Evaluation Of Improvement In Power Transfer Capability Of An Interconnected Power System With And Without Contingency

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ABSTRACT

Power Transfer Capability is an important index in power markets with large volume of inter-area power exchanges and wheeling transactions taking place on hourly basis. Its computation helps to achieve a viable technical and commercial transmission operation. The aim of my research was to evaluate power transfer capability and also to improve it using compensation technique. Load flow of 30-bus system was carried out considering normal and contingency conditions as tie-line outages. Base and optimized results show how compensation helps to improve system condition and tie-flows. Parameters like voltage magnitude, L-index, MW losses, MSV are computed to analyze the system performance.

Keywords: - L-index, reactive optimization, reactive compensation, voltage stability.

1. Introduction

In today's electric power market there is more competition in transmission providers and required to produce commercially viable information of available transfer capability (ATC) so that such information can help sellers, buyers, and power marketers in planning, operation and reserving transmission services. Power transfer capability improvement is used by the system operators to determine the ability of transmission system to transfer power and by system planners to indicate the system strength. Power Transfer Capability is an important index in power markets with large volume of inter-area power exchanges and wheeling transactions taking place on hourly basis. Its computation helps to achieve a viable technical and commercial transmission operation. Nowadays, the electric power industry is under deregulation in response to changes in the law, technology, market and competition. Deregulated power systems cannot bundle the generation, transmission, distribution and retail activities, which were traditionally carried out by vertically integrated utilities; therefore, different pricing policies will exist between different power companies. With the separate pricing of generation, transmission and distribution, it is necessary to find the capacity usage of different transactions happening at the same time so that a fair use-of transmission-system charge can be given to individual customer separately. Then the transparency in the operation of deregulated power systems can be achieved. In additional, the capacity usage is another important issue for transmission congestion managements; therefore, the power produced by each generator and consumed by each load through the network should be traced and improved. In these aspects, problems arise because all transactions have to share the same transmission network simultaneously. Those problems including ‘‘which line no, generators are supplying this load?’ ‘Which generator or load is making the biggest usage of this transmission line?’ and ‘Which line, generator or load is producing loss of this transmission line?’ etc., need to have acceptable solutions in a fair deregulated power system. To solve these problems, an algorithm, which can allocate the contributions of power flow and loss from individual line through the transmission system to the loads, is needed. This is both an essential and challenging task. Some methods have been proposed to trace the power transfer and loss in deregulated system. The losses allocated are based on the bus generation or load, but not on their relative location within the network.

The aim of this paper is to evaluate power transfer capability and also to improve it using reactive compensation technique. Load flow of 30-bus system is carried out considering normal and contingency conditions. Base case and optimized case results show how compensation help to improve system conditions. Parameters like voltage magnitude, severity index, MW losses, MSV are computed to analyze the system performance.

2. Literature Review

[1]. Thukaram dhadbanjan and Vyjayanthi Chintamani et al [2010], have described the total transfer capability (TTC) to evaluate in an interconnected power system and also to improve it by using controller device. TTC has been computed considering normal contingency conditions such as single line, tie line etc. Parameters like voltage stability indices, voltage magnitudes, L-index, minimum singular values, MW losses have been calculated to analyze the system performance.

[2]. Glavitsch. H, and Kessel, P. [1986], have described the methods for estimating the power system values and load ability of power system. The voltage stabilities has been calculated by finding the values of voltage stability indices and L-index, the load ability has also been Calculated by varying the loads in the system values of the network.

2.1 Voltage Stability Analysis

2.1.1 Minimum Singular Value

Minimum singular value (MSV) of the load flow jacobian, proposed by Lof et al. (1993) is a measure of voltage stability. The singularity of the power flow jacobian matrix is used for determining steady-state stability. Singularity of the power flow jacobian matrix indicates that the inverse does not exist and thus there is an infinite sensitivity in the solution to small perturbations in the parameter values. The MSV is used to indicate the distance between the studied operating point and the steady-state voltage stability limit. At the point of voltage collapse, no physically meaningful load flow solution is possible as the load flow jacobian becomes singular and at this point, the MSV becomes zero. Hence, the distance of the MSV from zero at an operating point is a measure of proximity to voltage collapse. The power flow Jacobian matrix can hence be written as which is a matrix composed of the four sub matrices: J_1, J_2, J_3, and J_4. Since there is a relatively strong coupling between reactive power and voltage magnitudes in the power system, the most interesting of the four sub matrices above is the one which contains the partial derivatives of reactive powers with respect to voltages, above denoted J_4. Another way of showing the significance of the matrix Gs as a static voltage stability indicator is to compute the determinant of the power flow Jacobian matrix with the use of Schur's formula. Under the assumption that the sub matrix

J_1 is non singular, and then the determinant of the power flow Jacobian matrix can be calculated

As $\quad det J = det J_1 * det G_s$

And $\quad G_{s} = J_4 - J_3 * J_1^{-1} * J_2$

Where G_s (Schur's complement) again is defined as can be seen from equation above, the power flow jacobian matrix will become singular either when the matrix G_s or when the matrix J_1 becomes singular. If there are no static angle stability problems, i.e. $det\ J_1 \sim 0$, then the power flow Jacobian matrix will become singular if and only if the matrix Gs becomes singular. The matrix Gs is hence a sub matrix, associated with the matrix J, t hat is indicative of steady-state voltage stability problems. The use of Gs for voltage stability analysis was proposed in, where the determinant of this sub matrix was presented as an example of a steady-state voltage stability index.

2.1.2 Calculation of L-index and its importance:-

Kessel and Glavitsch (1986) have proposed Static voltage stability index named as 'L' based on normal load flow solution. The value of L must lie within a unit circle, with a range L = 0 (no load on the system) to L = 1 (static voltage stability limit). The value of L is computed for each load bus in the system. Consider a system where n is total number of busses, with 1, 2…, g generator busses (g). A load flow result is obtained for a given system operating condition, Using the load flow results, the L-index [1] is computed as:-

$$L_j = \left| 1 - \sum_{i=1}^{i=g} F_{ji} * V_i / V_j \right|_{j=g+1} \ldots\ldots$$

…….(1)

The values of the F_{ji} are obtained from the load flow Y-Bus matrix :

$$\begin{bmatrix} I_g \\ I_l \end{bmatrix} = \begin{bmatrix} Y_{GG} Y_{GL} \\ Y_{LG} Y_{LL} \end{bmatrix} \begin{bmatrix} V_G \\ V_L \end{bmatrix} \ldots(2)$$

Values of [IG], [IL] and [VG], [VL] represents the complex currents and bus voltages; $[Y_{GG}]$, $[Y_{GL}]$, $[Y_{LG}]$ and $[Y_{LL}]$ are the matrix Y-bus matrix. from here the values of [FLG] was obtained as:-

$$[FLG] = -[YLL]^{-1}[YLG]$$

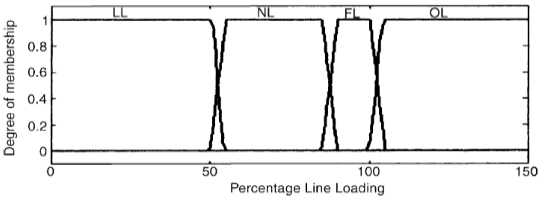
Significance of severity index:- The values of severity index lies in between 0 and 1. Values less than 1 and close to zero indicates that there is improvement in voltage stability. As the load/generation values increases the voltage magnitude and angle changes the voltage stability index Lj value for each load bus tends to get close to 1, indicating that the system is close to voltage collapse.

3.1. Fuzzy approach for contingency ranking:-

Fuzzy logic approach is used to identify the most critical line contingencies. The parameters considered for ranking are- line loading, bus voltage profiles and L- index values of the load buses. The post-contingent quantities are first expressed in fuzzy set notation before they can be processed by the fuzzy rules. The details of the fuzzy approach are given by Vishaka et. al. (2004).

3.1.1 LINE LOADING:-

Each post-contingent percentage line loading is divided into four categories using fuzzy set notations: lightly loaded (LL), 0–50%; normally loaded (NL), 50–85%; fully loaded (FL), 85–100%; over loaded (OL), above 100%.

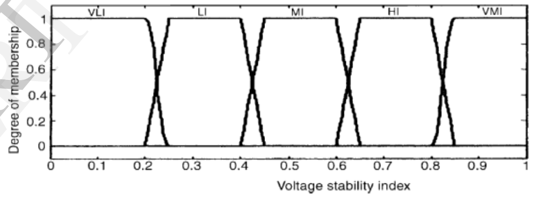


3.1.1. Bus voltage profiles

Each post-contingent bus voltage profile is divided three categories using fuzzy set notations: low voltage (LV), below 0.9 p.u.; normal voltage (NV), 0.9–1.02 p.u. and over voltage (OV), above 1.02 p.u.

3.1.3 Voltage stability indices

Each post-contingent voltage stability index is divided into five categories using fuzzy set notations: very low index (VLI), 0–0.2; low index (LI), 0.2–0.4; medium index (MI), 0.4–0.6; high index (HI), 0.6–0.8 and very high index (VHI), above 0.8.



4. Algorithm:-

1 Form Y_{bus}.

2 Given: Base case system's transmission data, load data information.

3 Solve the power flows for the base case data, checking for no limit violations.

4 Obtain the sub matrix of the Y-BUS matrix that are connected through load to generator and load to load as Y_{LG} and Y_{LL}.

5 Calculate the Y_{bus} matrix and find out the sub-matrix of the Y-matrix as:

6 Y_{bus} = $\begin{bmatrix} Y_{GG} Y_{GL} \\ Y_{LG} Y_{LL} \end{bmatrix}$

7 After finding the SUB-Matrix from Y-BUS matrix formulate

the severity index as L-INDEX which is formulated as:-

$$L_j = \sum_{i=1}^{i=g} F_{ji} \times V_i / V_j$$

where j= g+1……n.

8 The value of F_{ji} is founded out by :-

$$[F_{LG}] = -[Y_{LL}]^{-1}[Y_{LG}]$$

9 After this with the optimization technique find the value of V_L which is givenas:-

$$V_L = \sum_{j=g+1}^{n} (L_j)^2$$

10 The secure voltage limits are set between 0.9 ≤ V ≤ 1.05 and secure line loading is set between 50% - 110% of its rated value.

11 Identify the zone to zone interfaces.(zone-1 and zone-2)

12 Check the solution for violations of operational or physical limits. If there are violations, decrease the transfer power to the minimum amount necessary to eliminate them.

13 Identify the critical lines in each zone and rank them. To rank the critical contingencies NCOSI is computed using fuzzy logic approach as given below, and based on this index the single line contingencies are ranked.

$$NCOSI = \sum W_{LL} SI_{LL} + \sum W_{VP} SI_{VP} + \sum W_{VSI} SI_{VSI}$$

14 Identify the optimal locations for the reactive power compensation. The optimal reactive compensation location is selected after studying the system performance under critical line with and without contingency conditions.

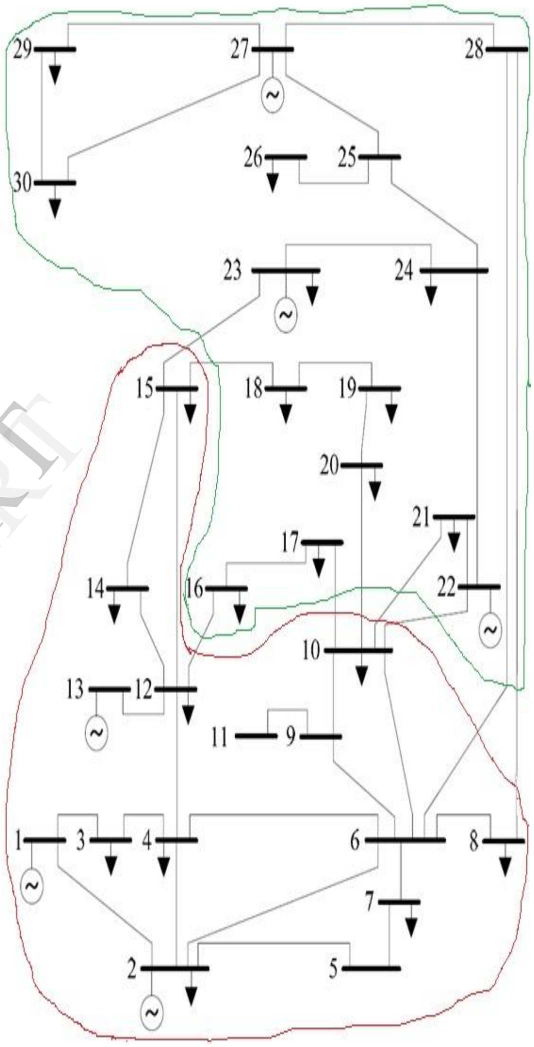
15 STOP.

5. Single Line Diagram:- IEEE 30-bus system :

In this the power system is divided into two zones as given below:

ZONE-1 from 1-15

ZONE-2 from 16-30



6. CONTINGENCY:-

In the past many widespread blackouts have occurred in interconnected power system. Therefore it is necessary to ensure that power systems should be operated more economically such that power is delivered reliably. Reliable operation implies that there is adequate power generation and the same can be transmitted reliably to the loads. Most power systems are designed with enough redundancy so that they can with stand all major failure events. It is important to know which line or unit outages will render line flows or voltages to cross the limit. To find the effects of outages, contingency analysis techniques are employed. Contingency analysis employ single failure event or multiple failure events one after another until all "credible outages" are considered. For each outage, all lines flows and bus voltages in the network are checked against their respective limits. This technique used for contingency analysis is line outages from the system one by one. After cascading outage of lines 30 the effect studied in the line number 27 and 29 and the change in the voltage level and stability is improved by the reactive compensation technique.

7. RESULTS AND DISCUSSION:-

In Table 7.1 Line No-3 without contingency under reactive compensation have shown that with the reactive compensation the value of voltage is increased to 0.8071p.u and losses are also reduced to 25.57 MW, therefore all the parameters have shown the improvement in the system. similar explanation can be done in Table 7.2- Table 7.6. In zone -1and zone-2, when we compare two lines with each other, i.e line no-4 and line no-26 from two zones proves to be best for the power transfer. And in Table-7.5- Table-7.6 after outage of line no 30 the line no 27 proves to be best for power transfer.

CriticallineforZone-1(without Contingency)		
Parameters	Without reactive compensation at	With reactive compensation at
	Line No. 3	Line No. 3
$\sum L^2$	0.0114	0.0329
V_{min} (p.u.)	0.6362	0.8071
P-Loss (MW)	71.94	25.57
MSV	1.0485	1.8612
Selected Line		x

Table-7.2 Line No-4 without contingency under reactive compensation

Critical line for Zone-1(without contingency)		
Parameters	Without reactive compensation at	With reactive compensation at
	Line No. 4	Line No. 4
$\sum L^2$	0.0171	0.0428
V_{min} (p.u.)	0.8501	0.9070
P-Loss (MW)	71.94	13.04
MSV	1.0485	6.8713
Selected Line		√

Table-7.3 in Zone-2:- Line No-18 without Contingency with Reactive Compensation:-

Critical line for Zone-2(without contingency)		
Parameters	Without reactive compensation at	With reactive compensation at
	Line No. 18	Line No. 18
$\sum L^2$	6.4317	4.8677
V_{min} (p.u.)	0.9083	0.9086
P-Loss (MW)	71.94	13.01
MSV	1.0485	7. 1879
Selected Line		x

Table-7.4 Line No-26 without Contingency under Reactive Power Compensation

Critical-lines-for-Zone-2(without contingency)		
Parameters	Without reactive compensation at	With reactive compensation at
	Line No. 26	Line No. 26
$\sum L^2$	0.1687	0.3399
V_{min} (p.u.)	0.8897	0.9059
P-Loss (MW)	71.94	12.88
MSV	1.0485	9.4945
Selected Line		√

TABLE-7.6:- Results for line no-29 with contingency after the outage of line no-30.

Critical lines for Zone-1(with contingency)		
Parameters	Without reactive compensation at	With reactive compensation at
	Line No. 29	Line No. 29
$\sum L^2$	0.0021	0.0242
Vmin (p.u.)	0.9117	0.9421
P-Loss (MW)	12.88	12.05
MSV	9.4945	1.2191
Selected Line		x

TABLE-7.5:- Results for line no-29 with contingency after the outage of line no-30.

Critical lines for Zone-1(with contingency)		
Parameters	Without reactive compensation at	With reactive compensation at
	Line No. 27	Line No. 27
$\sum L^2$	0.0059	0.3455
Vmin (p.u.)	0.9337	0.9517
P-Loss (MW)	12.88	12.05
MSV	9.4945	1.2191
Selected Line		√

8. Conclusion:-

- In this paper of power transfer capability improvement in an interconnected power system without and with contingency, a 30-bus system has been studied. which is divided into two zones and the critical lines have been identified and these critical lines have been studied with and without contingency under reactive power compensation technique and results shows that in zone-1 the line no -4 proves to be best with all the system parameters improvement. And in zone -2 the line no -26 proves to be best with all the system parameters improved. With contingency the line-no 27 proves to be best after outing of line no 30. Therefore the results for both the zones and also with contingency have shown an improvement in the system stability and power transfer capability.

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