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Optimal TCSC Placement Using Harmony Search Algorithm in Transmission System for Loss Minimization

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ABSTRACT: *This paper presents one of the latest heuristic algorithms, namely Harmony Search algorithm for solving optimal TCSC placement problem in transmission systems i.e., to select the optimal parameter setting of TCSC device which minimizes the real power loss. The proposed algorithm is tested on IEEE-14 bus system and better results are obtained when compared with existing method.*

Keywords: Harmony Search (HS) algorithm, Thyristor Controlled Series Capacitor (TCSC), real power loss.

1. INTRODUCTION

Dependency on the electrical energy is increasing day by day due to the increasing industrialization and urbanization. This results in rapid growth of power systems which resulted in few uncertainties. Power disruptions and individual power outages are the major problems which affect the economy of any country. To overcome these problems, FACTS devices are introduced to control the power flow in order to have more efficient, reliable and secure transmission system. FACTS devices can regulate the active, reactive power control and voltage magnitude control simultaneously by their fast control characteristics and their continuous compensating capability and hence reduce the over loading of the lines and maintain voltages in desired level and also they can improve both transient and small signal stability margins. Controlling the power flows in the network under normal and abnormal conditions will result in reduction of system power loss and improvement in the stability. The influence of FACTS-devices is achieved through switched or controlled shunt compensation, series compensation or phase shift control. The devices work electrically as fast current, voltage or impedance controllers. The power electronic devices allow very short reaction times down to far below one second.

Among the FACTS devices, Thyristor Controlled Series Capacitor (TCSC) is a variable impedance type series compensator which is connected in series with the transmission line to reduce transmission losses, improve transient stability, increase the power transfer capability, and dampen power system oscillations. There are basically two reasons for opting the TCSC device for power flow studies. They are Electro mechanical damping and reducing SSR (Sub Synchronous Resonance). TCSC should be incorporated with the conventional load flow algorithm [1] to achieve one or all of the above mentioned benefits. A Newton- Raphson power flow algorithm was proposed in [2], [3] to solve power flow problems in power system with thyristor controlled series capacitor (TCSC). A real power flow performance sensitivity index to obtain the optimal placement of TCSC was suggested in [4].

2. PROBLEM FORMULATION

The main aim of this paper is to minimize the power loss of transmission system by finding the optimal location and parameter setting of the TCSC device. The performance index is given by:

$$\text{Min } F = \sum_{K=1}^{ntl} P_{LK}$$

Where,
F is the objective function
P_{LK} is the k^{th} line real power loss
ntl is the number of lines in the system

The equality constraints are:

$$P_{gi} - P_{di} - \sum_{j=1}^{N} V_i V_j Y_{ij} (x_{tcsc}) \cos (\delta_{ij}+\gamma_j-\gamma_i) = 0$$

$$Q_{gi} - Q_{di} - \sum_{j=1}^{N} V_i V_j Y_{ij} (x_{tcsc}) \sin (\delta_{ij}+\gamma_j-\gamma_i) = 0$$

N is the set of bus indices
P_{gi} and Q_{gi} are the active and reactive power generations at bus i
P_{di} and Q_{gi} are the active and reactive power loads at bus i
δ_{ij} is the power angle.
Y_{ij} is the element in admittance matrix
V_i is the voltage magnitude at bus i
x_{tcsc} is the reactance of TCSC as a function of α
α is the thyristor firing angle.

The inequality constraints are:

$$P_{gi}^{min} \leq P_{gi} \leq P_{gi}^{max} \qquad i \in NG$$
$$Q_{gi}^{min} \leq Q_{gi} \leq Q_{gi}^{max} \qquad i \in NG$$
$$V_i^{min} \leq V_i \leq V_i^{max} \qquad i \in N$$
$$\delta_{ij}^{min} \leq \delta_{ij} \leq \delta_{ij}^{max} \qquad i \in N$$

$x_{tcsc}^{min} \leq x_{tcsc} \leq x_{tcsc}^{max}$
$\alpha^{min} \leq \alpha \leq \alpha^{max}$
NG is the set of generation bus indices

3. FUZZY TECHNIQUE FOR OPTIMAL LOCATION OF TCSC

3.1 Modelling of TCSC:

The thyristor Controlled series capacitor consists of three main components; they are Capacitor bank C, Bypass inductor L and Bidirectional thyristors, SCR1 and SCR2. The modeling of TCSC is shown in Fig 1.

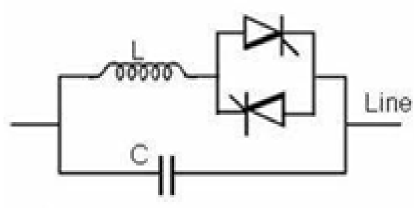

Figure.1 Modelling of TCSC

TCSC can act as a capacitive or inductive compensator by modifying the reactance of the transmission line. The operating range of TCSC is -0.7Xl to 0.2Xl. The TCSC is assumed to be connected between sending end and receiving end in a transmission line.

3.2 Optimal location of TCSC using Fuzzy Technique:

Optimal location is a node which is sensitive to the single and multiple contingencies. This section will describe the procedure for the optimal TCSC placement. Fuzzy logic provides a remedy for any lack of uncertainty in the data. The main purpose of this present work is the placement of TCSC device in optimal location. In this paper, TCSC devices are installed on the lines carrying high reactive power using fuzzy logic.The advantages of Fuzzy logic are, heuristics are included, representing the device allocation optimization process and determining its feasibility being implemented in the power system and also the solutions obtained from a fuzzy algorithm can be quickly assessed.

While designing the fuzzy logic for identifying the optimal TCSC locations, two objectives are considered. They are minimizing the active power loss and maintaining voltage within permissible limits. Power loss indices and voltages of the transmission system nodes are modeled by fuzzy membership functions. The TCSC placement suitability of each node in the transmission system is determined by a Fuzzy Inference System (FIS) containing a set of rules. Fuzzy technique proposed in [6]-[8] is used for solving the optimal location of TCSC.

4. IMPLEMENTATION OF HARMONY SEARCH ALGORITHM

Harmony search (HS) is a metaheuristic optimization algorithm developed by Z.W. Geem et al in 2001. This algorithm is inspired by the music improvisation process in which the musician searches for harmony and continues to polish the pitches to obtain a better harmony. In the HS algorithm each musician (= decision variable) plays (= generates) a note (= a value) for finding a best harmony (= global optimum) all together. HS may overcome the drawback of GA's building block theory which works well only if the relationship among variables in a chromosome is carefully considered. If neighbour variables in a chromosome have weaker relationship than remote variables, building block theory may not work well because of crossover operation. However, HS explicitly considers the relationship using ensemble operation. Application of HSA and GA in optimal placement of FACTS devices considering voltage stability and losses was proposed in [10]. The parameter values for HS are given in table 1.

Table.1 Parameter values for HS

Harmony memory size(HMS)	15
Pitch adjusting rate	2
Pitch limit	50
Maximum number of search	100
Number of harmony devices	2

Optimization procedure for the harmony search algorithm:

Step 1: Initialize each decision variable, a possible value range in each decision variable, harmony memory size (HMS), pitch adjusting rate (PAR), termination criterion (maximum number of search) .
Step 2: Initialize harmony memory (HM) and generate initial harmony [solution] vectors as many as HMS Sorted by values of objective function
Step 3: Generate a new harmony from HM based on three rules: memory Considering, Pitch adjusting and Random Choosing.
If new harmony is better than a stored harmony in HM, then go to step 4 otherwise go to step 5
Step 4: Update the HM.
Step 5: Repeat Steps 3 and 4 until the termination criterion is satisfied

5. RESULTS

MATLAB code for HS algorithm and power flow algorithm were developed and incorporated to include TCSC device in this paper. To validate the proposed technique, HS algorithm has been tested on IEEE-14 bus power system shown in Fig2. (The data for this mentioned system is taken from [5]) and compared with the method proposed in [9].

Comparison of HS with DE [9] and also power loss with and without TCSC are shown in Table 2.

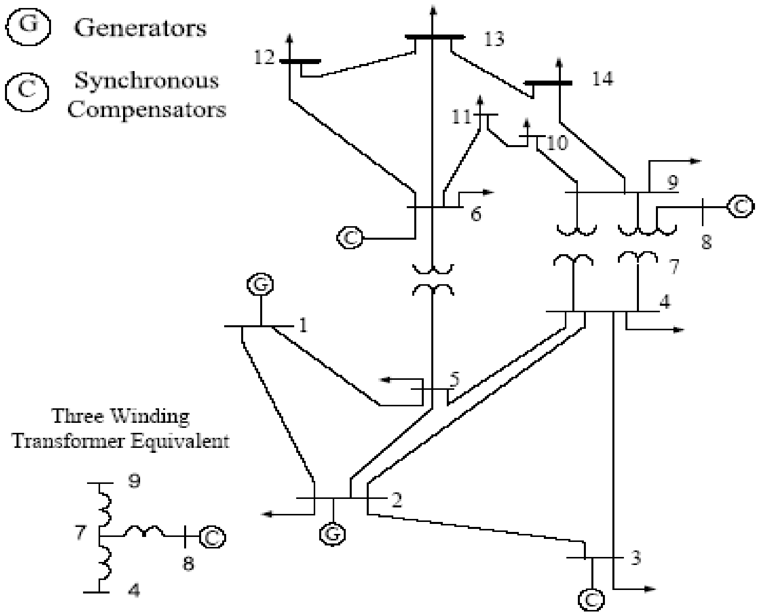

Figure.2 The IEEE-14 bus system

Table.2 Power loss without and with TCSC

Power loss in MW for 14 bus system		
Without TCSC	With TCSC	
Base case	DE[9]	Proposed HS method
21.82	21.54	21.52

VI. CONCLUSION

This paper has investigated the effectiveness of the optimal placement of the TCSC device to minimize the real power loss in transmission system using HS algorithm. Harmony Search algorithm has been successfully tested on IEEE-14 bus power system under consideration. The performance of HS is compared with DE, which is one of the best evolutionary algorithms. With this proposed algorithm, the optimal placement of TCSC in transmission line is possible and the proper power planning can be achieved with minimum system losses. Advantages of HS are that it does not require initial value setting for the variables and it is free from divergence and it can handle discrete variables as well as continuous variables.

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