Transmission Loss Allocation with TCSC using BSO Algorithm in Deregulated Power System

P.Jyoshna, Ch.Chengaiah

Abstract— The paper focus on issue of Transmission Loss minimization and allocation of transmission losses with the insertion of TCSC device in Load flow analysis using Brain Storm Optimization Algorithm (B.S.O.A). This Modelling is the modification of traditional Load flow analysis which is used for the minimization of Transmission loss. Since accurate power tracing for a particular transaction is very typical, based on the network's use of power in the system for transmission loss allocation, there are several methods are used out of these, here in this paper postage Stamp method and power flow tracing method is used to fairly allocate losses to all transactions based on the usage of power in the system network. These methods are tested for standard IEEE-14 Bus system. The result for this system is obtained with MATLAB/Simulink environment using the methodologies proposed.

Key words: loss Allocation, Deregulated power system, Power Flow Tracing (PFT).

1. INTRODUCTION

In today's modern power system, all over the world is stepping towards the restructuring of the power system. In restructuring of the system, transmission loss allocation and transmission loss minimization are the major problems in Deregulated system network. For transmission loss minimization, FACTS devices plays a vital role for loss minimization and for improving the system performance of the system network. FACTS devices such as TCSC,SVC and UPFC FACTS devices plays a vital role in controlling the power flows and for improving the voltage profile of the system over the transmission line impedance and to get the potential benefits of the system. These are considered as a key solution to major problems in the power system network where as an economic point of view the planning should be done carefully while inserting FACTS devices in the system with high amount of cost of the devices to the optimal placement of facts devices is necessary for reduction of losses and for the improvement of voltages to make the system stable in power system network. The above benefits can be achieved efficiently by the use of FACTS devices. To achieve the required objectives, it is necessary to select a suitable FACTS devices. Here in this paper TCSC device are placed in the optimal bus to reduce the loss and improve the system voltages and after minimizing the losses, the transmission loss allocation can be done by postage Stamp method and power flow tracing method. In subsequent sections the problem formulation and Optimization algorithm for the placement of TCSC device and for transmission loss allocation in deregulated systems, Transmission loss allocation algorithms are used.

II.PROBLEMFORMULATION

A.TCSC MODELLING:

TCSC is a series connected device, which explains the concept of a variable series reactance using modeling of TCSC, to satisfy the active power limits, series reactance is adjusted automatically to limit the power flow for the reduction of losses in the system .Here newton's method is used to determine the amount of reactance. The range of TCSC is restricted to be -0.7 to 0.3 of the line reactance [13]. The Modelling of TCSC as a controllable reactance XTCSC is shown in Fig. 1.

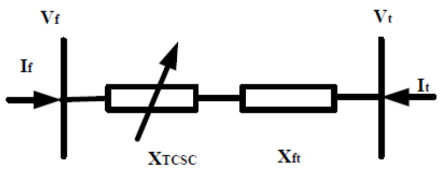

Fig1. TCSC's Variable reactance model

The transmission line's reactance can be expressed as:

$$X_{line} = X_{TCSC} + X_{ft} \quad (1)$$

Where,

X_{ft} = line Reactance between buses f and t

X_{TCSC} = Reactance of TCSC

X_{line} = Total reactance after placement of TCSC

Now, the problem is identified and simplified model of TCSC has been explained. In the next section, the Brain Storm optimization technique is discussed and how it can be applied to the problem for optimal placement of TCSC is discussed.

B. Objectives

The proposed work's objective is to determine the optimal reactance setting and optimal location of the TCSC device to reduce transmission losses in the power system [8], and for the allocation of the transmission losses fairly, Postage Stamp method and power flow tracing methods are used.

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The performance equation is given as

$$\min F = \sum_{l=1}^{ntl} P_{Ll} \quad (2)$$

Subject to the equality constraints

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

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

Subject to the inequality constraints

$$P_{Gi}^{min} \leq P_{Gi} \leq P_{Gi}^{max} \quad \forall\ i \in NG \quad (3)$$

$$Q_{Gi}^{min} \leq Q_{Gi} \leq Q_{Gi}^{max} \quad \forall\ i \in NG \quad (4)$$

$$V_i^{min} \leq V_i \leq V_i^{max} \quad \forall\ i \in N \quad (5)$$

$$\delta_{ij}^{min} \leq \delta_{ij} \leq \delta_{ij}^{max} \quad \forall\ i \in N \quad (6)$$

$$x_{tcsc}^{min} \leq x_{tcsc} \leq x_{tcsc}^{max} \quad (7)$$

Where

P_{Ll} is l^{th} line' active power loss

ntl is total no of transmission lines in the system

N is the no of buses

NG is no of generator buses

Q_{Gi} and P_{Gi} are the reactive and active power generation at bus i.

Q_{Di} and P_{Di} are the reactive and active power load at bus i

V_i is the magnitude of voltage at bus i

δ_{ij} is the power angle

x_{tcsc} is the reactance of TCSC

Brain storm Process:

By inspiring with the brain storm process in human beings, Shi in developed an algorithm known as Brain storm optimization Algorithm. Being the most intelligent creature, the process of problem solving by the human beings is the more superior than the algorithms inspired from the creatures,birds,animals etc.

At first Osborn in 1939 developed the idea of brain storming process. Brain storming process is described as the individual creativity technique or a group of people and to find a solution for particular problem, efforts are made by meeting different backgrounds of people together to obtain the solution. The procedural steps of brain storming procedure in human beings as follows.

1. The people with different backgrounds are met together.
2. According to Osborn's rules the innovative ideas are created by the people.
3. 3 or 5 people form as the problem owner and an idea of each is elected as better solution..
4. In step 3, the selected ideas act as clues for generating many ideas.
5. Randomly by selecting some ideas are used a clues for generating better ideas.
6 Using clues, best idea is taken in to consideration.
7. To get best solution for a particular problem, steps 2 to 6 are repeated till to get enough solution.

Osborn's Four rules of brain storming process I given as follows

1. Focus on quantity:

Here in order to get more chances of generating the best solution, the more no of ideas are to be generated..

2. Avoid Criticism:

From more perspectives and assumptions, the problems are being analysed , to get more unusual ideas and to get bet ideas from the list of ideas, the solutions are being welcomed.

3. Allowing unusual ideas

By analyzing the problems, participants can generate unusual ideas from more perspectives and suspending assumptions and to get a best and long enough list of ideas, the solutions are welcomed.

4. Cross-Fertilize

By associating and combining through better ideas, good ideas are obtained.

Brain storm optimization Algorithm:

Based on the process of brain storming, BSOA is proposed by Shi to solve the problems of optimization

In Brain storming process ,the idea are considered by individuals, brain storming groups are taken as clusters and best ideas in brain storming groups are taken as cluster center.

BSOA contains the four basic operations.

1. Initialization:

In population based heuristic Algorithms 'N' individuals are initialized randomly in search space as..

2. Clustering:

The population is divided in to different clusters, K-means strategy is used for clustering.

according to individual features.

3. Cluster center :

In Brain storming process, cluster center is considered by the best individual of a cluster. In brain storming group cluster center is elected with the probability pi,which is replaced by a random individual.The explorative and exploitative capabilities are affected by the control parameter pi.

The individuals in the cluters are perturbed with the probabilityp2.The perturbation step size is given by

$$S(x) = \log Sig\left[\frac{\frac{x\max}{2} - x}{t}\right] * r$$

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Where

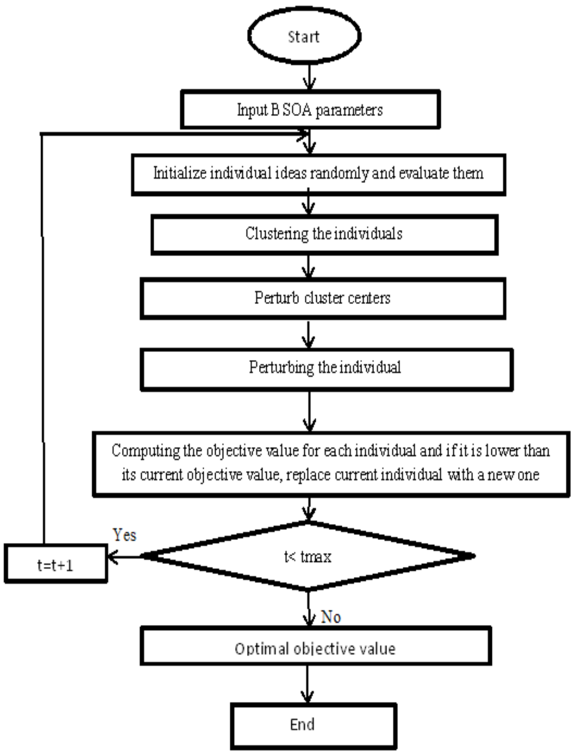
t is a Scaling factor, r is a random in (0,1) “logsig” represents logistic sigmoid function.

x and x max represents current and max iteration respectively. At this stage with a specified probability

p3,inorder to breed a new individual, two individuals will participate.

In order to breed new individual at this stage ,the specified probability p3 is taken in to consideration. The new objective values are computed after updating all the individuals with the new one if it satisfy the prescribed limit given by the system. All the parameters are updated till the end of the algorithm is reached.

Flow chart



Loss allocation methods:

a. Postage Stamp Method:

Here the total losses are first divided in to half of the total loses to Loads and remaining half to the Generators, which is to be predefined, losses then allocated to each generator and load proportionally based on their generation and consumption. This method is easily understandable and it is transparent and no complex calculations involved. Though it is simple but it has certain disadvantages.

$$LP_{Gj} = \frac{TL}{2}\frac{PG_j}{PG} \quad (8)$$

$$LP_{Di} = \frac{TL}{2}\frac{PD_i}{PD} \quad (9)$$

Where, PGj, PDi– generation of power and load at buses j and i respectively

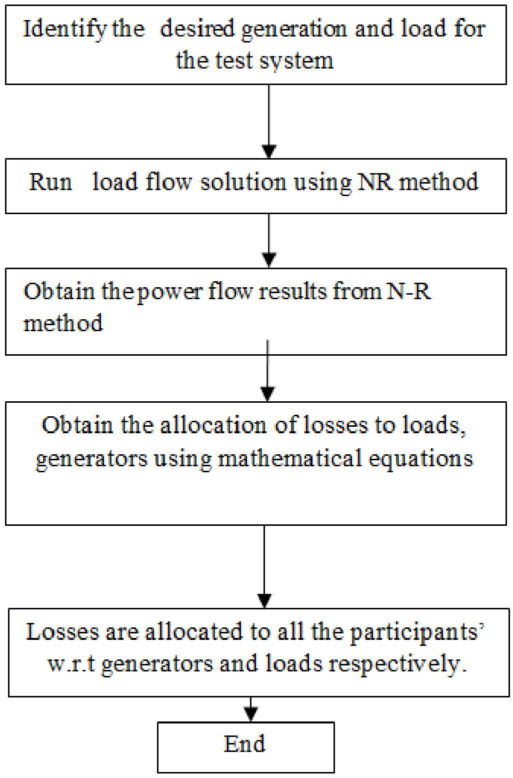
PG, PD – generation of total power, load of this system

LPGj– Allocation of real power Losses to the generator j

LPDi– Allocation of real power demand i

L–Total real power losses

Algorithm for postage stamp method:



b. Power Flow Tracing (PFT) method.

Power flow tracing method takes the Kirchoff’s’ principle in to consideration by equally sharing the losses to the Generator and loads respectively. Here in this method, after equally sharing the total losses, these losses are shared fairly by analyzing the system structure of the system fairly .Thus loss allocation can be done fairly to all the participants.

In this method the distribution factors can be determined by simple mathematical calculations of the network structure. Here the bus in which Zero injection power is made are given zero contribution for the allocation of loses. This is the advantage of this method.

Consider a network ,which consist of b branches, n nodes,PG,QG,PD,QD are nodal power generation of rel and reactive power and load of real and reactive powers respectively. [5]

$$P_{r-s}^{(gross)}=(P_{rs}/P_r)\Sigma[I_{u(r,k)}]P_{GK} \text{ for } s\in\alpha_r^d \quad (1)$$

Where,

α_r^d= set of nodes

P_r = nodal power

K= Buses

P_{GK}= power generation

P_{sr}=branch power flow

I_u= distribution of upstream matrix

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$$[I_u]_{rs} = \begin{cases} 1 & \text{for } r=s \\ -|P_{rs}|/P_r & \text{for } s \in \alpha_r^u \\ 0 & \text{otherwise} \end{cases}$$

$$P_{r\text{-}s}^{(net)}=(P_{rs}/P_r)\Sigma[I_{d(r,k)}]P_{DK} \text{ for } s\in\alpha_r^u \quad (10)$$

Where,

P_{DK}= load at bus K.

K=buses

P_{rs}=branch power flow

α_r^u= set of nodes .

I_d= distribution of downstream matrix

$$[I_d]_{sr} = \begin{cases} 1 & \text{for } s=r \\ -|P_{sr}|/P_s & \text{for } S \in \alpha_r^d \\ 0 & \text{otherwise} \end{cases}$$

From the Kirchoff's current law principle, the PFT Method allocates half of the total loses to loads and remaining half of the total loses to the generators respectively. The Generation and demand at each bus are calculated as

$$P'_{Gr}= (P_{r\text{-}s}^{net}+P_{Gr})/2 \quad (11)$$

$$P'_{Ds}= (P_{r\text{-}s}^{(gross)} +P_{Dr})/2 \quad (12)$$

Finally for each generator and demand, the real power losses allocation are computed as

$$L'_{Gr}=P_{Gr}-P_{Gr}' \quad (13)$$

$$L'_{Ds}=P'_{Ds}-P_{Ds} \quad (14)$$

By using mathematical equations ,this algorithm is tested for IEEE 14 Bus system with MATLAB in the following sections of the paper.

III. RESULTS OF IEEE-14BUS SYSTEM.

The IEEE-14 bus system consists of [8] two generators and 13 loads.These algorithms are tested for IEEE 14 Bus system in MATLAB environment and the results of real power losses and voltage profile with and without TCSC device are shown as shown in table-1 and table-2 respectively. The loss allocation of real power losses are show in table-3, table-4, table-5 and table-6 respectively.Here using Brain storming algorithm TCSC Device is placed in line 3-4 with the optimal size of -0.0212.

Table–1 power flow profile for IEEE 14 Bus system

From bus	To bus	Without FACTS devices	With FACTS devices
			With TCSC
		power loss MW	power loss MW
1	2	4.293	4.190
2	3	2.318	2.028
2	4	1.674	1.549
1	5	2.771	2.585
2	5	0.903	0.817
3	4	0.372	0.371
4	5	0.502	0.489
5	6	0.000	0.00
4	7	0.000	0.00
7	8	0.000	0.00
4	9	0.000	0.00
7	9	0.000	0.00
9	10	0.042	0.028
6	11	0.050	0.031
6	12	0.074	0.066
6	13	0.222	0.185
9	14	0.106	0.158
10	11	0.011	0.016
12	13	0.007	0.004
13	14	0.064	0.032
Total losses		13.410	12.547

Table–2 Voltage magnitude profile of IEEE 14 Bus system

Bus No	Without FACTS device	With FACTS device
		With TCSC
	Voltage (p.u.)	Voltage (p.u.)
1	1.060	1.100
2	1.045	1.100
3	1.01	1.0564
4	1.0189	1.0737
5	1.0216	1.0826
6	1.07	1.0655
7	1.0587	1.0773
8	1.090	1.1
9	1.0492	1.0671
10	1.0565	1.0707
11	1.0597	1.0648
12	1.0547	1.0518
13	1.0494	1.0482
14	1.0312	1.0410

Table–3 Allocation of losses to Generators for IEEE-14 Bus System

Transmission loss Without FACTS Device		
Generator No	Postage Stamp Method	Power flow tracing Method
1	5.7210	6.1061
2	0.9842	0.5984
Total	6.705	6.705

Table–4 Allocation of losses to Generators for IEEE-14 Bus System

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Transmission loss With FACTS Device		
Generator No	Postage Stamp Method	Power flow tracing Method
1	5.3495	5.7209
2	0.9235	0.5529
Total	6.273	6.273

Table–4 Allocation of losses to loads for IEEE-14 Bus System

Transmission loss without FACTS Device		
Load No	Postage Stamp Method	Power flow tracing Method
2	0.5616	0.2420
3	2.4378	2.6257
4	1.2370	1.5540
5	0.1967	0.0829
6	0.2898	0.1222
7	0.0000	0.000
8	0.0026	0.0033
9	0.7634	0.9591
10	0.2329	0.3324
11	0.0906	-0.0333
12	0.1579	0.0961
13	0.3494	0.2348
14	0.3856	0.4859
Total	6.705	6.705

Table–6 Allocation of losses to loads for IEEE-14 Bus System

Transmission loss With FACTS Device		
Load No	Postage Stamp Method	Power flow tracing Method
2	0.5254	0.2374
3	2.2808	2.4382
4	1.1573	1.4939
5	0.1840	0.0579
6	0.2712	0.0852
7	0.000	0.000
8	0.0024	0.0031
9	0.7142	0.9219
10	0.2179	0.3006
11	0.0847	-0.0029
12	0.1477	0.0739
13	0.3269	0.1791
14	0.3608	0.4850
Total	6.273	6.2733

The results obtained from IEEE-14 bus system with optimal allocation of TCSC Device, the postage stamp method and power flow tracing method allocated the losses equally to the loads and generators respectively and counter flow exist in power flow tracing method where as in postage stamp method it doesn't exist. It shares the losses of 6.2733MW to the generators and loads equally.

V.CONCLUSION:

In this paper Brain storm optimization algorithm is used for optimal location and setting of TCSC device to reduce the transmission losses. from the results obtained for the test system of IEEE 14 bus system ,it is observed that losses are reduced from 13.410MW to 12.537MW and from the loss allocation methods, postage stamp method gives fixed amount of loss irrespective of the network structure of the system. Whereas power flow tracing method gives allocation of power losses fairly to all market participants based on the network usage of the system. Thus it can be concluded that brain storm optimization algorithm gives best results in determining the location of the TCSC Device compared to conventional methods and power flow Tracing method gives best results in the allocation of losses to all the transactions.

Future scope: For better location and sizing of TCSC Device, Brain storm optimization algorithm is used. This can be extended to other optimization techniques with different FACT Devices for the minimization transmission losses and for the improvement of magnitude of voltage profile of system. The allocation of power losses can be extended with different allocation methods.

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