ISSN (Print) : 2320 – 3765
ISSN (Online): 2278 – 8875

International Journal of Advanced Research in Electrical, Electronics and Instrumentation Engineering

(An ISO 3297: 2007 Certified Organization)

Vol. 5, Issue 7, July 2016

Identification of Critical Transmission Line for Voltage Collapse Using Deterministic Indices in Ieee-14 Bus System

Rachana Choudhary[1], Jitendra Singh Bhadoriya[2] , Gaurav Gangil[3]

M. Tech Research Scholar, Dept. of Electrical Engineering Sobhasaria Engineering College, Sikar, Rajasthan, India[1]

Assistant Professor, Dept. of Electrical Engineering Sobhasaria Engineering College, Sikar, Rajasthan, India[2 & 3]

ABSTRACT: In power system transmission lines play an important role for maintaining the reliability & continuity of supply. Due to some critical condition like overloaded voltage, thermal heating it causes heavy power loss which creates the condition of line outage. Voltage collapse occur in the overloaded or overheated transmission lines. We have Introduced several deterministic indices to know the present status of transmission lines, so that protective operation could be performed before actually voltage collapse occur in power system network. We have calculated indices for IEEE-14 Bus system using line data and bus data. The results based on indices show the critical transmission line & critical bus on which we have to make proper operation for the smooth functioning of power system network.

KEYWORDS: LSI (Line Stability Index), FVSI (First Voltage Stability Index), VSF (Voltage Sensitivity Factor), NVSI (New Voltage Stability Index)

NOMENCLATURE: -

R	Line Resistance
X	Line Impedance
P	Active Power
Q	Reactive Power
Vs	Sending end Voltage
Vr	Receiving end Voltage
δ	Angle Difference Between Supply voltage and Receiving end Voltage
δr	Receiving end Voltage
δs	Sending end Voltage
θ	Line Impedance Angle
Qr	Receiving end power
Xr	Receivind end impedence
Pi	Active power of Bus i
Qi	Reactive Power of i
Vi	Voltage of bus i
Qj	Reactive power of bus j

ISSN (Print) : 2320 – 3765
ISSN (Online): 2278 – 8875

International Journal of Advanced Research in Electrical, Electronics and Instrumentation Engineering

(An ISO 3297: 2007 Certified Organization)

Vol. 5, Issue 7, July 2016

I. INTRODUCTION

In recent years, lack of new generation and with the increased loading of transmission and distribution lines, transmission networks have forced power transmission and distribution systems to operate closer to their security limits. Voltage instability problem has become a concern and serious issue for power system planners and operators. The main challenge of this problem is to narrow down the locations where voltage instability could be initiated and to understand the origin of the problem. As a result some voltage stability indices have been proposed to identify weak nodes for protective measures, which helps proper placement of reactive power compensator and distributed generators for enhancement of system stability.
One effective way to narrow down the workspace is to identify weak buses in the systems, which are most likely to face voltage collapse. Voltage instability or collapse is believed to be a local load bus problem, which can cause trouble to the entire system and depends mostly on load conditions in the system [1].
Load modeling for power system stability studies has always been a challenge for a number of reasons. The actual load below sub-transmission level consists of large varieties of components like thermostatic loads, resistive and inductive loads, induction motors, and lighting loads. Furthermore, number and type of loads varies continuously through time as different load components are switched on or off in response to residential, commercial and industrial activities. This statistical nature of load makes it very difficult to establish a load model that is generically applicable for power system studies [2]. To correctly analyze the voltage stability of a power system, suitable dynamic models are usually required based on nonlinear differential and algebraic equations.
However, in many cases, static analysis tools can be used to identify influencing factors for long term voltage stability [3].
The reactive power at a particular bus is increased until it reaches the instability point. At the instability point, the connected load at the particular bus is determined as the maximum lodability. The maximum loadability for each load bus will be sorted in ascending order with the smallest value being ranked highest.
The highest rank implies the weak bus in the system that has the lowest sustainable load. This technique is tested on the IEEE test system and results show that it is able to estimate the maximum load ability in a system. As most nodes are not voltage controlled, proper load modeling is more important in a distribution system than in a transmission system [4]
The critical line means the line which is close to its voltage stability limit. Maximum load ability depends on the solvability margin of load flow when the Jacobian matrix becomes singular.

II. THE WEAKEST BUS

With the increased loading of transmission and distribution lines, voltage instability problem has become a concern and serious issue for power system planners and operators. The main challenge of this problem is to narrow down the locations where voltage instability could be initiated and to understand the origin of the problem. One effective way to narrow down the workspace is to identify weak buses in the systems, which are most likely to face voltage collapse. The weakest bus has been identified as the bus, which lacks reactive power support the most to defend against voltage collapse. Network configuration, R/X ratio of interconnections, load models, load directions, presence of generators and compensators are most influential factors of the strength of a bus in a distribution system. In turn, identifying weak buses can give correct information for the optimal reactive power planning involved that would decide which buses are the most severe and need to have new reactive power sources installed [5]. Ranking of bus based on strength has also been found useful in determining location for distributed generator to enhance loadability of the system [6]. Different voltage stability indices have been developed to determine the strength of load buses in a system, which has been explained in brief in the next section.

III. METHODS ARE USED TO FIND SENSITIVE NODE

There are several methods are given for finding voltage sensitivity in different bus network applied at different situations. Description of these methods are following:
i). Line Stability Index Formulation (LSIF).
ii). Fast voltage stability index (FVSI)
iii). Voltage Sensitivity Factor (VSF).

ISSN (Print) : 2320 – 3765
ISSN (Online): 2278 – 8875

International Journal of Advanced Research in Electrical, Electronics and Instrumentation Engineering

(An ISO 3297: 2007 Certified Organization)

Vol. 5, Issue 7, July 2016

iv). L-Index:
v). New Voltage Stability Index (NVSI).

1).Line Stability Index Formulation

Based on the transmission concept in a single line M. Moghavvemi's derived a line stability index to find the voltage of an interconnected system in a reduced single line network, in this formulation the discriminator of the voltage quadratic equation is set to be greater or equal than zero to maintain stability. A typical single transmission line where index is derived from is illustrated in Fig. 1:

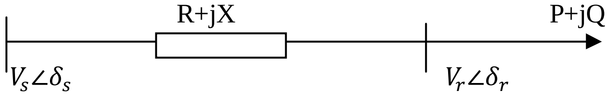

Fig 1Transmission Line

Fig.1.Single line diagram of a transmission line in the power system Where, $V_s\angle\delta_s$, $V_r\angle\delta_r$ are the sending end and receiving end voltages. R+jX is the impedance of the transmission line P+jQ is the receiving end apparent power θ is the line impedance angle δ is the angle difference between the supply voltage and the receiving end voltage. The line stability index is expressed by L_{mn}, proposed by Moghavvemi and Omar (1998) is formulated based on a power transmission concept in a single line. The line stability index Lmn is given by [1]

$$L_{mn} = \frac{4XQ}{[V_s \sin(\theta-\delta)]^2} \quad (1)$$

When the stability index Lmn is less than 1, the system is stable and when this index exceeds the value 1, the entire system loses its stability and voltage collapse occurs. Hence the value of Lmn must be lower than 1 to maintain a stable system. [1]

2).Fast Voltage Stability Index (FVSI):

It is calculated using reactive power flow as,

$$FVSI = \frac{4Z^2Q_r}{V_s^2X_r} \quad (2)$$

The value of evaluated index close to 1 indicates that the particular line is near to instability point. The critical bus is determined by finding out the maximum permissible load on the bus. The most critical bus in the system is the bus which can bear smallest maximum load. [7]

3).Voltage Sensitivity Factor:

Voltage Sensitivity Factor Based on general concept, SF(sensitivity factor) index for a system represented by F(z,λ) can be defined as $SF = \left\|\frac{dz}{d\lambda}\right\|$ when SF becomes large, the system turns insecure and ultimately collapses. Here the system voltages are checked with respect to the change in loading, which results in a Voltage sensitivity factor (VSF) calculated as VSF= $\left\|\frac{dv}{dp}\right\|$ High sensitivity means even small changes in loading causes large changes in the voltage magnitude, which indicates the weakness of a bus. [8].

4). Line Stability Factor (LQP):

The LQP was used in the comparison since this factor is more sensitive to change in reactive power. The formulation begins with the power equation in a power system and finally LQP [3] is expressed as

$$LQP = 4\left(\frac{X}{V_i^2}\right)\left(\frac{X}{V_i^2}P_i^2 + Q_i\right) \quad (3)$$

All the above said indices have effectively shown the variation of reactive power load but not real power load. Most of these indices have been derived from the receiving end reactive power equation of transmission line. Instead of that, the index solved by considering the receiving end real power equation, it depends the resistance of the transmission line.

ISSN (Print) : 2320 – 3765
ISSN (Online): 2278 – 8875

International Journal of Advanced Research in Electrical, Electronics and Instrumentation Engineering

(An ISO 3297: 2007 Certified Organization)

Vol. 5, Issue 7, July 2016

However, the resistance values are negligible or even zero in standard and practical line data, and hence the index remains either infinite or zero. [9].

5).New Voltage Stability Index (NVSI)
NVSI may be mathematically explained as follows:

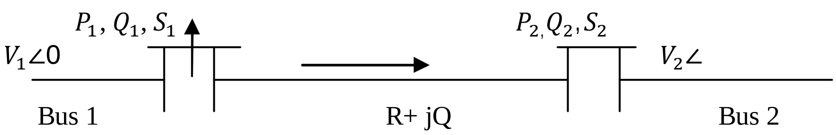

Fig 2 Line Mode

From the Fig. 2, current flowing between bus 1 and 2,
Comparatively resistance of transmission line is negligible. The equation may be rewritten a and the receiving end power, S=V2I* Incorporating and solving this is an equation of order two of V2. The condition to have at least one solution is: Taking the suffix "i" as the sending bus & "j" as the receiving bus, NVSI can be defined by

$$NVSI_{ij} = \frac{2X\sqrt{P_i^2+Q_j^2}}{2Q_jX-V_i} \qquad (4)$$

The procedure to estimate the NVSI in all transmission lines in power system is shown in Fig. 2. The value of NVSI must be less than 1.00 in all transmission lines to maintain a stable system.
The merits of the index are that it relates both real and reactive power whereas other indices relate only the reactive power of the system. Moreover usage of fuzzy logic method produces more accurate and exact results. The number of mappings is reduced from 7 to 3 outperforming the existing methods.

IV. RESULTS & DISCUSSION

We have taken the standard data of IEEE-14 Bus system for evaluating the values of several indices. In Table 1. The Bus corresponding to the critical transmission lines are given. since over voltage on transmission line will create transient instability during power flow through Load

Table 1

S.No.	Name of Sensitive Method	Indices Used	Weakest Bus	Critical Transmission line
1	Line Stability Index Formulation	$L_{mn} = \frac{4XQ}{[V_s \sin(\theta - \delta)]^2}$	Bus no. 7 & 9	Line no.15
2	Fast Voltage Stability Index(FVSI)	$FVSI = \frac{4Z^2Q_r}{V_s{}^2X_r}$	Bus no. 5	Line no. 2
3	Voltage Sensitivity Factor	$VSF = \left\|\frac{dv}{dp}\right\|$	Bus no. 4 ,5 & 7	Line no. 2,7,&8
4	Line Stability Factor(LSP)	$LQP = 4\left(\frac{X}{V_i{}^2}\right)\left(\frac{X}{V_i{}^2}P_i{}^2 + Q_i\right)$	Bus no. 4 & 9	Line no. 9
5	New Voltage Stability Index(NVSI)	$NVSI_{ij} = \frac{2X\sqrt{P_i{}^2 + Q_j{}^2}}{2Q_jX - V_i}$	Bus no. 4 &9	Line no.15

As already stated different values of indices indicate the healthy condition of transmission line during power flow. Different set of values are given in Table no. 2

ISSN (Print) : 2320 – 3765
ISSN (Online): 2278 – 8875

International Journal of Advanced Research in Electrical, Electronics and Instrumentation Engineering

(An ISO 3297: 2007 Certified Organization)

Vol. 5, Issue 7, July 2016

Table-2

Line No	Lmn	FVSI = 1.0e-003 *	VSI =	LSF =	NVSI =
1	0.0965	0.0311	0.0004	9.9769	0.1178
2	0.6660	0.8042	Infinite	37.6078	0.6908
3	0.0778	0.0506	0.0001	33.3806	0.6345
4	0.4882	0.3706	0.0000	29.7301	0.5448
5	0.8270	0.2429	0.0009	29.3187	0.5333
6	0.3675	0.3581	0.0007	28.8382	0.4261
7	0.0211	0.0041	Infinite	7.1004	0.0920
8	0.3894	0.2552	Infinite	35.2607	0.5190
9	0.1319	0.3187	0.0002	93.7801	24.2423
10	0.2425	0.2718	0.0008	42.4942	0.8356
11	0.1679	0.2042	0.0021	33.5374	0.6606
12	0.0552	0.0911	0.0012	43.1333	1.0476
13	0.0961	0.0820	0.0005	21.9654	0.3523
14	0.5011	0.3527	0.0005	29.7015	0.5439
15	1.0276	0.0547		18.5493	1.0000
16	0.0358	0.0122		14.2479	1.0000
17	0.0488	0.0589		45.5900	1.0000
18	0.4507	0.1386		32.3858	1.0000
19	0.0533	0.0508		33.7027	1.0000
20	0.8690	0.3612		58.6812	1.0000

Graphs between transmission line & several indices are also plotted, which shows the critical condition for dangerous transmission line & corresponding Bus in the system.

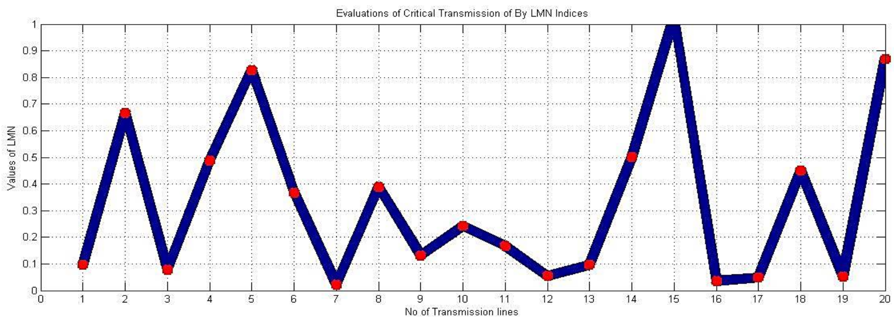

Fig.3 Evaluations of Critical Transmission Lines by LMN Indices

DOI:10.15662/IJAREEIE.2016.0507072

ISSN (Print) : 2320 – 3765
ISSN (Online): 2278 – 8875

International Journal of Advanced Research in Electrical, Electronics and Instrumentation Engineering

(An ISO 3297: 2007 Certified Organization)

Vol. 5, Issue 7, July 2016

The maximum value of LMN indices is 1 ,that will show the critical condition for transmission line and corresponding connected bus shown in figure 3. Like wise the critical values are also evaluated by FVSI ,LSF,NVSI .In case of VSI indices we will only calculate the critical Bus shown in figure no.5.

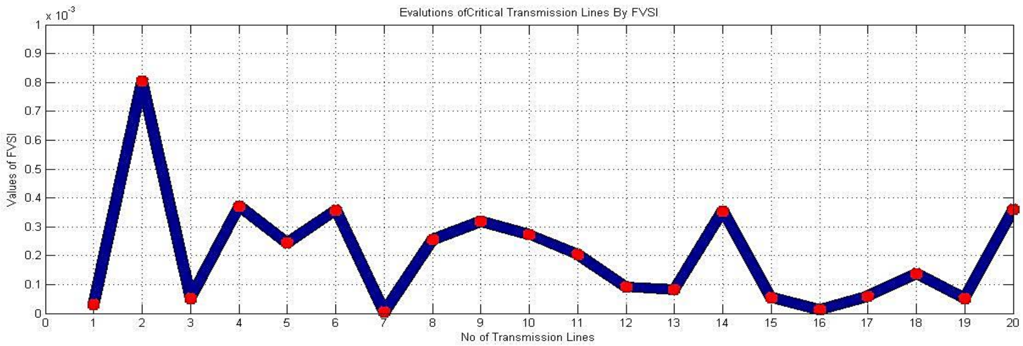

Fig.4 Evaluations of Critical Transmission Lines by FVSI Indicese

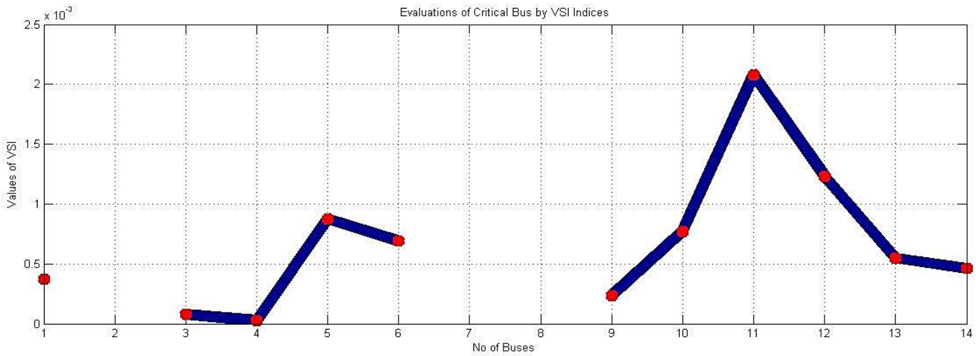

Fig.5 Evaluations of Critical Bus by VSI Indices

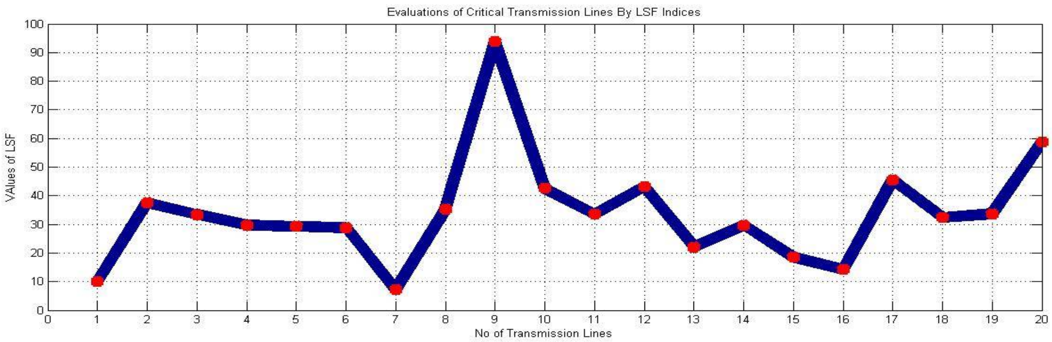

Fig.6 Evaluations of Critical Transmission Lines by LSF Indices

ISSN (Print) : 2320 – 3765
ISSN (Online): 2278 – 8875

International Journal of Advanced Research in Electrical, Electronics and Instrumentation Engineering

(An ISO 3297: 2007 Certified Organization)

Vol. 5, Issue 7, July 2016

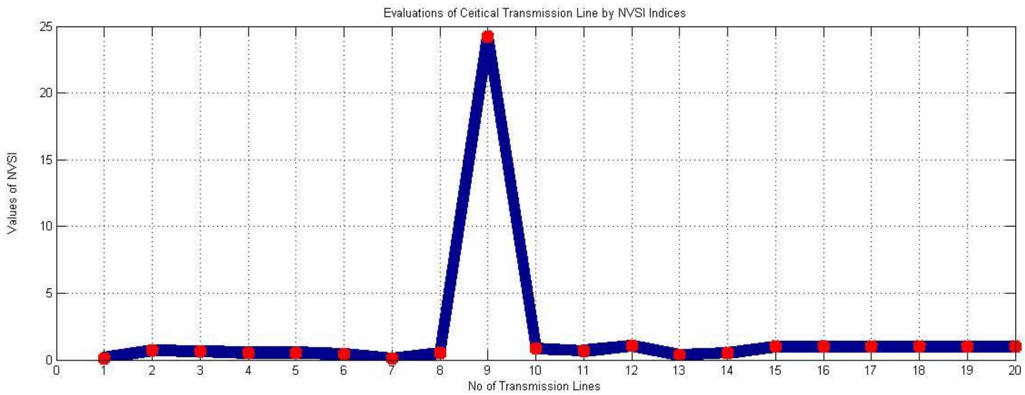

Fig.7 Evaluations of Critical Transmission Lines by NVSI Indices

V. CONCLUSION

We have successfully calculated the several deterministic indices for IEEE-14 Bus system. The critical transmission line & bus are different for different indices. Peak values of indices verses transmission lines or Bus denotes the unhealthy condition, which should be recover to maintain the reliable operation of power system network. In future We can install FACTS Devices or Distributed Generation (DG) to enhance the power transfer capability of line & smooth operation of transfer of bulk amount of power from sending end to receiving end. Since it is deterministic method, so solution will evaluated quickly as compare to stochastic method with greater accuracy & precision in small computational time.

REFERENCES

[1] V.Ajjarapu and S.Battula, "effect of load modeling on steady state voltage stability," *Electric Machines & Power Systems*, vol. 23, pp. 501 - 514, 1995.
[2] K.Morison, H Hamadani, and W. Lei, "Load Modeling for Voltage Stability Studies," in *Power Systems Conference and Exposition, 2006. PSCE '06.2006 IEEE PES*, 2006, pp. 564-568.
[3] P. Kundur, J. Paserba, V. Ajjarapu, G. Andersson, A. Bose, C. Canizares, N. Hatziargyriou, D. Hill, A. Stankovic, C. Taylor, T. Van Cutsem, and V. Vittal, "Definition and classification of power system stability IEEE/CIGRE joint task force on stability terms and definitions," *Power Systems, IEEE Transactions on*, vol. 19, pp. 1387-1401, 2004.
[4] N. Mithulananthan, M. M. A. Salama, C. A. Can˜izares and J. Reeve, "Distribution system voltage regulation and var compensation for different static load models," *International Journal of Electrical Engineering Education*, vol. 37, pp. 384-395, 2000.
[5] Y. L. Chen, "Weak bus oriented reactive power planning for system security," *Generation, Transmission and Distribution, IEE Proceedings*, vol. 143, pp. 541-545, 1996.
[6] Tareq Aziz, T. K. Saha, N. Mithulanathan, "Distributed Generators Placement for Loadability Enhancement based on Reactive Power Margin," *submitted in IPEC, 2010*. Singapore.
[7]P.R. Sharma1, Rajesh Kr.Ahuja2,Shakti Vashisth3,Vaibhav Hudda4 Department of Electrical Engineering, YMCAUST, Faridabad1, 2, 3 Department of Electrical Engineering, AKGEC, Gaziabad4 "Computation of Sensitive Node for IEEE- 14 Bus system Subjected to Load Variation "international journal of innovative research in electrical, electronics, instrumentation and control engineering vol. 2, issue 6, june 2014
[8] Tareq Aziz, Student Member, IEEE, T. K. Saha , Senior Member, IEEE and N. Mithulananthan , Member, IEEE School of Informtaion Technology and Electrical Engineering The University of Queensland, St. Lucia Brisbane, Australia E-mail address: taziz@itee.uq.edu.au"Identification of the weakest bus in a distribution system with load uncertainties using reactive power margin".
[9] Byung Ha Lee and Kwang Y. Lee, Senior Member Transactions on Power Systems, Vol. 6, No. 3, August 1991 "A STUDY ON VOLTAGE COLLAPSE MECHANISM IN ELECTRIC POWER SYSTEMS" Department of Electrical and Computer Engineering The Pennsylvania State University Park, PA 16802.
[10] H. K. Clark, "New challenges: Voltage stability " IEEE Power Engg Rev, April 1990, pp. 33-37.
[11] T. Van Cutsem: "A method to compute reactive power margins with respect to voltage collapse", IEEE Trans. On Power Systems, No. 1, 1991
[12] Ph.D thesis of Dr. C.K. Chanda on "Global voltage stability indicator index" in 2003,BESU.
[13] T.K.Abdul, G.B.Jasmon "A New Technique for Voltage Stability Analysis in a Power system & Improved Load Flow Algorithm for Distribution Network". IEEE Catalogue no 95TH8130
[14] M.Fozdar,V.R.gottipatti,C.M.Arora," Improvement of Voltage stability and Effects of Load ability"
[15] Chanda, S.; Das, B.; , "Identification of weak buses in a power network using novel voltage stability indicator in radial distribution system," *International Conference on Power Electronics (IICPE), 2010 India*, vol., no., pp.1-4, 28-30 Jan. 2011 doi: 10.1109/IICPE.2011.5728121

ISSN (Print) : 2320 – 3765
ISSN (Online): 2278 – 8875

International Journal of Advanced Research in Electrical, Electronics and Instrumentation Engineering

(An ISO 3297: 2007 Certified Organization)

Vol. 5, Issue 7, July 2016

[16] P.Kessel and H. Glavitsch "Estimating the Voltage Stability of a Power System," *Power Delivery, IEEE Transactions on*, vol. 1, pp. 346-354, 1986.
[17]. Power System Engineering, Second Edition by D.P.Kothari,I.J.Nagrath.
[18]. PUSHPENDRA MISHRA, 2H. N. UDUPA, 3PIYUSH GHUNE1Research Scholar - MIT, Indore, 2Dean Academics - MIT, Indore, 3Assistant Professor – MIT, Indore E-Mail: mishrapushpendra08@gmail.com, hnudupa@gmail.com, piyushghune@yahoo.com"CALCULATION OF SENSITIVE NODE FOR IEEE – 14 BUS SYSTEM WHEN SUBJECTED TO VARIOUS CHANGES IN LOAD"Proceedings of IRAJ International Conference, 21st July 2013, Pune, India, ISBN: 978-93-82702-22-1
[19]. Voltage Collapse Sensitivity in Power Systems F.A. Althowibi 1 ,M.W. Mustafa 2 PhD Student, Dept. of EPE, UniversitiTeknologi Malaysia, Skudai, Johor, Malaysia 1 Professor, Dept. of EPE, UniversitiTeknologi Malaysia,Skudai, Johor, Malaysia 2.
[20] Y. L. Chen, "Weak bus oriented reactive power planning for system security," *Generation, Transmission and Distribution, IEE Proceedings*, vol. 143, pp. 541-545 1996.

BIOGRAPHY

MRS. RACHANA CHOUDHARY

Mrs. Rachana Choudhary was born in Distt.Sikar(Raj) India in 1993. He received B. Tech degree (2014) from GOVT. WOMEN ENGINEERING COLLEGE, AJMER Rajasthan Techanical University (RTU) in electrical and electronics engineering, and M-Tech student (Power System) in SOBHASARIA GROUP OF INSTITUTION SIKAR, Rajasthan Techanical University (RTU) Kota (Raj) India. The research areas include Distributed Generation, Particle Swarm Optimization, and Smart Grid.

Mr. JITENDRA SINGH BHADORIYA

Mr. Jitendra Singh Bhadriya was born in Distt. Bhopal (M.P.), India, in jan. 1989. He received BE degree (2011) from Government Engineering college Bhopal in electrical engineering, and completed M-Tech (instrumentation) from SCHOOL OF INSTRUMENTATION, Devi Ahilya University (DAVV) lndore (M.P.) India in 2013 . He was visiting research scholar in NIT-Bhopal for duration 2012-2013.The research areas include Distributed Generation, voltage stability, power system protection, Particle Swarm Optimization, and Smart Grid. At the moment he is Asst. Professor in the Department of Electrical Engineering at Sobasaria Engineering college ,sikar (Rajsthan).

Mr. GAURAV GANGIL

Mr. Gaurav Gangil was born in 4th june 1987 in gwalior (mp) India. He obtained his graduation degree in electrical engineering in 2009 from REC REWA MP INDIA. He completed his M.Tech from MITS Gwalior in 2013. His research area includes power quality, voltage stablity, electrical drives and optimization techniques like GA, PSO etc. At the moment he is assistant professor in department of electrical engineering of sobhasaria engineering college sikar rajasthan.