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Voltage Stability Analysis & Compensation using GA of Radial Distribution Networks in Indian Power System

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Abstract: The electric power system consists of generation, transmission and distribution. Till recently the emphasis has been very high on generation and transmission compared to distribution. The revenue loss of electric utility industry is mainly due to distribution losses, which accounts for about 75% of total systems losses. Distribution systems are becoming large and being stretched too far, leading to higher system losses and poor voltage regulation. The modern power distribution network is constantly being faced with an ever-growing load demand. Distribution networks experience distinct change from a low to high load level every day. In certain industrial areas, it has been observed that under certain critical loading conditions, the distribution system experience voltage collapse. In this thesis a new approach for finding voltage stability of distribution systems is presented .Voltage stability index is calculated for all the nodes in the radial distribution system. The node having the minimum voltage stability index is more prone to voltage collapse.[1] That node is identified as candidate node for compensation. Fixed capacitors are installed at the candidate nodes for improvement of Voltage stability index approach.

Keywords: Distribution System, Voltage Stability, LTD, Automatic Voltage Control , GA.

I. INTRODUCTION

The analysis of a distribution system is an important area of activity, as distribution systems provide the vital link between the bulk power system and the consumers. A distribution circuit normally uses primary or main feeders and lateral distributors. A main feeder originates from the substation and passes through the major load centers. Lateral distributors connect the individual transformers at their ends. Many distribution systems used in practice have a single circuit main feeder and are defined as radial distribution systems. Radial systems are popular because of their simple design and generally low cost [2]. The I^2R loss in a distribution system is significantly high compared to that in a high-voltage transmission system. The pressure of improving the overall efficiency of power delivery has forced the power utilities to reduce the loss especially at the distribution level.

The I^2R loss in a distribution system can be reduced by network reconfiguration. The modern power distribution network is constantly being faced with an ever-growing load demand. Distribution networks experience distinct changes from low load level to high load level every day. In certain industrial areas, it has been observed that under certain critical loading conditions, the distribution system experience voltage collapse. Due to this phenomenon, system voltage collapses periodically and urgent reactive compensation needs to be supplied to avoid repeated voltage collapse.

II. EFFECT OF SHUNT CAPACITOR

Shunt capacitors supply the type of reactive power or current to counteract the out of phase component of current required by an inductive load. In sense, shunt capacitors modify the characteristic of an inductive load by drawing a leading current, which counteracts some or all of the lagging component of the inductive load current at the point of installation. Therefore a shunt capacitors has the same effect as an overexcited synchronous condenser or generator or motor. As shown in Fig (1) by the application of shunt capacitors to a feeder, the magnitude of source current can be reduced, the power factor can be improved, and consequently the voltage drop between the sending end and load is also reduced, however, shunt capacitors does not affect current or power factor beyond their point of application. Fig (1.a) and (1.b) show the simple line diagram before the addition of shunt capacitor, and Fig (1c) and (1.d) show them after the addition. Voltage drop in the feeders with lagging power factor can be approximated as

$$VD=I_R R+I_X X_L \quad (1)$$

Where
R=total resistance of feeder circuit, Ω
X_L =total inductive reactance of feeder circuit, Ω
I_R= real power (or in phase) component of current, A
I_X= reactive (or out of phase) component of current lagging the Voltage by 90 degrees, A

When a capacitor is installed at the receiving end of the line, as shown in Fig (1.2c) the resultant voltage drop can be calculated approximately as

$$VD=I^1{}_R R+I^1{}_X X_L-I_C X_L \quad (2)$$

Where I_C =reactive (or out-of phase) component of current leading the voltage by 90 degree, A calculated by using**,** the difference between the voltage drops calculated by using Eqs (1) and (2) the voltage rise due to the installation of capacitor and can be expressed as

$$VR=I_C X_L \quad (3)$$

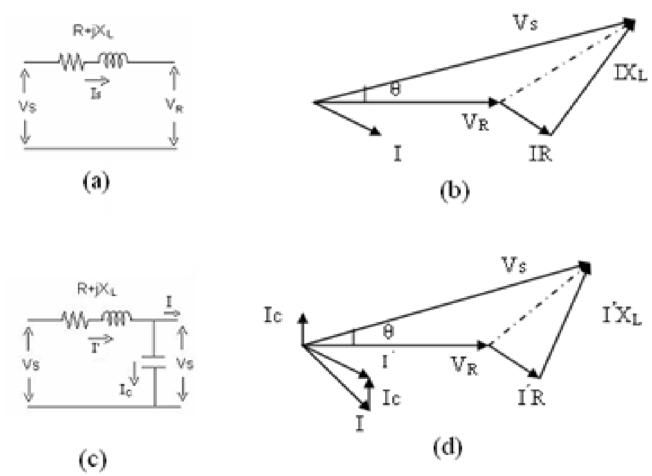

Fig.1.Voltage–phasor diagrams for a feeder circuit of lagging power factor : (a) and (b) without and (c) and (d) with shunt capacitor.[5]

III. DISTRIBUTION SYSTEM LOSSES AND VOLTAGE STABILITY

It has been established that 70% of the total system losses are occurring in the primary and secondary distribution system, while transmission and sub- transmission lines account for only 30% of the total losses. Therefore the primary and secondary distribution system must be properly planned to ensure losses within the acceptable limits.

1. Losses in distribution system: The two important indicators, for electric distribution utility performance are system losses and supply reliability. As a result of increased energy cost and the demand outstripping the availability, the improvement of system performance by reduction of losses has assumed importance.

The main factors that contribute to increase in line losses in the primary and secondary distribution systems are:

1. Feeder length
2. Inadequate size of conductors
3. Location of distribution transformers
4. Use of over rated distribution transformers
5. Low voltage
6. Low power factor
7. Load density in kW/sq.Km
8. Disposition of generating stations and major load center
9. Pattern of energy consumption viz
   a).Percentage agricultural consumption.
   b)Percentage energy consumed by bulk industries.
10. Ratio of H.T to L.T consumption
11. Power factor and load factor of loads
12. Configuration of system viz..
13. Ratio of H.T to L.T line lengths
14. Length of H.T lines per transformer
15. Length of L.T lines per transformer
16. Number of transformers

2. Feeder length:-The primary and secondary distribution lines in rural areas are radically laid and usually extended over long distances. This results in high line resistance and therefore high I^2R losses in the line. The rural loads are usually scattered and generally fed by radial feeders. The conductor size of these feeders must be adequate. The size of the conductor should be selected on the basis of km-KVA capacity of standard conductors. Therefore inadequate size of conductors also contributes to distribution system losses.

3. Location of distribution transformers- Most often the distribution transformers are not located centrally with respect to the customer. Consequently the farthest customers obtain an extremely low voltage even though a reasonable good voltage level is maintained at the transformer secondary's, this again leads to higher line losses.

4. Location of distribution transformers: Most often the distribution transformers are not located centrally with respect to the customer. Consequently the farthest customers obtain an extremely low voltage even though a reasonable good voltage level is maintained at the transformer secondary's, this again leads to higher line losses.[3]

5. Use of over- rated distribution transformers: Studies on 11kV feeders have revealed that often the ratings of distribution transformers are much higher than the maximum KVA demand on the LT feeder. Over rated transformer produces an unnecessarily high iron loss.

6. Low voltage: Whenever the voltage applied to an induction motor varies from rated voltage, its performance is adversely affected. A reduced voltage in case of an induction motor results in higher currents drawn for the same output which leads to higher losses. This can be overcome by adjusting tap changer at power transformer and at distribution transformer, if available.

7. Low power factor: In most of the LT distribution systems, it is found that the power factor varies from as worse as 0.65 to 0.75. A low power factor contributes towards high distribution losses. For a given load, if the power factor is low, the current drawn is high consequently the losses proportional to the square of the current will be more.

8. Electric distribution losses may be divided in to two types:

- Power losses
- Energy losses

The power losses at the time of system peak, increases the requirement of generating capacity, while the energy losses make it necessary to supply additional energy over that required, by the system load. In a distribution feeder, losses occur for the following reasons:

1. Line losses on phase conductors
2. Line losses on ground wires and ground
3. Transformer core and leakage losses
4. Excess losses due to lack of coordination of var. elements
5. Excess losses due to load imbalance on the phases.

A. Reduction of Line Losses

The following methods are adopted for reduction of distribution system losses.

- Construction of new sub-station
- Reinforcement of the feeder
- Reactive power compensation
- High voltage distribution system
- Grading of conductor
- Feeder reconfiguration

B. Effect of the Losses

Losses cause various harmful effects. Common effects are as follows:-

- Losses increase the operating & maintenance cost of running a power system.
- Thermal losses reduced the overall lifetime of the electrical equipments.
- Losses responsible for the poor power factor.
- Losses minimized the reliability of the power system.
- Losses reduced the efficiency of performance of the system.[10]

C. Voltage Stability

Voltage stability issues have been a major concern in distribution systems. In general, a system enters a state of voltage instability when a disturbance, increase in load, or system change causes voltage to drop quickly or drift downward, and operators and automatic system control fails to halt the decay. The voltage decay may take a few seconds or 10 to 20 minutes. If the decay continues unabated, steady state angular instability or voltage collapse will occur.

IV. PRACTICAL CONSIDERATIONS AND SLOW DYNAMICS

A. Radial Systems

Radial systems present the closest picture of the voltage stability problem, and can involve essentially all of the slow dynamics phenomena. They also provide an effective demonstration of present analytical methods aimed at the voltage stability problem. For a radial system operating close to its voltage stability limit, a small increase in load (active or reactive), a loss of generation or shunt compensation, a drop in sending end voltage, or loss of transmission can bring voltage instability. When load changes cause receiving-end voltage to fall, several mechanisms may come into play. First, the residential active and reactive load will drop with voltage. The industrial active and reactive load, dominated by induction motors, will change little. However, the extensive capacitors in the industrial area will supply less reactive power, causing a net increase in reactive load. The drop in residential load will reduce line loading and, hence, line reactive losses. This may more than offset the increase in industrial reactive load, and thus temporarily stabilize voltage at some low value, perhaps in the vicinity of 95% [6]. Next action is operation of distribution transformer LTCs to restore distribution voltage. The residential active load will increase, while the industrial reactive load will decrease.

The increasing residential load will usually outweigh the decreasing industrial load, causing the primary voltage to fall further. Any line charging or capacitors in the primary will produce less reactive power and primary reactive losses will increase, thus further dropping primary voltage. Typically, LTCs will be at or close to limits, primary voltage will be in the vicinity of 90%, and the distribution voltages just below nominal. The next action is that of thermostats and consumers as they respond to low distribution voltage. Many loads which are constant resistance in the first minutes after a drop in voltage become constant power as these control come into play over a few minute‘s duration. Today, lighting is among the few loads that do not recover to a constant power characteristic in the minutes after a drop in voltage. Lighting is not, however, a constant resistance load. Incandescent lamps are about halfway between constant resistance and constant current, while the active part of fluorescent lamps is close to constant current.[4] However, if generator reactive loading exceeds generator capability, plant operators or exciter or field protection may reduce excitation and allow voltages to drop. More remote generators will drop as a result. The temporary reactive help from nearby generators will last only three to five minutes in the case of operator intervention, and only a minutes or less if protective circuits intervene. If all industrial loads are served by distribution transformers with active LTCs, the system may be “marginally stable” down to about 80% primary voltages. Only when the controlled distribution voltages reach 90% or less would motor stalling occur.

V. STABILITY ANALYSIS IN RADIAL DISTRIBUTION NETWORKS

Voltage stability analysis of radial distribution networks is presented. Voltage stability index is calculated for all the nodes for the proposed radial distribution network. It is shown that the node, at which the value of voltage stability index is minimum, is more sensitive to voltage collapse.

1. Voltage stability: is the ability of a system to maintain voltage so that when load admittance is increased, load power will increase, and so that both power and voltage controllable.

2. Voltage collapse: is the process by which voltage instability leads to very low voltage profile in significant part of the system (voltage may collapse due to 'angle instability' as well and sometimes only a careful post-incident analysis can discover the primary cause).

3. Voltage security: is the ability of a system, not only to operate stable, but also to remain stable (as far as the maintenance of system voltage is concerned) following any reasonably credible contingency or adverse system change.[11]

A. Distribution Load Flow

Vector Based Distribution load flow method (VDLF) is used for load flow analysis. The following assumptions are considered in the distribution load flow

- Three phase radial distribution networks are balanced and can be represented by their equivalent single line diagram
- Half-line charging susceptances of distribution lines are negligible and these distribution lines are represented as short lines.

Consider a line connected between two nodes as shown in Fig.2

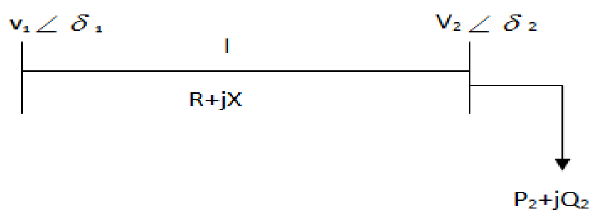

Fig.2. Electrical equivalent of line connected between two nodes of a distribution line.[7]

In fig.2- V_1 and V_2 are the voltages magnitudes of the two nodes 1 and 2. Let the current flowing through it be I. The substation voltage (at sending end) is assumed to be 1+j0 p.u. Let the power factor angle of load P_2+jQ_2 be θ_2. The phasor diagram of this line

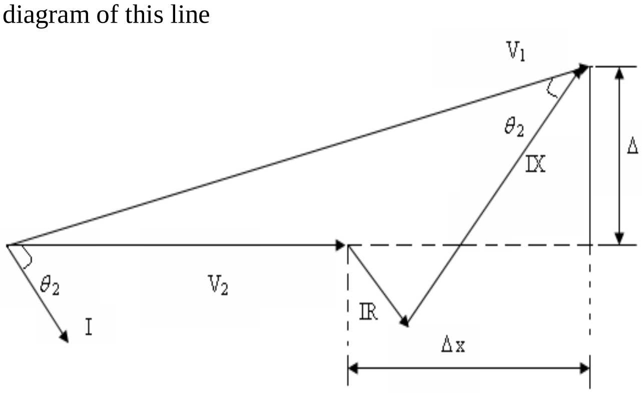

Fig.3. Basic phasor diagram of a line connected between two nodes[9].

From fig.3 the following equations are derived

$$V_1^2=(V_2+\Delta x)^2+\Delta y^2 \quad \textbf{(4)}$$

Where

$$\Delta x=IR\cos(\theta_2)+IX\sin(\theta_2) \quad \textbf{(5)}$$

$$\Delta y=IX\cos(\theta_2)-IR\sin(\theta_2) \quad \textbf{(6)}$$

Using the equations 5 and 6 in 4 we have

$$V_1^2=(V_2+IR\cos(\theta_2)+IX\sin(\theta_2))^2+(IX\cos(\theta_2)-IR\sin(\theta_2))^2 \quad \textbf{(7)}$$

$$V_1=[(V_2+IR\cos(\theta_2)+IX\sin(\theta_2))^2+(IX\cos(\theta_2)-IR\sin(\theta_2)^2]^{1/2} \quad \textbf{(8)}$$

To eliminate I from the equation 6 use

$$I\cos(\theta_2)=P_2/V_2$$

$$I\sin(\theta_2)=Q_2/V_2$$

Where

P_2=Total active power load including active power loss beyond node 2.

Q_2= Total reactive power load including reactive power loss beyond node 2.

Thus $\Delta x= IR\cos(\theta_2)+IX\sin(\theta_2)$

$$=(P_2R+Q_2X)/V_2$$

$$\Delta y= IX\cos(\theta_2)-IR\sin(\theta_2)$$

$$=(P_2X-Q_2R)/V_2$$

Thus equation 6 becomes

$$V_1^2=(V_2+(P_2R+Q_2X)/V_2)^2+((P_2X-Q_2R)/V_2)^2 \quad \textbf{(9)}$$

$$=V_2^2+2V_2(P_2R+Q_2X)/V_2+(P_2R+Q_2X)^2/V_2^2+(P_2XQ_2R)^2/V_2^2$$

$$V_1^2V_2^2=V_2^4+(P_2R+Q_2X)^2+2V_2^2(P_2R+Q_2X)+(P_2X-Q_2R)^2$$

$$V_2^4+2V_2^2(P_2R+Q_2X)+(P_2^2+Q_2^2)(R_2^2+X_2^2)-V_1^2V_2^2=0$$

$$V_2^4+2V_2^2(P_2R+Q_2X-V_1^2/2)+(P_2^2+Q_2^2)(R_2^2+X_2^2)=0$$

Equation is in the form of $ax^2+bx+c=0$, the roots of this equation are

$$(-b+(b^2-4ac)^{1/2})/2a \text{ and } (-b-(b^2-4ac)^{1/2})/2a$$

From the two solutions for V_2 only positive root of quadratic equations gives a realistic value. Thus V_2 is solved as follows:

$$V_2=\{[(P_2R+Q_2X-0.5V_1^2)-(P_2^2+Q_2^2)(R_2^2+X_2^2)]^{1/2}+(P_2R+Q_2X-0.5V_1^2)\}^{1/2} \quad \textbf{(10)}$$

This is straightforward solution and doesn't depend on the phase angle, which simplifies the formulation of the problem. In distribution system the voltage angle is not so important because the variation of voltage angle from the substation to tail of distribution feeder is only few degrees. However, if complex power flows in lines are required phase angles also considered.

The equation 10 can be written in general form as

$$V_2=(B[j]-A[j])^{1/2} \quad \textbf{(11)}$$

Where subscript '2' is the receiving end of j^{th} branch.

Subscript '1' is the sending end of j^{th} branch.

$$A[j]= P_2R[j] +Q_2X[j]-0.5V_1^2 \quad \textbf{(12)}$$

$$B[j] = [A[j]^2- (P_2^2+Q_2^2) (R[j]^2+X[j]^2)]^{1/2} \quad \textbf{(13)}$$

Where P_2 and Q_2 are total real and reactive power load feed through node 2. After calculating the effective loads at all nodes, the voltages can be calculated using equations 11, 12 and 13. Let Ploss[j] and Qloss[j] be the real and reactive power loss of branch 'j', then the initial estimates of loads are taken as the loads are taken as the effective loads at all nodes and then losses are calculated using the equations Phase angle calculation.

$$Ploss[j]=R[j]*(P_2^2+Q_2^2)/V_2 \quad \textbf{(14)}$$

$$Qloss[j] =X[j]* (P_2^2+Q_2^2)/V_2^2 \quad \textbf{(15)}$$

In this method phase angles can also be calculated along with the voltage magnitudes at the end of convergence.

$$I_1=(V_1\angle\delta_1-V_2\angle\delta_2)/|Z|\angle\theta \quad \textbf{(16)}$$

$$P_{2effect}+ Q_{2effect}= V_2\angle\delta_2*I^* \quad \textbf{(17)}$$

from equations (16) and (17) we can write

$$P_{2effect}+ Q_{2effect}= V_2\angle\delta_2 (V_1 \angle-\delta_1- V_2 \angle-\delta_2)/ |Z|\angle -\theta$$

$$= (V_2\angle\delta_2 *V_1\angle-\delta1-V2\angle -\delta_2* V_2\angle -\delta_2)/ |Z|\angle -\theta$$

$$=V_2* V_1\angle(\delta_2- \delta_1) - V_2* V_2\angle(\delta_2- \delta_2) /|Z|\angle -\theta$$

$$P_{2effect}=V_1* V_2 \cos (\delta_{21}+\theta)/|Z|-V_2\cos (\theta)/|Z|$$

As the phase angles are already calculated θ is known and V_1, V_2 and δ_1 are also known at the end of convergence of voltages. δ_1 is taken as zero.

$$\cos (\delta_{21}+\theta) = (|Z|/ (V_1V_2))*[P_{2effect}+ (V2 *V_2) \cos (\theta)/|Z|]$$

$$= (|Z|/ (V_1V_2))*[P_{2effect}+ (V2 /V_1)*\cos (\theta)]$$

Let $x= \delta_{21}+\theta$

$$y= (|Z|/ (V_1V_2))*[P_{2effect}+ (V2 /V_1)*\cos (\theta)]$$

Then $x=\cos^{-1}(y)$

$$x= \delta_2 -\delta_1+\theta$$

Therefore

$$\delta2=x+\delta_1-\theta \quad \textbf{(18)}$$

VI. VOLTAGE STABILITY ANALYSIS

A. Voltage Stability Index

From Eq. (5), it is seen that, a feasible load flow solution of radial distribution networks will exist if

$$(b^2- 4.0a\ c) \geq 0.0$$

Where $b = 2(P_2R+Q_2X-0.5V_1^2)$

$$c= (P_2^2+Q_2^2) (R^2+Q^2)$$

From equations (16), (17) and (8) we get

$$[(P_2R+Q_2X-0.5V_1^2)]^2-4 (P_22+Q_2^2) (R2+X2)>0$$

After simplification we get,

$$V_1^4-4(P_2^2X^2+Q_2^2R^2-2P_2Q_2RX)-4(P_2R+Q_2X) V_1^2>0$$

$$V_1^4-4.0\{P_2X-Q_2R\}^2-4.0\{P_2R+Q_2X\} V_1^2\geq 0. \quad \textbf{(19)}$$

Let $SI_2 =V1^4-4.0 \{P_2 X -Q_2 R\}^2 -4.0 \{P_2 R+Q_2 X\} V_1^2$

Where SI_2= voltage stability index of node 2

For stable operation SI [i] ≥ 0, for i = 2, 3…N.

By using this voltage stability index, one can measure the level of stability of radial distribution networks and thereby appropriate action may be taken if the index indicates a poor level of stability.[12]

B. Genetic Algorithm

Genetic Algorithm (GA), first introduced by John Holland in early seventies, is becoming a flagship among various techniques of machine learning and function optimization. Algorithm is a set of sequential steps needs to be executed in order to achieve a task. A GA is an algorithm with some of the principles of genetics included in it. The genetic principles "Natural Selection" and "Evolution Theory" are main guiding principles in the implementation of GA. The GA combines the adaptive nature of the natural genetics and search is carried out through randomized information exchange.

Genetic Algorithms surpass all the limitations of conventional algorithms by using the basic building blocks that are different from those of conventional algorithms. It is different from them in the following aspects.

1. GA works with a coding of the parameter set, and not the parameters themselves.
2. GA searches from a population of point and not from a single point like conventional algorithms.
3. GA uses objective function information, not derivative or other auxiliary data.
4. GA use probabilistic transition rules by stochastic operands, not deterministic rules.

Algorithm:

The complete algorithm for finding the Stability Index is given below:

1. Read system data, bus data, itermax, epsilon, base kVA, base voltage and initial voltages at all buses.
2. Form idegree, itagf, itagto, adjq, and adj1 vectors.
3. Calculate effective load at each bus starting from the last bus.
   $P_{p\ effective\ load}$ = P_p+ sum of all loads beyond the node P.
   $Q_{p\ effective\ load}$ = Q_p+ sum of all loads beyond the node p.
4. Initialize sum of active power loss slp=0, sum of reactive power loss slq=0, previous iteration active power loss pl=0, reactive power loss ql=0.
5. Start iteration count it=1.
6. Initialize total active power loss tploss[i] =0, total reactive power loss tqloss[i] =0 for i=1 to n.(tploss[i] = total active power loss, tqloss[i]= total reactive power loss).

7. Assign slp=pl, slq=ql, pl=ql=0.
8. If iteration it=1 go to step 10 else go to step 9
9. Find the effective losses at each bus
   For i=n to l
   For j=itagf[i] to itagto[i]
   q=adjq[j], k=adjl[j]
   tploss[i]= tploss[i] +tploss[q] +ploss[k]
   tqloss[i]= tqloss[i] +tqloss[q] +qloss[k]
   Where ploss[k] = active power loss of k^{th} line,
   Loss[k] = reactive power loss of k^{th} line
10. Calculate load at each bus with losses
    Active power P[i]= $P_{effective\ load[i]}$ + tploss[i].
    Reactive power Q[i]= $Q_{effective\ load[i]}$ + tqloss[i].
11. For bus no i=2 to n
    For j=itagf[i], q=adjq[j], k=adjl[j]
    A= (P[i]*r[k] + Q[i]*x[k])-(0.5* V[q]*V[q])
    B=sqrt(A*A–(r[k]*r[k]+x[k]*x[k])*(P[i]*P[i] +Q[i]*Q[i]))
    V[i]= sqrt(B-A)
    ploss[k]= r[k]* (P[i]*P[i]+Q[i] *Q[i])/V[i]*V[i]
    qloss[k]= x[k]* (P[i]*P[i]+Q[i] *Q[i])/V[i]*V[i]
    Pl=pl+ploss[k]
    Ql=ql+qloss[k]
12. Δploss= slp-pl; Δqloss= slq-ql
    Set ploss[i]=qloss[i]=0 for 1 to nline
13. if Δploss< epsilon and Δqloss<epsilon go to step 16 else go to step 5.
14. If iteration > intermix go to step 99.
15. 15 Calculate phase angle at each bus using equation (14). Print Stability Indexes,
    Voltages and phase angles at each bus and total active power loss.
16. For i=2 to n, calculate Stability index by using
    $SI(i) = V1^4 - 4.0\,\{P_2 X - Q_2 R\}^2 - 4.0\,\{P_2 R + Q_2 X\}\,V_1^2$

Find minimum of SI (i) for i=2 to N and print i^{th} bus has minimum stability index & go to 100.

99. Problem is not converged in intermix iterations.
100. Problem is converged in it iterations.

VII. RESULTS ANALYSIS FOR 15 BUS SYSTEM

Number of buses=15
Base Voltage=11 KV
Number of lines=14
Base KVA=100 KVA
Slack Bus No=1
Tolerance limit=0.001
Chromosome length=8
Population size=20
Elitism probability=0.2
Crossover probability=0.8
Mutation probability=0.01

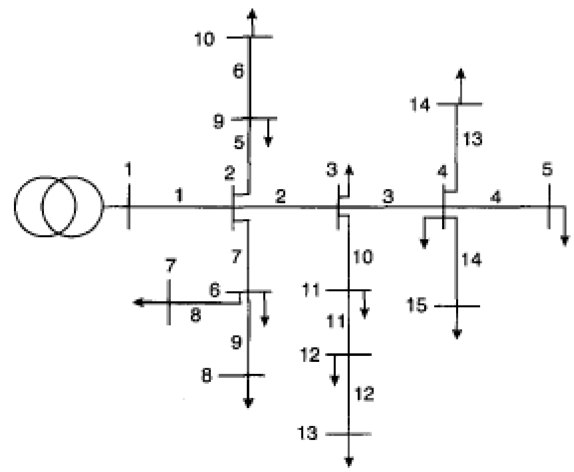

Fig.4. Single line diagram of 15 bus system:[8]

TABLE I: Line Data for 15-Bus System

From Bus	To Bus	R(ohms)	X(ohms)
1	2	1.35309	1.32349
2	3	1.17024	1.14464
3	4	0.84111	0.82271
4	5	1.52348	1.0276
2	9	2.01317	1.3579
9	10	1.68671	1.1377
2	6	2.55727	1.7249
6	7	1.0882	0.734
6	8	1.25143	0.8441
3	11	1.79553	1.2111
11	12	2.44845	1.6515
12	13	2.01317	1.3579
4	14	2.23081	1.5047
14	15	1.19702	0.8074

Table (1a): line data.

Bus No.	Converged Voltages (in.p.u)	Phase Angles (Degrees)	Stability Index
1	1	0	1
2	0.97128	0.00065	0.88843
3	0.95667	0.00101	0.83723
4	0.9509	0.00115	0.81755
5	0.94992	0.0014	0.81422
6	0.95823	0.00386	0.84278
7	0.95601	0.00442	0.8353
8	0.95695	0.00418	0.83862
9	0.96797	0.00147	0.87789
10	0.9669	0.00173	0.87402
11	0.94995	0.00268	0.81426
12	0.94583	0.00372	0.80026
13	0.94452	0.00405	*0.79586*
14	0.94861	0.00173	0.80973
15	0.94844	0.00177	0.80916

Table (1b): load data.

From the above table with four capacitors the losses are reduced (0.36189 in p.u.) but when the fifth capacitor is installed, the losses tends to become increased (0.38337in p.u) here by it is concluded that only four capacitors are installed on the bus in the system.

TABLE II: Converged Voltages, And Stability Index Values for 15-Bus System for Rounded Values of Capacitor Size

Bus No.	Real Power (k.w)	Reactive Power (kvar)
1	0	0
2	44.1	44.991
3	70	71.41428
4	140	142.8286
5	44.1	44.991
6	140	142.8286
7	140	142.8286
8	70	71.41428
9	70	71.41428
10	44.1	44.991
11	140	142.8286
12	70	71.41428
13	44.1	44.991
14	70	71.41428
15	140	142.8286

TABLE III: Converged Voltages, Phase Angles and Stability Index Values for 15-Bus System after Placement of Capacitors

Bus No.	Before Compensation		Compensation using GA	
	Voltages (Base Case)	Stability Index	Voltages	Stability Index
1	1	1	1	1
2	0.97128	0.88843	0.98813	0.94477
3	0.95667	0.83723	0.98457	0.92494
4	0.9509	0.81755	0.98385	0.91753
5	0.94992	0.81422	0.98289	0.91397
6	0.95823	0.84278	0.98064	0.9169
7	0.95601	0.8353	0.98029	0.91573
8	0.95695	0.83862	0.97988	0.91422
9	0.96797	0.87789	0.98488	0.93306
10	0.9669	0.87402	0.98382	0.92907
11	0.94995	0.81426	0.98218	0.91608
12	0.94583	0.80026	0.98384	0.92228
13	0.94452	0.79586	0.98725	0.93525
14	0.94861	0.80973	0.984	0.90921
15	0.94844	0.80916	0.98498	0.92178
Real power losses (in p.u.)	0.61794	-	0.36189	-
% Reduction in losses	-	-	41.4360	-

From the above table with four capacitors the losses are reduced (0.36189 in p.u.) but when the fifth capacitor is installed, the losses tends to become increased (0.38337in p.u) here by it is concluded that only four capacitors are installed on the bus in the system as shown in fig.4.

VIII. CONCLUSION

In this project a new voltage stability index has been proposed to identify the nodes that are on the verge of voltage collapse, the value of the proposed voltage stability index is calculated at each node of the network for a radial distribution systems and the node at which the value of voltage stability index is minimum is most sensitive to voltage collapse, by using the voltage stability index one can measure the level of stability of radial distribution networks and there by appropriate action may be taken if the index indicates the poor level of stability, further, capacities are installed in the candidate node for the improvement for stability index, the size of the capacitor is found by Gas.

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