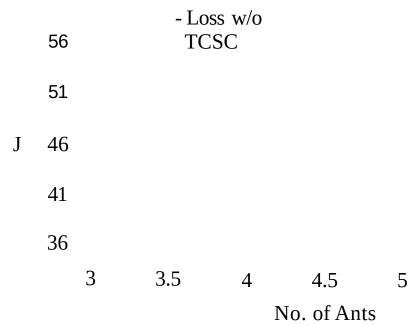
Qd (MVar)=60

Loss without TCSC (MW) = 45.7609

Nonode= 10

TableS:

No. of ants	Loss with TCSC (MW)	Improvement (MW)	Value of TCSC at line (p.u)			
			P	Q	R	S
3	40.2782	5.4827	0.4384	0.0356	0.2087	0.3397
4	39.3275	6.4334	0.2555	0.0865	0.3821	0.3133
5	39.0554	6.7055	0.2883	00348	0.5320	0.7355
6	37.8665	7.8944	0.7224	0.0463	0.1787	0.0935



7. CONCLUSION

In this paper, TCSC has been modeled and their effect on minimize loss was studied. For TCSC placement, a Fast Voltage Stability Index (FVS1) was implemented. ACO was developed to find the compensation ratio of TCSC (s). The main idea of this studies is the value of loss real power after locate TCSC must lower than before locate TCSC. MATLAB programming was implemented to solve problem above.

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