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Assessment of Voltage Stability in a Power system Network and its Improvement along with Impact of line Susceptance

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Abstract - *In this paper a method for improving voltage stability by compensating losses has been discussed based on the consideration of tap changing transformer and half line charging in the transmission lines. Variation of Reactive power with respect to voltage has been proposed to find out the weakest bus of the system. Active and reactive power loss of each line is found out. Considering tap changing transformer and half line charging in the transmission lines the active & reactive power loss and hence the voltage stability is to be improved. P-V curve has been plotted for each condition and also voltage collapse point has been observed. The proposed method has been implemented on a 6-bus 8-line system & shows its effectiveness for different methods.*

***Key Words*: Voltage Stability, [∂V/∂Q] index, Voltage Collapse Point, Line Loss, Tap Changing Transformer.**

1. INTRODUCTION

It is now impossible to think our daily-life without electricity and economic growth of a country also depends on it. India ranks among the top producer and consumer of electricity due to large population density. In such condition security must be taken for big outages as there was a major electricity collapsed in 21 Indian states on 30th and 31st July, 2012 [1]. Now a days due to the increasing demand, the existing power system transmission lines cannot meet the required loading thereby voltage instability occurs. Generally, voltage stability refers to the ability of a system to remain in stable operating condition i.e., maintaining acceptable voltage at all the network busses at fault as well as under normal condition. Voltage security of a system can be determined by the voltage stability analysis which also helps to find the stability limit for a network subjected to a fault or increase of reactive power demand [2]. Power flow analysis plays a vital role in power system analysis for operation, future planning, scheduling and power exchanging. It mainly evaluates bus voltage, phase angle of voltage, real and reactive power flowing through transmission lines considering two bus network interconnected system. It follows a numerical analysis which is iterative in nature and has lots of mathematical steps [6].

Due to the ever-increasing power demand, the electrical network expanding and therefore stability limits must be increased for a developing country like India as a stable power system network ensures profitability. Systems blackout takes place if the voltage level of network bus falls below rated voltage and remain in unstable region. Hence accessing power losses minimization, operation and planning, studying and improving voltage stability is very crucial [1]. Offline system planning and online stability monitoring tool can be utilized for the protection of voltage collapse in power system. There are different methods and so many stability indices for the analysis of voltage stability limit. L-index, VSI, Jacobian matrix singularity indices, power flow solution pairs, P-V and Q-V curve-based indices are some of the well-known methods discussed [3-4]. Also, different types of soft computing techniques are used for voltage stability analysis which has their own advantages and disadvantages [5,7,12]. voltage stability margin (VSM) method and the reactive power-voltage (QV) and real power-voltage (PV) model analysis can be used for the voltage stability analysis in large power system network [13-16].

Although Per unit system and single line diagram gives easy and simplified understandings but the calculation time increases with increasing network size. MATLAB programming based short time evaluation has developed for all the commonly used load flow analysis methods, viz., Gauss-Seidel method, Newton-Raphson method and fast Decoupled method [6]. A power system is said to be stable when it holds steady state values after a disturbance. The operating condition needs to be within the stability limit all the time of operation even be secure at the event of a fault. Voltage instability results to uncontrollable decline of voltage magnitudes in Q-V and P-V curve and leads to voltage collapse [8]. The newton Raphson method plays an important role in power flow analysis having the advantages of fast calculations and fast converging ability. Although it lacks in occupying large memory but using storage devices, this problem can be ignored. With this solution newton Raphson method becomes the most practical technique comparing with other load flow analysis techniques [6]. In so many stability improvement techniques, Power transformer with on load tap changers is used for automatic operation of voltage stability and the tap changing makes into the effect of voltage dependence with respect to load of the network [11].

In this paper, stability analysis is carried out on an IEEE 6-bus 8-line transmission network [8]. Initially the active and reactive power line losses are calculated using load flow analysis method and observe the lines which bear more losses. The weakest bus of the network has been identified by [∂V/∂Q] indicator from the Jacobian matrix of Newton-Rapson method. Thereafter, the lines having more active and reactive losses are connected with an on-load tap changing transformer so that the line losses decrease and the weakest bus voltage increases which has been investigated by the P-V curve and improves power system stability.

2. TAP CHANGING TRANSFORMER

The real time operating point of a system and how far it is from the stability limit is very important to know for power system operators. The system security and feasibility must be assessed by the operator for uninterrupted operation of the network following a fault or load change [11]. Voltage instability problem can be corrected by tap changing transformer. It is one of the best ways to deal with the instability or insecurity problems in a power system network. Off load tap changing and on load tap changing are the general ways in this type of mitigation [10]. The tap changing transformer gives a constant secondary voltage. In case of large voltage error, the tap changer with a time delay is operated for the restoration of load [11]

Power transformers equipped with On-Load Tap-Changers (OLTCs) have been main components of electrical networks and industrial application for nearly 80 years. The OLTC allows voltage regulation and/or phase shifting by varying the transformer ratio under load without interruption [17].

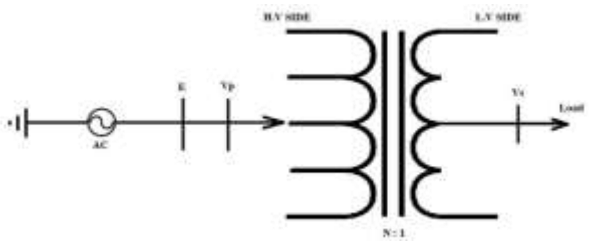

Fig 1. Tap Changing Transformer [10].

Tap changing transformers are used without interrupting the supply of the system. Transformer plays an important role of managing the active & reactive power flow by controlling phase angle and voltage respectively [18]. On-Load Tap-changers (OLTCS) are one of the indispensable components for the regulation of power transformers used in electrical energy networks and industrial application.

3. ROLE OF REACTIVE POWER

In view of reliability, the role of reactive power differentiates active power in three major ways. They are, first, as the bus voltage is sensitive to reactive power and losses of reactive power over long transmission lines is more, transferring reactive power for long distance is not economical. Therefore, compensation of reactive power comes to affect in weakly regions. Second, maintaining voltage stability and voltage security of a network depends on reactive power and finally, operating conditions and system configuration plays a vital role on reactive power losses [9].

4. SIMULATION

A 6- bus, 8-line transmission network has been taken for test pursues. It has 1 slack bus, 1 generator bus and 4 load bus.

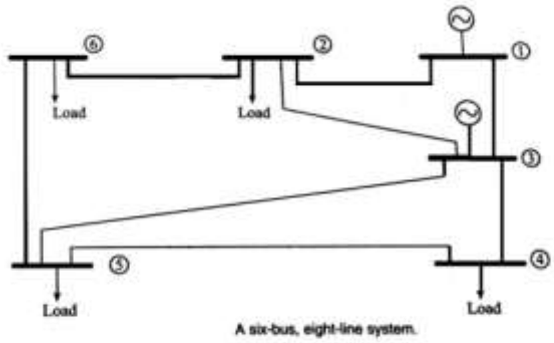

Fig 2. 6 bus 8-line transmission network.

To obtain the load flow solution of the 6-bus system we have developed a MATLAB program using N-R method of load flow solution. The result of this load flow solution is given bellow.

Voltage Magnitude	Voltage Angle	Active Power	Reactive Power
1.0400	0	0.7502	0.3634
0.9555	-0.2033	-1.0000	-0.1001
1.0060	-0.0678	1.5000	0.7502
0.9275	-0.1646	-0.4500	-0.2499
0.9270	-0.1734	-0.4000	-0.2499
0.9251	-0.2407	-0.3500	-0.1001

Fig 3. New estimated voltage, angle, Active and Reactive power

Weakest Bus:

The weakest bus is the bus in which the variation of voltage with respect to reactive component is highest. So, it is required to find the highest value of [∂V/∂Q] from J4 elements in the Jacobian matrix.

To find out the weakest bus in the system under study, the Jacobian matrix (J) of this system is obtained by the load flow analysis method. From the diagonal elements of the J4, the values of [∂Q/∂V] for the load buses are obtained.

Taking the inverse of [∂Q/∂V] the values of [∂V/∂Q] has been calculated for the load busses of the system.

Table - 1: J4 Elements

11.733	-4.7742	-4.7742	-4.7742	-4.7742
0	18.6336	0	0	0
0	0	10.1349	0	0
-3.0046	-3.0046	-3.0046	13.1015	-3.0046
-2.9185	-2.9185	-2.9185	-2.9185	**7.4825**

From the above table it is observed that the value of ∂V/∂Q is higher in the 6[TH] bus (0.1336451721) i.e., bus 6 is the weakest bus. If we increase the load to that bus then after a certain point the system will collapse.

Line loss:

The main objective is to analyze the voltage stability of multi-bus power network. So, it is required to first calculate the losses. For this, the line flow solution of the system from which system losses can be estimated. The line losses corresponding to each line in both directions are given in the fig 4.

LINE From Bus	To Bus	P(ij)	Q(ij)	LINE From Bus	To Bus	P(ij)	Q(ij)
1.0000	3.0000	24.8685	9.2617	3.0000	1.0000	-24.6081	-7.3084
2.0000	3.0000	-66.3758	-9.7779	3.0000	2.0000	67.8549	19.6385
3.0000	4.0000	51.3552	31.4384	4.0000	3.0000	-49.9223	-24.2737
3.0000	5.0000	55.3994	31.2475	5.0000	3.0000	-53.8006	-23.2532
4.0000	5.0000	4.9252	-0.7139	5.0000	4.0000	-4.9165	0.7570
5.0000	6.0000	18.7193	-2.4988	6.0000	5.0000	-18.4703	3.7438
1.0000	2.0000	50.1541	27.0830	2.0000	1.0000	-50.1541	-15.0678
2.0000	6.0000	16.5320	14.8316	6.0000	2.0000	-16.5320	-13.7510

Fig 4. Line loss.

The total Active and Reactive power losses can be calculated by simply adding the line power flows in both direction considering 2-bus system and are given table below.

Table - 2: Active & Reactive power loss for corresponding 8-lines

Active Power Loss (Pl)	Reactive Power Loss (Ql)
0.2604	1.9533
1.4791	9.8606
1.4330	7.1648
1.5989	7.9943
0.0086	0.0432
0.2490	1.2450
0	12.0152
0	1.0806

So, from the above table we can identify that the loss in the 4[th] (active loss) & 7[TH] (reactive loss) line is more than that of others. Now we have tried to compensate the loss by connecting a Transformer (a=0.8) in line 7. Although line susceptance is a transmission parameter, we have taken susceptance for furthermore decrease in losses along with tap-changing transformer. It has been considered that the half line charging of (B/2=0.02) in line 4 and 7.

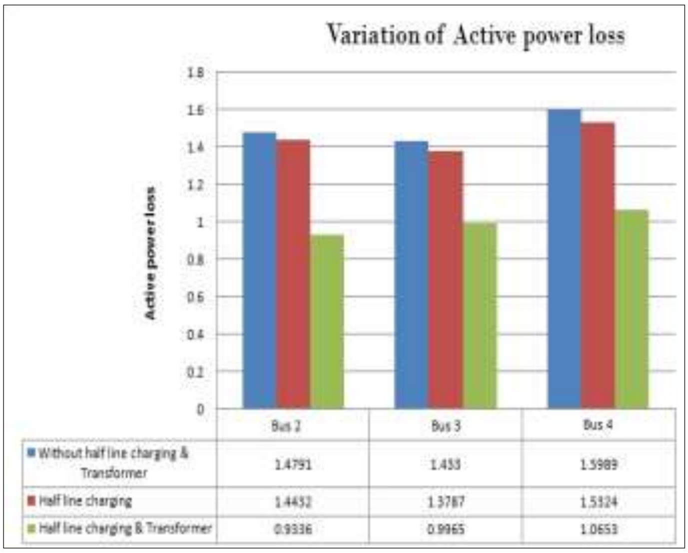

Fig 5. Graphical Representation of Variation of Active Power Loss with Half line charging & Transformer

The active power line loss variation with half line charging and Transformer is shown fig 5. For the bus no 2,3 & 4. It can be seen that the loss is less with half line charging and become more lesser considering both the half line and transformer in the line.

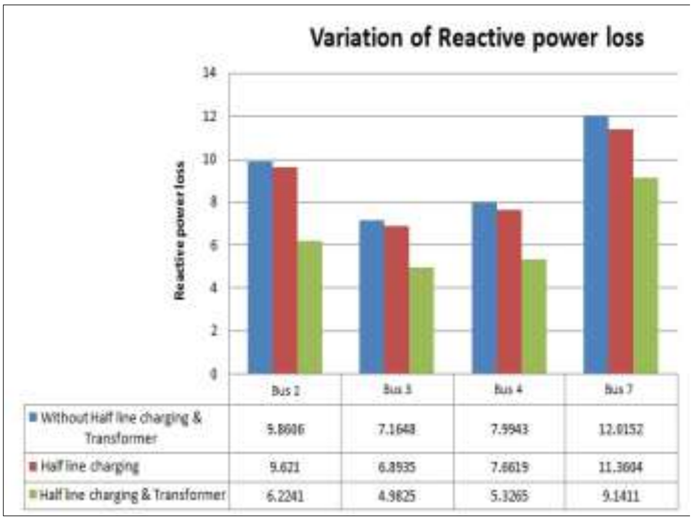

Fig 6. Graphical Representation of Variation of Reactive Power Loss with Half line charging & Transformer

The reactive power line loss variation with half line charging and Transformer is shown fig 5. for the bus no 2,3,4 & 7. After considering the half line changing & Transformer in the line, we have seen that the line loss is reduced and the variation is plotted graphically.

Total Losses:

Here first we calculate the total losses without transformer and half line charging using load flow analysis method. Then it is required for compensate the losses. So initially the half line charging has been considered in required lines for reducing losses and for further compensation we connect a transformer in line. Total losses of the network are shown in Table III below and also plotted in graph.

Table - 3: Total losses for different operation configuration

Configuration	Total Ploss	Total Qloss
Without half line charging & Transformer	5.029	41.357
Half line charging	4.84	39.44
Half line charging & Transformer	3.71	31.8

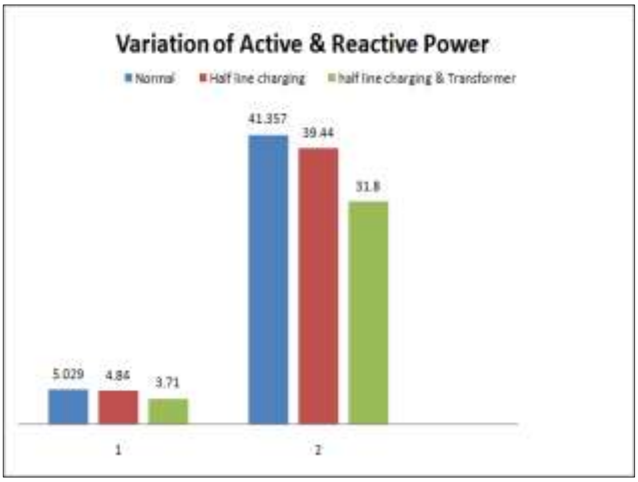

Fig 7. Graphical Representation of Variation of total Active & Reactive power losses of the network with considering Half line charging & Transformer.

So, from the Table III & fig 7. it can be seen that the loss is compensated by considering half line charging and connecting tap changing transformer in the line. And thus, the total losses are reduced and the system become stable.

To find out the voltage collapse point, the active power (P) of the weakest bus is increased in step keeping Reactive Power(Q) constant and the corresponding value of V for each step is obtained by load flow analysis method, from which a P-V curve is plotted which is shown in the fig 8.

Here in the P-V curve three conditions/configurations has been taken as follows:

- Without half line charging & Transformer i.e. when B/2=0, T=1, we found that here the breaking point is 0.98. Beyond this value, the voltage collapsed.
- By considering half line changing (B/2=0.02) at line 4 and 7 we found that here the breaking point is 0.99. And beyond this value, the voltage collapsed again.
- Again, by adding transformer (a=0.8) at line 7 we found that the breaking point is 1.5 and if the value is increased the voltage will get collapsed.

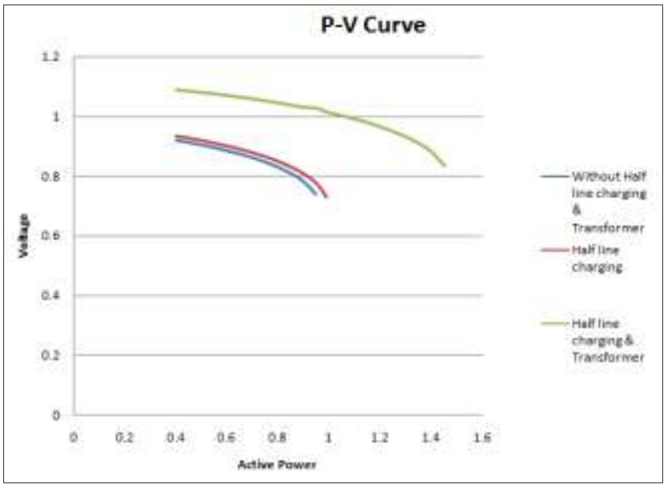

Fig 8. P-V curve considering different configuration.

So, from the P-V curve shown in fig 8. we observed that the voltage is improved by adding half line changing and it becomes more improved by adding the transformer in the line. Also, the voltage collapse point gets improved and hence the voltage stability.

5. CONCLUSION

The target is to improve the voltage stability of a network. So, we calculate the active and reactive power losses of the system. We observed that the losses are quite high in some of the lines and by the power system analysis we know that the losses of the system reduce the voltage stability and voltage may become collapsed. So, to improve the voltage stability, it is required to compensate the losses and we have implemented it in this project. So, we have calculated the line losses of system network by using load flow analysis method and by [$\partial V/\partial Q$] indicator we obtain the weakest bus of our 6-bus 8-line system. Now to minimize the losses we have considered tap changing transformer & half line charging to the lines which contain more losses. And we plot the variation of voltage & collapse point in the P-V curve for each condition or configuration. From there the losses are being compensated & improving voltage collapse point and thus improvement of voltage stability of the system network.

REFERENCES

[1] Mitali Chakravorty, Mrinalini Das and Sarmila Patra, "Importance of Load Flow Analysis in Voltage Stability Studies" Proceedings of 30th Indian Engineering Congress, the 21st Century Engineering: The Make in India Pathway, pp. 45-50, 2015.

[2] Gagari Deb, Kabir Chakraborty and Sumita Deb, "Voltage Stability Analysis using Reactive Power Loading as 1ndicator and 1ts 1mprovement by FACTS Device" 1st IEEE International Conference on Power Electronics. Intelligent Control and Energy Systems (ICPEICES-2016), pp. 1-5, 2016.

[3] Yunfei Wang, Iraj Rahimi Pordanjani, Weixing Li, Wilsun Xu, Tongwen Chen, Ebrahim Vaahedi, Jim Gurney, "Voltage stability Monitoring Based on the Concept of Coupled Single-Port Circuit", IEEE Transections on power systems, vol. 26, no. 4, pp. 2154-2163, 2011.

[4] Yang Wang, Caisheng Wang, Feng Lin, Wenyuan Li, Le Yi Wang and Junhui Zhao, "Incorporating Generator Equivalent Model into Voltage Stability Analysis", IEEE Transactions on Power Systems, vol. 28. No. 4. pp. 4857-4866, 2013.

[5] Kabir Chakraborty, Abhinandan De, Abhijit Chakraborty, "Voltage stability assessment in Power network using self organizing feature map and radial basis function", Computers and Electrical Engineering, vol.38. pp. 819-826, 2012.

[6] Lalit Kumar Gautam, Mugdha Mishra, Tanuj Bisht, "A Methodology for Power Flow & Voltage Stability Analysis" International Research Journal of Engineering and Technology, vol. 02, pp. 321-326, 2015.

[7] Scott G. Ghiocel and Joe H. Chow, "A Power Flow Method Using a New Bus Type for Computing Steady-State Voltage Stability Margins", IEEE Transactions on Power Systems, vol. 29, no. 2, pp. 958-965, 2014.

[8] Sita Singh, Jitendra Hanumant, Ashutosh Kashiv, "Application of SVC on IEEE 6 Bus System for Optimization of Voltage Stability", Indonesian Journal of Electrical Engineering and Informatics, vol. 3, pp. 1-6, 2015.

[9] Wenping Qin, Peng Wang, Xiaoqing Han, and Xinhui Du, "Reactive Power Aspects in Reliability Assessment of Power Systems", IEEE Transaction on Power system, vol. 26, pp. 85-92, 2011.

[10]V.S. Vakula, Chetlapalli sai Praveen, Niddan Rames, "Automatic control of On Load Tap Changing of Transformers for Enhancement of Voltage Stability", IJEDR, vol. 5, 2017.

[11]Mahmood Reza Shakarami, Reza Sedaghati, "A Study on Integrated Performance of Tap-Changing Transformer and SVC in Association with Power System Voltage Stability", International Journal of Electrical and Computer Engineering, vol. 8. No. 7. 2014.

[12] K. Kawabe and K. Tanaka, "Analytical Method for Short-Term Voltage stability Using the Stability Boundary in the P-V plane", IEEE Transections on

Power systems, vol. 29, No. 6, pp. 3041-3047,2014.

[13] Bhawana Telang, Prabodh Khampariya, "Voltage Stability Evaluation Using Modal Analysis", International Journal of Scientific Research Engineering & Technology, vol. 4, pp. 408-411, 2015.

[14] Enemuoh F. O., Onuegbu J. C. and Anazia E. A., "Model based analysis and evaluation of Voltage Stability of Bulk Power system", International Journal of Engineering Research and Development, vol. 6, pp. 71-79, 2013.

[15] M. Amroune, A. Bourzami, T. Bouktir, "Weakest Buses Identification and Ranking in Large Power Transmission Network by Optimal Location of Reactive Power Supports", TELKOMNIKA Indonesian Journal of Electrical Engineering, vol. 12, no. 10, pp. 7123-7130, 2014.

[16] Chandrabhan sharma and Marcus G. Ganness, "Determination of the applicability of Using Model Analysis for the Prediction of Voltage Stability", IEEE/PES Transmission and Distribution Conference and Exposition, Chicago, IL, USA, 2008.

[17] Dieter Dohnal, "On load tap changers for power transformers", A technical digest: M.R Publication, 2013

[18] T.K.Nagsarkar, M.S.Sukija, 'Power System Analysis',Oxford Higher Education, Seventh Impression,2012.

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