Transmission Loss Allocation In Deregulated Power System with Optimal Placement Of TCSC Device Using Optimization Algorithm

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Abstract:

The demand for power generation is increasing day by day and there is need for more electricity sellers with optimum cost to the market participants. so the Deregulation creates a competition among the Market players and makes them innovative in framing the rules and regulations in a power system in open access policy so that the market participants can have the flexibility in buying the power from different electricity producers of their choice.Since FACTS devices plays a vital role in minimizing the losses and regulating the voltage in the power system. Here TCSC is used to reduce the transmission losses and Cuckoo search optimization algorithm is used for optimal location and sizing of TCSC in a transmission system and are tested with IEEE 30 bus system.After minimizing the losses, transmission loss allocation can be done in deregulated power system using postage stamp method proportional sharing principle method and the results are compared for IEEE 30 bus system using MATLAB/IMULINK Environment.

Key Words*: Deregulation, Postage Stamp method, proportional sharing principle method, Transmission Loss allocation, TCSC.*

Introduction:

The power industry across the globe is experiencing a radical change in its business as well as in an operational model where, the vertically integrated utilities are being unbundled and opened up for competition with private players. This enables an end to the era of monopoly.In a deregulated power system transmission loss has to be allocated to individual suppliers, generators and contracts. Loss allocation does not affect generation levels or power flows; however it does modify the distribution of revenues and payments at the network buses among suppliers and consumers.

In a deregulated power system, every supplier has to supply the power they want to sell plus the transmission loss corresponding to that transaction. Therefore, system operator has to allocate losses to every individual generation and load. Depending on the contract, a supplier may supply the contracted load and the corresponding loss or supply the load and pay for the loss. In later case, the loss may be supplied by a contracted generator or ISO may buy the power to meet the loss from a spot market. Depending upon who will supply the loss, the allocation will vary to some extent.

The electric power was then looked upon as a service. Control consisting of planning and operational tasks was administered by a single entity or utility. The vertical integration of all tasks gave rise to the term – vertically integrated utility. The arrangement of the earlier setup of the power sector was characterized by operation of a single utility generating, transmitting and distributing electrical energy in its area of operation.

Thus, these utilities enjoyed monopoly in their area of operation. They were often termed as monopoly utilities. Why were earlier utilities the ‘monopolies'? The reason for monopoly can be traced right back to the early days when electricity was comparatively a new technology.

. This created a win-win situation for both- government and the electrical technology promoters thus creating competition among the market participants.This project proposed the simple novel methodologies to allocate the real power losses to the market participants effectively by using simple circuit laws and loss formulae.

The proposed methodologies are tested on IEEE 30 Bus System and IEEE 30 Bus system to allocate the real power losses transparently to the market participants by using MATLAB/SIMULINK 7.02.

II.PROBLEM FORMULATION:

A.TCSC MODELLING:

TCSC is defined as “A capacitive reactance compensator which is made up of a series capacitor bank, parallel with an inductor which is thyristor controlled and shunted by the series capacitor” [6]. Thyristor Controlled Series Capacitor (TCSC) provides a powerful means of increasing and controlling power transfer level of a transmission line by varying the apparent impedance of the same transmission line. Taking into consideration the line permissible loading capacity, the reactance of TCSC depends on the compensation ratio and the reactance of the transmission line. The range of TCSC is restricted to be -0.3 to -0.7 of the line reactance [13]. The Modelling of TCSC as a controllable reactance XTCSC is shown in Fig. 1.

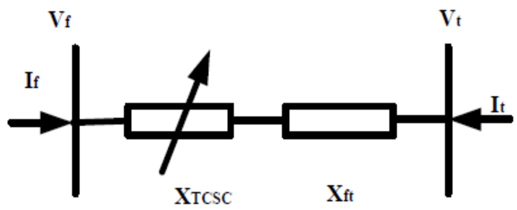


Fig1. Variable reactance model of TCSC

The total reactance of the transmission line can be expressed mathematically as:

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

Where,
X_{ft}= Reactance of a transmission line between buses f and t
X_{TCSC}= Reactance of the TCSC
X_{line}= Total reactance of line after placing the TCSC

Now, the problem is identified and the TCSC simplified model has been clarified. In the next section, the optimization techniques Adaptive Cuckoo Search Algorithm (ACSA) and how it can be applied to our problem for optimal placement of TCSC is discussed.

B. Objective function:

The objective is to determine the optimal location and reactance setting of the TCSC device to minimize the transmission loss in power system network [8], which can be evaluated from the power flow solution and written as

$$\text{Ploss} = \Sigma_{i=1}^{nl} G_l (V_i^2 + V_j^2 - 2V_iV_j cos\delta_{ij}) \ (2)$$

Where

nl = number of transmission lines

G_l= conductance of l^{th} transmission line

V_i and V_j = voltages at bus i and bus j

δ_{ij}=power angle

CuCkoo Search Optimization Algorithm:

CS Algorithm is a nature-inspired met-heuristic algorithm, developed by Xin-She Yang and Suash Deb in 2009. The CS Algorithm based on Cuckoo reproduction strategy by the way that some cuckoo birds lay their eggs, primarily based on Levy flights distribution [9], [12]. Cuckoo bird will dumb their eggs into others bird nest known as the host bird nest. If the host bird discover cuckoo eggs, the eggs will be threw out by the host bird or the nest will abandoned. However, Cuckoo eggs will be hatched earlier than the host bird eggs which give higher chances of Cuckoo chick to live. To implement this CS optimization technique, the following rules are used.

a. Each Cuckoo bird lays one egg at one time and keeps it in a randomly chosen nest of host birds

b. The best nests having higher quality of eggs will be taken to the next generations

c. The number of host birds nests are fixed and the possibility to discover the Cuckoo eggs by host birds are with a probability of pa = 0.25.

In the Cuckoo search algorithm the Levy distribution is followed and has no control on the step size in the generation technique. Therefore, an adaptive cuckoo search Algorithm is proposed without using Levy distribution. In this ACS Algorithm, the step size is proportional to the objective function of the individual nest in the search space and the present generation. The step size of ACS algorithm is given as

$$step_i(t+1) = \left(\frac{1}{t}\right)^{\left(\frac{bestfit(t)-fit_i(t)}{bestfit(t)-worstfit(t)}\right)} \ (3)$$

Where

t = Cuckoo search Generation

fit_i (t) = Fitness value of i^{th} nest in t^{th} generation

bestfit (t) = Best fitness in t^{th} generation

worstfit (t) = Worst fitness in t^{th} generation.

Initially step size is high. The generation inversely varies with the step size. Therefore the step size is small when the algorithm reached to the global optimised solution and based on the fitness value. From the Eq. (1), it is observed that the step size is adaptively decided from the fitness value [2]. The adaptive Cuckoo search algorithm (ACS) is modelled as

$$X_i(t+1) = X_i(t) + randn * step_i(t+1)(4)$$

Transmission loss Allocation Methods:

i) **Postage Stamp Method:**

This method is simple in structure and easy to implement for any type of system. The postage stamp method allocates the transmission losses to the generation and load based on the active power generation. But the network structure is not considered in this type of allocation and it will not be beneficial for the two loads of identical type which locate near generators and far away from generators respectively because the same amount of loss will be allocated for both the loads irrespective of the distance of the transmission in the system.

$$LP_{Gj}= \frac{TL}{2}\frac{PG_j}{PG} \quad (5)$$

$$LP_{Di} = \frac{TL}{2}\frac{PD_i}{PD} \quad (6)$$

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

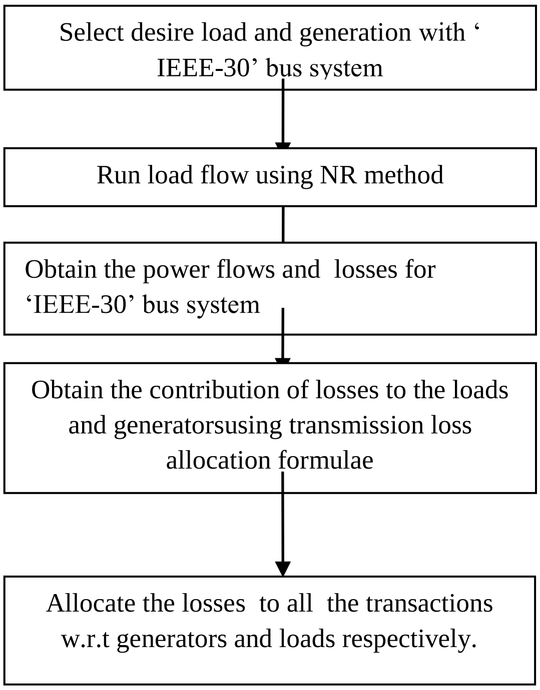
PG, PD –Total power generation and load of this system

LPGj–Losses allocated to the generator i

LPDi–Losses allocated to the demand j

L–Total losses of the system

Algorithm for postage stamp method:



ii) Power flow tracing Algorithm:

Power flow tracing algorithm is based on the principle of Kirchoff’s Current law i.e which s which states that the nodal inflows is equal to the nodal outflows meeting at the node. It is based on the network structure and the losses can be allocated to the market participants by the assumption that the 50% of losses is allocated to the generators and 50% of losses to the loads. The purpose of power flow tracing is to identify the contribution factors of each generator speech load and to determine the distribution factors of power injection to each bus on the outflow branches.

Transmission loss allocation:

Proportional sharing principle method express branch flows as the sum of components supplied from individual generators or to loads.

$P_{j-i}^{(gross)}=(P_{ji}/P_j)\Sigma[A_{u(j,k)}]P_{GK}$ for $i \in \alpha_j^d$

α_j^d= set of nodes supplied from node i

P_j = nodal power

K= Buses (generator bus)

P_{GK}= generating power at bus k

P_{ji}=branch power flow (j€upstream,i Є down stream)

A_u= upstream distribution matrix

$$[A_u]_{ji} = \begin{cases} 1 & \text{for } j=i \\ -|P_{ji}|/P_j & \text{for } j \in \alpha_j^u \\ 0 & \text{otherwise} \end{cases}$$

$P_{i-j}^{(net)}=(P_{ij}/P_i)\Sigma[A_{d(j,k)}]P_{DK}$ for $i \in \alpha_i^u$ (7)

P_{DK}= load at bus K.

K=buses (load bus),

P_{ji}= branch power flow (j Є upstream, i Є down stream),

α_i^u= set of nodes supplying node i.

Ad=down stream distribution matrix

$$[A_d]_{ij} = \begin{cases} 1 & \text{for } i=j \\ -|P_{ij}|/P_i & \text{for } i \in \alpha_i^d \\ 0 & \text{otherwise} \end{cases}$$

In order to assign 50% of losses to the generation and 50% to the demand, the final generation and demand per bus are computed as,

$P'_{Gi}= (P_{i-j}^{net}+P_{Gi})/2$ (8)

$P'_{Dj}= (P_{i-j}^{(gross)} +P_{Di})/2$ (9)

Finally the real power losses allocated to every generator and demand are computed as

$L'_{Gi}=P_{Gi}-P_{Gi}'$ (10)

$L'_{Di}=P'_{Dj}-P_{Dj}$ (11)

Results and Discussions:

The proposed algorithm is tested on IEEE 30 bus system consists of 30 buses, 41 transmission lines and 6generators. Using NR method the transmission losses are determined. To minimize theTransmision losses TCSC is used for IEEE-30 Bus Sytem. The optimal location and sizing of TCSC can be determined by using Cuckoo search optimization algorithm. The power flow analysis in IEEE 30 bus system with and without inserting the TCSC device is tested for IEEE 30 Bus system. Which I shown in table-1.After applying the CSA technique to the proposed network, it is observed that the optimal location of the TCSC is at line no 5 connecting between busses 2-5 with the per-unit impedance of -0.0612, the results are shown in table 1.

Table-1 Transmission line losses for IEEE 30 Bus system with and without TCSC device.

S.No	From To	Losses without TCSC	Losses with TCSC
1	1-2	6.072	6.24
2	1-3	3.727	3.524
3	2-4	1.229	1.048
4	3-4	1.030	0.973
5	2-5	3.130	4.010
6	2-6	2.352	2.003
7	4-6	0.752	0.645
8	5-7	0.113	0.015
9	6-7	0.331	0.168
10	6-8	0.102	0.103
11	6-9	0.000	0.000
12	6-10	0.000	0.000
13	9-11	0.000	0.000
14	9-10	0.000	0.000
15	4-12	0.000	0.000
16	12-13	0.000	0.000
17	12-14	0.055	0.054
18	12-15	0.149	0.145
19	12-16	0.036	0.034
20	14-15	0.003	0.002
21	16-17	0.014	0.013
22	15-18	0.030	0.029
23	18-19	0.004	0.004
24	19-20	0.023	0.023
25	10-20	0.099	0.100
26	10-17	0.034	0.035
27	10-21	0.188	0.189
28	10-22	0.028	0.028
29	21-23	0.002	0.002
30	15-23	0.013	0.012
31	22-24	0.044	0.044
32	23-24	0.002	0.002
33	24-25	0.054	0.055
34	25-26	0.042	0.042
35	25-27	0.037	0.038
36	28-27	0.000	0.000
37	27-29	0.083	0.083
38	27-30	0.156	0.155
39	29-30	0.032	0.032
40	8-28	0.002	0.003
41	6-28	0.065	0.065
Total Loss (MW)		20.034	19.918

Table-2: Transmission loss allocation to the Generators for IEEE -30 bus system.

Generator No	**Loss allocation without TCSC in MW(Total loss=20.034)**		**Loss allocation with TCSC in MW(Total loss=19.918)**	
	Postage Stamp Method		**Power flow tracing method**	
	Loss allocation without TCSC	**Loss allocation with TCSC**	**Loss allocation without TCSC**	**Loss allocation with TCSC**
1	8.7780	8.7268	9.2898	9.2325
2	1.2388	1.2321	0.7262	0.7266
Total Loss	**10.016**	**9.959**	**10.016**	**9.959**

After minimizing the transmission losses the loss allocation can be done by using postage stamp method and Power flow tracing method which is shown in

Table-2.

From the results of Table-2 the transmission losses are allocated to the Generators without TCSC device is 10.016MW and with TCSC device, the losses allocated to the Generators is 9.951 MW, which is 50% of Total transmission losses.

From the result analysis, the postage stamp method is independent of the Network structure. It allocates the losses with the fixed amount irrespective of the transmission distance, where as the power flow tracing method allocates the transmission losses based on the structure of the network.

From the result analysis of table-3, the transmission losses are allocated to the Loads in a transmission system. The postage stamp method and power flow tracing method allocates 50% of total transmission losses in a transmission system. The results shows the loss allocation to the loads with and without inserting TCSC device using postage stamp method and power flow tracing method.

By inserting TCSC device on line 5 the losses are reduced from 20.034MW to 19.981MW.out of these total transmission losses, by the assumption of loss allocation methods 50% of total losses is allocated to the Generators and 50% of total transmission losses to the loads. Without inserting TCSC device, 10.016MW is allocated to the generators and loads respectively.With the insertion of TCSC device, 9.959MW is allocated to the generators and loads respectively.

Table-3: Transmission loss allocation to the Loads for IEEE -30 bus system.

Load No	**Loss allocation without TCSC in MW(Total loss=20.034)**		**Loss allocation with TCSC in MW(Total loss=19.918)**	
	Postage Stamp Method		**Power flow tracing method**	
	Loss allocation without TCSC	**Loss allocation with TCSC**	**Loss allocation without TCSC**	**Loss allocation with TCSC**
2	0.7164	0.7123	0.2978	0.3028
3	0.0792	0.0788	0.0484	0.0470
4	0.2509	0.2495	0.2015	0.1956
5	3.110	3.0921	3.1464	3.4219
6	0.000	0.000	0.000	0.000
7	0.7527	0.7484	0.9513	0.7893
8	0.9905	0.9847	1.0178	0.9815
9	0.000	0.000	0.000	0.000
10	0.1915	0.1904	0.1861	0.1791
11	0.3302	0.3282	0.3208	0.3086
12	0.3698	0.3676	0.2970	0.2882
13	0.3302	0.3282	0.2652	0.2573
14	0.2047	0.2035	0.1899	0.1852
15	0.2707	0.2692	0.2582	0.2510
16	0.1156	0.1149	0.1029	0.1002
17	0.2971	0.2954	0.3071	0.2967
18	0.1056	0.1050	0.1099	0.1072
19	0.3136	0.3118	0.3371	0.3272
20	0.0726	0.0722	0.1113	0.1075
21	0.5778	0.5744	0.6521	0.6303
22	0.000	0.000	0.000	0.000
23	0.1056	0.1050	0.1137	0.1103
24	0.2872	0.2856	0.3337	0.3236
25	0.000	0.000	0.000	0.000
26	0.1156	0.1149	0.0964	0.0946
27	0.000	0.000	0.000	0.000
28	0.000	0.000	0.000	0.000
29	0.0792	0.0788	0.1147	0.1114
30	0.3500	0.3479	0.5573	0.5423
Total Loss	**10.016**	**9.959**	**10.016**	**9.959**

Conclusion

From the results, TCSC is used to minimize the transmission losses from 20.034MW to 19.981MW.

From the Loss allocation methodologies the following conclusions can be drawn.

Postage Stamp method though simple and transparent to implement it does not take the network in to consideration and allocates the fixed real power losses to the participants irrespective of distance between the generators and loads.

Power flow tracing method takes the network in to consideration and allocates the real power losses proportionally to all the transactions. But in this method assumptions are made that the line inflows are equal to the line out flows. Power flow tracing method overcomes the disadvantages of postage stamp method and it allocates the real power losses directly by using simple circuit laws. This method gives accurate results compared to the Postage Stamp method.

Future Work

Here in this work only real power losses are considered for loss allocation. This can be extended by using other FACTS devices to minimize losses and then the proposed methods can be used to allocate the losses. This can also be extended to allocate the reactive power losses for better voltage stability and pricing canalso be done which is a major issue in today’s competitive market.

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