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Location Identification for FACTs Device

Neha S. patel[1], Priyank R.Bhavsar[2]

[1]*PG student, Department of Electrical Engineering, Sankalchand Patel College of Engineering, Gujarat, India*
[2]*Associate professor, Department of Electrical Engineering, Sankalchand Patel College of Engineering, Gujarat, India*

Abstract—*As result of deregulation of the power system the power transmission line have to transfer power at their maximum transmission limits because of the competitive scenario of the electric market hence secured operation of power system has become one of the most issue of modern generation. It is essential for power system to study the impact of contingencies on system security by proper use of FACTs devices in electric network. This paper present three different selection factors to decide the best location to place FACTs device to improve the system security under contingencies . Three selection factors Contingency Severity Index (CSI), Excess Power Flow (EPF), Number of Times Overloaded Line (NOTOL) are considered. This approach is tested on IEEE 6-Bus and IEEE 30- Bus system and give ranking of most preferable lines for placement of FACTs devices.*

Keywords – Contingency Severity Index (CSI), Excess Power flow (EPF), Number of Times Overloads Line (NOTOL) Flexible ac Transmission system(FACTs)

1. INTRODUCTION

Day by day, increasing load on the power system, also increasing severe contingency so the transmission network parameter is working near to its thermal limits and voltage limits that leading threat to power system security. The whole system can lead to blackout because of severe condition of overloading. This is very important for power system security that the system would work within safe limits. The overloading of the system can be recovered which improve system security by two alternative, firstly restructuring of power system and secondly by controlling the line parameter of a system. But environmental, cost problems are major problems for power transmission network expansion due to power system restructuring requires expanding potentials of the system network. To Control the power flow of line in power system without generation rescheduling can improve the performance. [2]

Hence, for best utilization of available capacities of system and power flow control, installing FACTs devices. FACTs devices such as (TCPAR) Thyristor Controlled Phase Angle Regulator, (TCSC) Thyristor Controlled Series Capacitor, Unified Power Flow Controlled (UPFC). These devices can play an important role to reduce the flow of over-loaded lines, increasing load -ability, low system loss improve stability, reduce cost of production, stability margin increased These devices used to control the power flows in the line so power system security enhanced.[3]

2. POWER SYSTEM SECURITY

The security of power system can be defined as its ability to withstand a set of severe but credible contingencies and to survive the transition to acceptable new steady state condition.

Contingency Creation

It is the initial step of contingency analysis. It is made up of all set of viable contingencies that may happen in a power system. This process consists of making contingency lists.

Contingency Selection

It is the second step in contingency analysis it is the process which includes finding of severe contingencies from all that may cause to violate bus voltages and power through lines. Here in this procedure contingency list is reduced by rejection of least severe contingency and taking into consideration of most severe outages. In this process the performance index has been used to find the most severe ones.

Contingency Evaluation

It is the third step and the most significant step as it includes necessary control and security actions which are required in order to reduce the effects of most severe contingencies in a power system.[2]

3. METHOD FOR OPTIMAL LOCATION FOR FACTs DEVICE

There are several methods for finding the optimal location of facts devices like: [4]

- Sensitivity Approach
- Contingency severity Index

3.1 Sensitivity Approach

The Sensitivity approach is characterized by to change in active power performance index with respect to the FACTs parameter. The sensitivity approach calculates to find the optimal location of FACTs devices like a thyristor controlled series capacitor (TCSC) and thyristor controlled phase angle regulator (TCPAR) .

3.1.1 Real power performance index

The severity of the system loading under contingency and normal events can be drawn by an actual power line flow performance index given below[3]

$$PI = \sum_{m=1}^{N} \frac{W_m}{2n} \left(\frac{p_{lm}}{p_{lm}^{\max}} \right)^{2n} \quad \text{..................(1)}$$

p_{lm} = real power flow

$p_{lm}^{\max}$ = rated capacity of line m

N= exponent

W_m = real non negative weighting coefficient which may be used to reflect the importance of lines.

3.2 Contingency severity Index [1]

The fundamental principle used in FACTs placement for enhancing static security of the power system is to decide a branch, which is most severity to the biggest number of contingencies. Contingency severity Index (CSI) is a second method to determine the location of FACTs devices which is find from underneath equations. This chapter portrays the definition and calculation of the contingency severity index (CSI) and optimal placement procedure for the FACTs.

3.3 Problem Formulation

Selection three Factors to be considered for Optimal location of FACTS Controllers are:[1]

Selection Factor-1: Concept of Contingency Severity Index (CSI)

The CSI of a branch "j" is defined as of the sensitivities of branch "j" to all the considered contingencies and is experessed as

$$CSI_j = \sum_{i=1}^{m} p_i \, u_{ij} \, w_{ij} \quad \text{...........................(2)}$$

Where,

p_i is the probability of occurrence for contingency "i" .

u_{ij} and w_{ij} are elements of matrices U and W respectively.

M=The Total number of single contingency

p_i u_{ij} w_{ij} = The element of matrix P,U,W

This equation is defined as sum of considered contingency 'i' for all branches are calculated A branch which has highest CSI value will be more sensitive for security margin.

The participation matrix u:

This is an (m x n) binary matrix, where m is the aggregate of single contingency and n is the aggregate of branches of interest. uij is an element of matrix U, whose values are "1" or "0" depending on comparing branch is overloaded. If uij=0, the branch 'j' is not overloaded for contingency 'i'. If uij =1, the branch 'j' is overloaded for contingency 'i'.

The Ratio Matrix W:

This is a matrix of normalized excess overload branch flow as for to the base case flow through branch "j" during contingency "I" in dimensions of (m x n) and it is given by bellowing equation:

$$W_{ij} = \frac{P_{ij contingency}}{P_{ojbase case}} - 1 \quad \text{.......................(3)}$$

Where

Pij,cont = Power flow through branch" j" during specified contingency i

P oj,norm = base case Power flow through branch j

Selection Factor-2: Concept of Excess Power Flow (EPF) When there is a contingency, certain transmission lines may be overloaded with reference to thermal limit. The excess power flow in the various overloaded lines with reference to thermal limit of the corresponding lines for different contingency conditions have to be calculated. The sum of excess power flow in a particular branch for the different contingencies is the best factor to be considered for ranking of branches under different contingencies.

Selection Factor-3: Concept of Number of Times Overloaded (NOTOL) When there is different contingency condition, whether the line under study is getting overloaded or not and that particular line how many times getting overloaded for different contingencies have to be observed. Utilizing this aspect, all the lines under study have to be ranked.

Selection of branches for placement of FACTS Controllers

The branches are listed out based on the CSI value in descending order. While choosing selection factor-1, the branch with largest value of CSI is considered as the best location for FACTS Controller and to proceed further with next highest CSI value for the next FACTS Controller.

However when considering selection factor 2 along with selection factor-1, the branch with highest EPF gets higher priority. Similarly when considering selection factor-3 in addition to the above factors the branch with more number of times overloaded for different contingencies gets higher priority. Thus for selection of optimal location of line for placing FACTS Controller, it is essential to consider all the selection factors in a best combination way.

4. RESULTS AND SIMULATION

Simulation and analysis is done for the ranking of transmission lines for placement of FACTs devices for different contingency cases of IEEE 6 bus and IEEE 30 bus system by all selection factors individually as well as by combination of all selection factors.

A.IEEE 6 BUS RESULTS

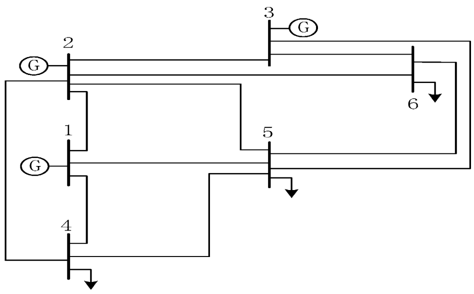

Figure-1 : IEEE 6 Bus System

The ranking method has been tested on IEEE 6-bus system which consist of three generator buses and three load buses are shown in figure 1.

Case 1 : Ranking of branches for IEEE 6 bus system

1. Ranking based on selection factor CSI

It can be seen that by considering selection factor-1 (CSI) line 1 is most suitable location for placement of FACTs device with highest value of CSI.

Table 1: Ranking of Branches for IEEE6 Bus system based on the proposed selection factors CSI of the Branch

Line No.	from bus	to bus	selection factor-1 (CSI)
1	1	2	0.16674939
2	1	4	0.1162547
5	2	4	0.09695934
3	1	5	0.07754107

2. Ranking based on selection factor EPF

It can be seen that by considering selection factor-2 (EPF) line-1 is most suitable location for placement of FACTs devices with highest value of EPF.

Table 2: Ranking of Branches for IEEE6 Bus system based on the proposed selection factors EPF of the Branch

Line No.	from bus	to bus	selection factor-2 (EPF)
1	1	2	30.00321
3	1	5	21.56756
5	2	4	8.384185
2	1	4	6.491353

3. Ranking of branches for IEEE 6 bus NOTOL

It can be seen that by considering selection factor-3(NOTOL) line-1 is most suitable location for placement of FACTs devices with highest value of NOTOL.

Table 3: Ranking of Branches for IEEE6 Bus system based on the proposed selection factors NOTOL of the Branch

Line No.	from bus	to bus	selection factor-2 (EPF)
1	1	2	30.00321
3	1	5	21.56756
5	2	4	8.384185
2	1	4	6.491353

4.Ranking of branches for IEEE6 bus system based on the combination of all selection factors

Table 4: Ranking of branches for IEEE6 bus system based on the combination of all selection factors

Line No.	from bus	to bus	selection factor-1 (CSI)	selection factor-2 (EPF)	selection factor-3 (NOTOL)	Rank
1	1	2	0.1667494	30.003209	3	1
2	1	4	0.1162547	21.567559	2	3
5	2	4	0.0969593	8.3841845	2	2
3	1	5	0.0775411	6.4913531	1	4

The ranking of branches for optimal location were studied based on the proposed selection factors viz., CSI, EPF and

NOTOL. It can be seen that considering combination of all selection factors line-1 is most suitable location for placement of FACTs device.

B. IEEE 30 BUS RESULTS

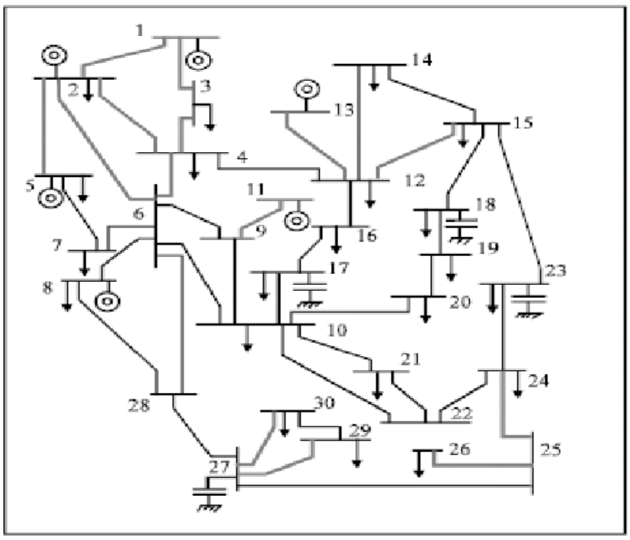

Figure1: IEEE 30 Bus System

Case 2 : Ranking of branches for IEEE 30 bus system based on the proposed selection factor viz CSI, EPF, NOTOL

1.Ranking based on selection factor CSI

It can be seen that by considering selection factor-1 (CSI) line-27 is most suitable location for placement of FACTs device with highest value of CSI.

Table 1: Ranking of Branches for IEEE30 Bus system based on the proposed selection factors CSI of the Branch

Line No.	from bus	to bus	selection factor-1 (CSI)
27	10	21	0.13798
23	18	19	0.048414
22	15	18	0.047269
21	16	17	0.032259
10	6	8	0.003324

2. Ranking based on selection factor EPF

It can be seen that by considering selection factor-2(EPF) line-10 is most suitable location for placement of FACTs devices with highest value of EPF.

Table 2: Ranking of Branches for IEEE30 Bus system based on the proposed selection factors EPF of the Branch

Line No.	from bus	to bus	selection factor-2 (EPF)
10	6	8	22.31361
29	21	22	9.518213
22	15	18	7.802625
30	15	23	6.209976
16	12	13	5.538462
32	23	24	1.886208
35	25	27	1.205858
38	27	30	1.084967
40	8	28	0.875
37	27	29	0.723998
23	18	19	0.70939
41	6	28	0.549921
39	29	30	0.366601
21	16	17	0.27754
28	10	22	0.26136
33	24	25	0.20288
27	10	21	0.102809

3. Ranking based on selection factor NOTOL

It can be seen that by considering selection factor-3(NOTOL) line-32 is most suitable location for placement of FACTs devices with highest value of NOTOL.

Table 3: Ranking of Branches for IEEE30 Bus system based on the proposed selection factors NOTOL of the Branch

Line No.	from bus	to bus	contingency producing overloads	selection factor-3 (NOTOL)
32	23	24	6-7,16-17,18-19,19-20,10-20,23-24,25-27,27-29	8
23	18	19	16-17,10-17,10-21,25-26	4
21	16	17	19-20,10-22,6-7	3
38	27	30	29-30,6-28	2
27	10	21	22-24	1
37	27	29	8-28	1
39	29	30	8-28	1
41	6	28	6-10	1

4.Ranking of branches for IEEE30 bus system based on the proposed selection factors

Table 4: Ranking of branches for IEEE30 bus system based on the proposed selection factors

Line No.	from bus	to bus	selection factor-1 (CSI)	selection factor-2 (EPF)	selection factor-3 (NOTOL)	Rank
23	18	19	0.0484	7.8026	4	1
27	10	21	0.1379	0.1082	1	2
21	16	17	0.0322	6.2099	3	3
1	1	2	0	1.2058	0	0

The ranking of branches for optimal location were studied based on the proposed selection factors viz., CSI, EPF and

NOTOL. It can be seen that considering combination of all selection factors line-23 is most suitable location for placement of FACTs device.

5. CONCLUSION

From above analysis it can been that for IEEE 6 and IEEE 30 bus system by using different selection factors like CSI, EPF, NOTOL individually the best location for placement of FACTs device can be found and by combining all factors at a time more reliable results can be obtained.

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BIOGRAPHIES

Neha S. Patel
M.Tech. research scholar
Department of EE, SPCE,
Visnagar, Gujarat, India

Priyank R. Bhavsar
Associate professor
Department of EE, SPCE,
Visnagar, Gujarat, India