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RELIABILITY IMPROVEMENT OF RADIAL DISTRIBUTION SYSTEM WITH INCROPORATING PROTECTIVE DEVISES - CASE STUDY

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ABSTRACT

This paper present an effective approach of real time evaluation of radial distribution system power flow solution with an objective of determining the voltage profiles, total losses and indices. Two matrices the bus-injection to branch-current matrix (BIBC) and the branch-current to bus voltage matrix (BCBV) and a simple matrix multiplication are used to obtain power flow solutions. In this work we have considered the load diversity factor for analysis of load data for real time system. Assessment of customer and energy oriented indices is an important part of distribution system operation and planning. Distribution system reliability assessment is a measure of continuity and quality of power supply to the consumers, which mainly depends on interruption profile, based on system topology and component reliability data. The performance of the system was investigated on two stage basis first consisting a standard 33 bus systems and then real time distribution system as case study. To demonstrate the effectives of the proposed method, a 24-node 11kv Jeevakona urban distribution feeder is selected, which is a heavily loaded feeder and is already installed by 18 KVAR capacitor bank at each Distribution Transformer (DTR) in LT side with pole mounted. For analyzing the results average load data is considered with an average power factor for feeder and distributed depending on the connected load. The results are presented

KEYWORDS: *reliability indices, failure rate, repair time, radial distribution network, Diversity Factor, load factor, Distribution Load Flow, Distribution Transformer (DTR).*

I. INTRODUCTION

The demand for electrical energy is ever increasing. Today over 21% (theft apart!!) of the total electrical energy generated in India is lost in Transmission (5-7%) and Distribution (15-18%). The electrical power deficit in the country is currently about 35%. Clearly, reduction in distribution losses can reduce this deficit significantly. It is possible to bring down the distribution losses to 6-8% level in India with the help of newer technological options (including information technology) in the Electrical Power Distribution Sector which will enable better monitoring and control. The electric utility system is usually divided into three subsystems which are Generation, Transmission, and Distribution. Electricity distribution is the final stage in the delivery of electricity to end users. A Distribution Network carries electricity from the transmission system and delivers it to consumers. Typically, the network would include medium-voltage (less than 50 kV) power lines, electrical substations and pole-mounted transformers, low-voltage (less than 1000 V) distribution wiring and sometimes electricity meters. Electric power is normally generated at 11-25kV in a power station. To

transmit over long distances, it is then stepped-up to 400kV, 220kV or 132kV as necessary. Power is carried through a transmission network of high voltage lines. Usually, these lines run into hundreds of kilometers and deliver the power into a common power pool called the grid[1,2,- 26]. The grid is connected to load centers through a sub-transmission network of normally 33kV (or sometimes 66kV) lines. These lines terminate into a 33kV (or 66kV) substation, where the voltage is stepped-down to 11kV for power distribution to load points through a distribution network of lines at 11kV and lower. The power network, which generally concerns the common man is the distribution network of 11kV lines or feeders downstream of the 33kV substation. Each 11kV feeder which emanates from the 33kV substation branches further into several subsidiary 11kV feeders to carry power close to the load points (localities, industrial areas, villages, etc.,). At these load points, a transformer further reduces the voltage from 11kV to 415V to provide the last-mile connection through 415V feeders (also called as Low Tension (LT) feeders) to individual customers, either at 240V (as single-phase supply) or at 415V (as three-phase supply). A feeder could be either an overhead line or an underground cable. In urban areas, owing to the density of customers, the length of an 11kV feeder is generally up to 3 km. On the other hand, in rural areas, the feeder length is much larger (up to 20 km). A 415V feeder should normally be restricted to about 0.5 - 1.0 km. unduly long feeders lead to low voltage at the consumer end. The Section II gives about Diversity factor, Section III load flow studies, Section IV Load flow technique, Section V Reliability indices, Section VI test and real time systems, and conclusions.

II. DIVERSITY FACTOR AND LINE LOSSES

The probability that a particular piece of equipment will come on at the time of the facility's peak load. It is the ratio of the sum of the individual non-coincident maximum demands of various subdivisions of the system to the maximum demand of the complete system. The diversity factor is always greater than 1. The (unofficial) term diversity, as distinguished from diversity factor refers to the percent of time available that a machine, piece of equipment, or facility has its maximum or nominal load or demand (a 70% diversity means that the device in question operates at its nominal or maximum load level 70% of the time that it is connected and turned on).Diversity factor is commonly used for a number of mathematics-related topics [1, 26-29]. One such instance is when completing a coordination study for a system. This diversity factor is used to estimate the load of a particular node in the system. The total I2R loss (PLt) in a distribution system having n number of branches is given by

$$P_{Lt} = \sum_{i=1}^{n} I_i^2 R_i \quad \text{---------} \quad 1$$

Here Ii and Ri are the current magnitude and resistance, respectively, of the ith branch. The branch current can be obtained from the load flow solution. The load flow algorithm described in is used for this purpose. The branch current has two components; active (Ia) and reactive (Ir). The loss associated with the active and reactive components of branch currents can be written as[27- 29]

$$P_{La} = \sum_{i=1}^{n} I_{ai}^2 R_i \quad \text{--------} \quad (2)$$

$$P_{Lr} = \sum_{i=1}^{n} I_{ri}^2 R_i \quad \text{--------} (3)$$

Note that for a given configuration of a single-source radial network, the loss PLt, associated with the active component of branch currents cannot be minimized because all active power must be supplied by the source at the root bus. However, the loss PLr associated with the reactive component of branch currents can be minimized by supplying part of the reactive power demands locally.

III. LOAD FLOW STUDIES

The load-flow study in a power distribution system has great importance because it is the only system which shows the electrical performance and power flow of the system operating under steady

state.Load-Flow studies are used to determine the system voltages, whether they remain within specified limits, under various contingency conditions, and whether equipment such as transformers and conductors are overloaded. Load-flow studies are often used to identify the need for additional Generation, Capacitive/Inductive VAR support or the placement of capacitors and/or reactors to maintain system voltages within specified limits. An efficient load-flow study plays vital role during planning of the system and also for the stability analysis of the system. Distribution networks have high R/X ratio whereas the transmission networks have high X/R ratio and the distribution networks are ill-conditioned in nature. Therefore, the variables for the load-flow analysis of distribution systems are different from those of transmission system.Many modified versions of the conventional load-flow methods have been suggested for solving power networks with high *R/X* ratio. The following are the effective load flow techniques used in the distribution networks: which are Single-Line Equivalent Method,Very Fast Decoupled Method,Ladder Technique,Power ssummation Method and Backward and Forward Sweeping Method. The proposed algorithm is tested for standard test system on a Real Time system.

IV. FORMULATION OF LOAD FLOW MODEL

(a) Algorithm development:

The method is developed based on two derived matrices, the bus-injection to branch-current matrix and the branch current to bus-voltage matrix, and equivalent current injections. In this section, the development procedure will be described in detail. For distribution networks, the equivalent current-injection based model is more practical [5-13]. For bus, the complex load S is expressed by [27]

$$S_i=P_i+jQ_i \quad \text{---------- (4)}$$

Where i = 1, 2, 3,……..., *N*

And the corresponding equivalent current injection at the –kth iteration of solution is

$$I_i^k=I_i^k(V_i^k)+jI_i^k(V_i^k)=(P_i+jQ_i/V_i^k)^* \quad \text{--------- (5)}$$

Where Vi^k and $Ii^k$are the bus voltages and equivalent current injection of bus i at kth iteration respectively.

(b) Relationship Matrix Development

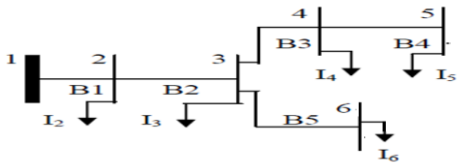


Figure 1. Simple distribution system

A simple distribution network shown in fig.1 is used as an example the current equations are obtained from the equation (4) .The relationship between bus currents and branch currents can be obtained by applying Kirchhoff's current law (KCL) to the distribution network. Using the algorithm of finding the nodes beyond all branches proposed by Gosh et al. The branch currents then are formulated as functions of equivalent current injections for example branch currents B_1, B_3 and B_5 can be expressed as

$$\left.\begin{aligned} B_1&= I_2+I_3+I_4+I_5+I_6 \\ B_3&=I_4+I_5 \\ B_5&= I_6 \end{aligned}\right\} \quad \text{---------- (5)}$$

Therefore the relationship between the bus current injections and branch currents can be expressed as

$$\begin{bmatrix} B1 \\ B2 \\ B3 \\ B4 \\ B5 \end{bmatrix} = \begin{bmatrix} 1 & 1 & 1 & 1 & 1 \\ 0 & 1 & 1 & 1 & 1 \\ 0 & 0 & 1 & 1 & 0 \\ 0 & 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & 0 & 1 \end{bmatrix} \begin{bmatrix} I2 \\ I3 \\ I4 \\ I5 \\ I6 \end{bmatrix} \quad \text{------ (6)}$$

Eq (4a) can be expressed in general form as

$$[B]= [BIBC] [I] \quad \text{---------- (7)}$$

Where BIBC is a bus injection to branch current matrix, the BIBC matrix is a upper triangular matrix and contains values of 0 and 1 only. The relationship between branch currents and bus voltages as shown in Figure 1. For example, the voltages of bus 2, 3, and 4 are

$$V_2=V_1-B_1Z_{12} \quad \text{---------- (8a)}$$
$$V_3=V_2-B_2Z_{23} \quad \text{---------- (8b)}$$
$$V_4=V_3-B_3Z_{34} \quad \text{---------- (8c)}$$

where V_i is the voltage of bus i, and Z_{ij} is the line impedance between bus i and bus j.
Substituting (8a) and (8b) into (8c) can be rewritten as

$$V_4=V_1-B_1Z_{12}-B_2Z_{23}-B_3Z_{34} \quad \text{---------- (9)}$$

From (9), it can be seen that the bus voltage can be expressed as a function of branch currents, line parameters, and the bus voltage. Similar procedures can be performed on other buses; therefore, the relationship between branch currents and bus voltages can be expressed as

$$\begin{bmatrix} V1 \\ V1 \\ V1 \\ V1 \\ V1 \end{bmatrix} - \begin{bmatrix} V2 \\ V3 \\ V4 \\ V5 \\ V6 \end{bmatrix} = \begin{bmatrix} Z12 & 0 & 0 & 0 & 0 \\ Z12 & Z23 & 0 & 0 & 0 \\ Z12 & Z23 & Z34 & 0 & 0 \\ Z12 & Z23 & Z34 & Z45 & 0 \\ Z12 & Z23 & 0 & 0 & Z56 \end{bmatrix} \begin{bmatrix} B1 \\ B2 \\ B3 \\ B4 \\ B5 \end{bmatrix} \quad \text{------- (10)}$$

Equation can be rewritten as Where BCBV is the branch –current to bus voltage (BCBV) matrix.

$$[\Delta v]= [BCBV] [B] \quad \text{---------- (11)}$$

(c) Building Formulation Development:
Observing (7), a building algorithm for BBIBC matrix can be developed as follows:
Step1) For a distribution system with m-branch section and n bus, The dimension of the BIBC matrix is
m× (n-1).
Step2) If a line branch (B_i) is located between bus i & bus j, copy the column of the i^{th} bus of the BIBC
matrix to the column of the j^{th} bus and fill a 1 to the position of the k^{th} row and the j^{th} bus column.
Step3) Repeat step (2) until all line sections is included in the BIBC matrix. From (10) a building algorithm for BCBV matrix can be developed as follows.
Step 4)For a distribution system with m-branch section and n-k bus, the dimension of the BCBV matrix is
(n-1) ×m.
Step 5)If a line section is located between bus i & bus j, copy the row of the i^{th} bus of the BCBV matrix to the row of the j^{th} bus and fill the line impedance (Z) to the position of the j^{th} bus row and the k^{th} column.
Step 6) Repeat step (5) until all line sections is included in the BCBV matrix.
It can also be seen that the building algorithms of the BIBC and BCBV matrices are similar. In fact, these two matrices were built in the same subroutine of our test program. Therefore, the computation resources needed can be saved. In addition, the building algorithms are developed based on the traditional bus-branch oriented database; thus, the data preparation time can be reduced.

(d) Solution Technique Developments

The BIBC and BCBV matrices are developed based on the topological structure of distribution systems. The BIBC matrix represents the relationship between bus current injections and branch currents. The corresponding variations at branch currents, generated by the variations at bus current injections, can be calculated directly by the BIBC matrix. The BCBV matrix represents the relationship between branch currents and bus voltages. The corresponding variations at bus voltages, generated by the variations at branch currents, can be calculated directly by the BCBV matrix. Combining (7) and (11), the relationship between bus current injections and bus voltages can be expressed as

$$[\Delta V]=[BCBV][BIBC][I]=[DLF][I] \quad \text{----------(12)}$$

And the solution for distribution power flow can be obtained by solving (12) iteratively

$$I_i^k=I_i^r(V_i^k)+jI_i^i(V_i^k)=((P_i+jQ_i)/V_i^k)^* \quad \text{----------(13a)}$$

$$[\Delta V^{k+1}]=[DLF][I^{k}] \quad \text{----------(13b)}$$
$$[V^{k+1}] = [V^{\circ}] + [\Delta V^{k+1}] \quad \text{---------- (13c)}$$

According to the research, the arithmetic operation number of LU factorization is approximately proportional to N^3. For a large value of N, the LU factorization will occupy a large portion of the computational time. Therefore, if the LU factorization can be avoided, the power flow method can save tremendous computational resource. From the solution techniques described before, the LU decomposition and forward/backward substitution of the Jacobean matrix or the Y admittance matrix are no longer necessary for the proposed method. Only the DLF matrix is necessary in solving power flow problem. Therefore, the proposed method can save considerable computation resources and this feature makes the proposed method suitable for online operation.

(e)Losses Calculation

The Real power loss of the line section connecting between buses i and i+1is computed as

$$P_{RLOSS}(i,i+1) = R_{i,i+1}\frac{P^2{}_i + Q^2{}_i}{||V_i||^2} \quad \text{---------- (14)}$$

The Reactive power loss of the line section connecting between buses i and i+1is computed as

$$P_{XLOSS}(i,i+1) = X_{i,i+1}\frac{P^2{}_i + Q^2{}_i}{||V_i||^2} \quad \text{---------- (15)}$$

The total Real and Reactive power loss of the feeder P_{FRLOSS} is determined by summing up the losses of all sections of the feeder, which is given by:

$$P_{FRLOSS}(i,i+1) = \sum_{i=1}^{N-1} P_{RLOSS}(i,i+1) \quad \text{---------- (16)}$$
$$P_{FXLOSS}(i,i+1) = \sum_{i=1}^{N-1} P_{XLOSS}(i,i+1) \quad \text{---------- (17)}$$

V. RELIABILITY INDICES:[23]

(i) System Average Interruption Duration Index (SAIDI)

The most often used performance measurement for a sustained interruption is the System Average Interruption Duration Index (SAIDI). This index measures the total duration of an interruption for the average customer during a given period. SAIDI is normally calculated on either monthly or yearly basis; however, it can also be calculated daily, or for any other period. To calculate SAIDI, each interruption during the time period is multiplied by the duration of the interruption to find the customer-minutes of interruption. The customer-minutes of all interruptions are then summed to determine the total customer-minutes. To find the SAIDI value, the customer-minutes are divided by the total customers. Where U_i=Annual outage time, Minutes, N_i=Total Number of customers of load point i. SAIDI is measured in units of time, often minutes or hours. It is usually measured over the course of a year, and according to IEEE Standard 1366-1998 the median value for North American utilities is approximately 1.50 hours. The formula is,

$$SAIDI = \frac{Sumofcustomer\,\text{int}\,erruptionduration}{Tota\,\ln umberofcustomers}\frac{\sum U_i * N_i}{\sum N_i} \quad (18)$$

(ii)Customer Average Interruption Duration Index (CAIDI)

Once an outage occurs the average time to restore service is found from the Customer Average Interruption Duration Index (CAIDI). CAIDI is calculated similar to SAIDI except that the denominator is the number of customers interrupted versus the total number of utility customers. CAIDI is,

$$SAIDI = \frac{Sumofcustomer\,\text{int}\,erruptionduration}{Tota\,\ln umberofcustomer\,\text{int}\,erruptions}\frac{\sum U_i * N_i}{\sum \lambda_i * N_i} \quad (19)$$

Where U_i=Annual outage time, Minutes, N_i= Total Number of customers of load point i. λ_i=Failure Rate.

CAIDI is measured in units of time, often minutes or hours. It is usually measured over the course of a year, and according to IEEE Standard 1366-1998 the median value for North American utilities is approximately 1.36 hours [20].

(iii)System Average Interruption Frequency Index (SAIFI)

The System Average Interruption Frequency Index (SAIFI) is the average number of time that a system customer experiences an outage during the year (or time period under study). The SAIFI is found by divided the total number of customers interrupted by the total number of customers served. SAIFI, which is dimensionless number, is

$$SAIDI = \frac{Total\ number\ of\ customer\ interruptions}{Total\ number\ of\ customers\ served} \frac{\sum \lambda_i * N_i}{\sum N_i} \qquad (20)$$

$$SAIFI = \frac{SAIDI}{CAIDI} \qquad \ldots\ldots\ldots (21)$$

Where N_i=Total Number of customers interrupted. λ_i=Failure Rate. SAIFI is measured in units of interruptions per customer. It is usually measured over the course of a year, and according to IEEE Standard 1366-1998 the median value for North American utilities is approximately 1.10 interruptions per customer.

(iv)Average Service Availability Index (ASAI)

The Average Service Availability Index (ASAI) is the ratio of the total number of customer hours that service was available during a given period of the total customer hours demanded. This is sometimes called the service reliability index. The ASAI is usually calculated on either a monthly basis (730 hours) or a yearly basis (8,760 hours), but can be calculated for any time period. The ASAI is found as, Where T= Time period under study, hours., r_i=Restoration Time, Minutes, N_i=Total Number of customers interrupted., N_T=Total Customers served.

$$ASAI = [1 - (\frac{\sum (r_i * N_i)}{(N_T * T)})] * 100 \qquad \ldots\ldots\ldots (22)$$

$$ASUI = 1 - ASAI \qquad \ldots\ldots\ldots (23)$$

(v)Average Energy Not Supplied (AENS) : This is also called as Average System Curtailment Index (ASCI)

$$AENS = \frac{Total\ energy\ not\ supplied}{Total\ number\ of\ customers\ served} = \frac{\sum L_{a(i)} * U(i)}{\sum N_i} \qquad . (24)$$

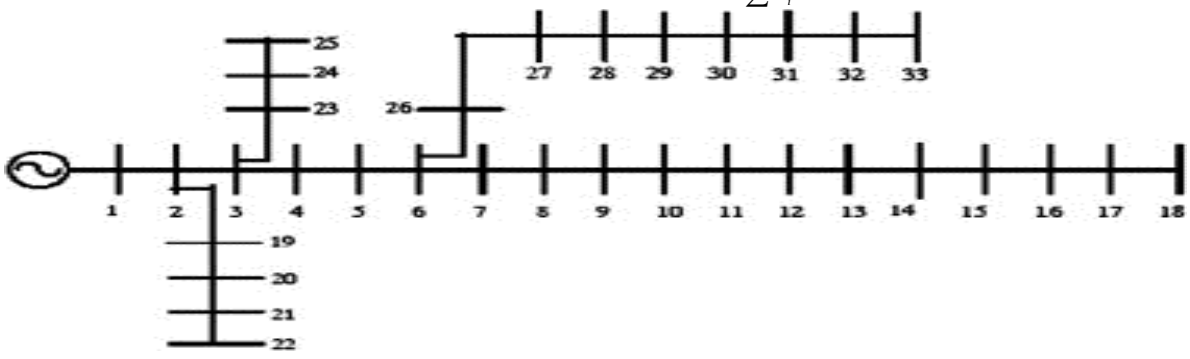


Figure 2. IEEE 33 Bus Test system

VI. TEST AND REAL TIME SYSTEMS & RESULTS [1-2]

(a) IEEE Test System System Data for the radial distribution systems have following characteristics

Base Voltage = 11KV.Base MVA=100.Conductor type = All Aluminum Alloy Conductor (AAAC) Resistance = 0.55 ohm/KM., Reactance = 0.351 ohm/KM. The proposed power flow algorithm was implemented using MATLAB. Two methods are used for test systems and convergence tolerance is set to 0.001p.u.Power Summation Method and BIBC &BCBV Method. Accuracy Comparison For any new method, it is important to make sure that the final solution of the new method is the same as

the existent method. An IEEE 33 bus system is taken as a Test System and Jeevakona Feeder as a Real Time System.

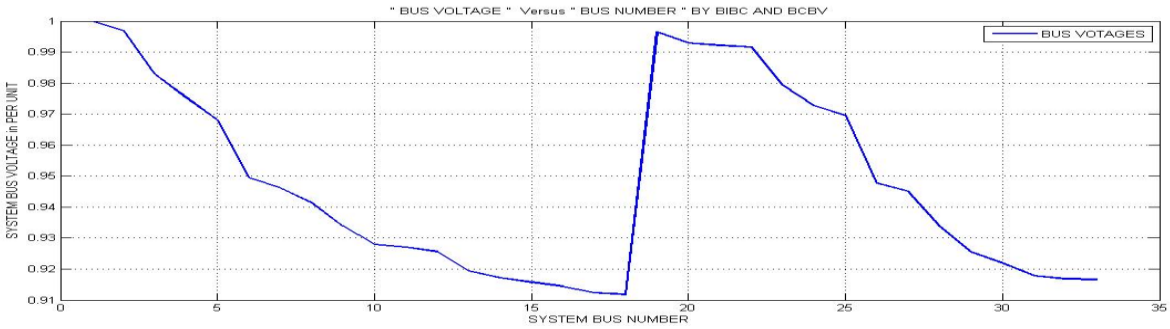


Figure 3. Voltage profiles by BIBCAND BCBV

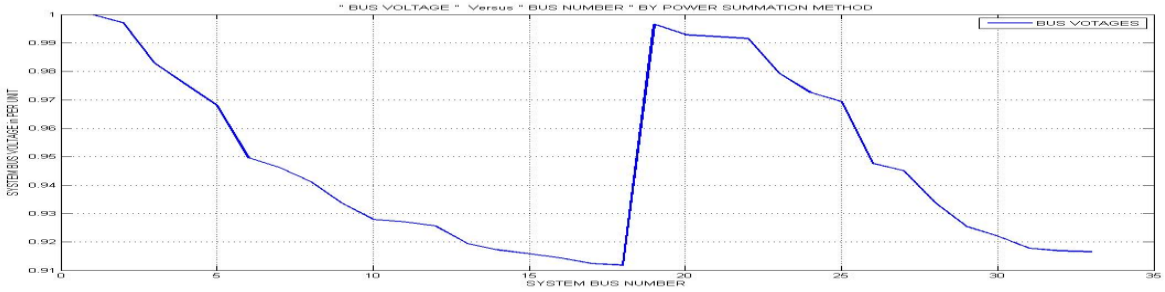


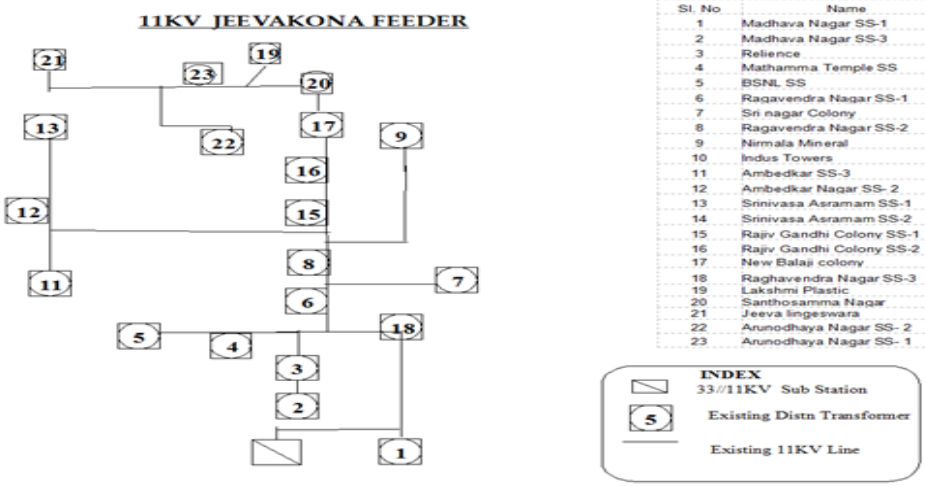
Figure 4. Voltage profiles by Power summation method

Table 1: test system 33 Bus Test System Losses for Two Different Methods

BIBC & BCBV Method		
TLP=	203.9264	KW
TLQ=	135.2418	KVAR
Power Summation Method		
TLP=	203.9875	KW
TLQ=	135.2758	KVAR

The final bus voltages for both methods are show in above shown in figure 3 and 4.The voltage of both methods are very close each other. It means that the accuracy of the both methods is almost the same and the losses are in Table 1.

(b)Real Time System and Results:



Sl. No	Name	Cap	Code
1	Madhava Nagar SS-1	100	30003
2	Madhava Nagar SS-3	100	30034
3	Reliance	100	30058
4	Mathamma Temple SS	100	30067
5	BSNL SS	100	30046
6	Ragavendra Nagar SS-1	160	30002
7	Sri nagar Colony	100	30048
8	Ragavendra Nagar SS-2	100	30039
9	Nirmala Mineral	100	30053
10	Indus Towers	63	
11	Ambedkar SS-3	100	30033
12	Ambedkar Nagar SS- 2	100	30015
13	Srinivasa Asramam SS-1	100	30035
14	Srinivasa Asramam SS-2	40	
15	Rajiv Gandhi Colony SS-1	100	30001
16	Rajiv Gandhi Colony SS-2	100	30038
17	New Balaji colony	40	30057
18	Raghavendra Nagar SS-3	100	30076
19	Lakshmi Plastic	63	30036
20	Santhosamma Nagar	40	30054
21	Jeeva lingeswara	100	30005
22	Arunodhaya Nagar SS- 2	40	30056
23	Arunodhaya Nagar SS- 1	100	30055

Figure 5. Real time Radial Distribution System

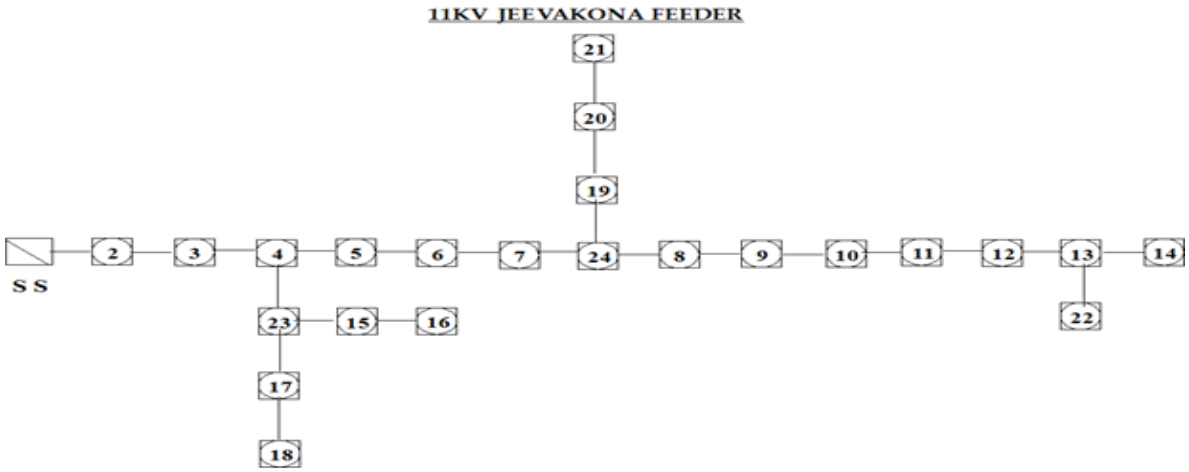


Figure 6. As per test system arrangement real time Radial Distribution System

The layout of Jeevakona feeder is shown in figure 5 and rearranging as per standard radial distribution system is shown in figure 6, Load is not constant throughout the day, it varies from time to time. By considering the terms Diversity factor and Power Factor for five different conditions. i.e. 1. Average DF Good PF. 2. High DF High PF. 3. High DF Low PF.,4. Low DF High PF. 5. Low DF low PF. General condition that occurs is Average DF and Good PF where Average DF is 0.62 and Good PF is 0.92. When the load is high (High DF) and the PF is also high (High PF), this condition does not occur in practical condition but for the analysis only is considered condition. When the load is high (High DF), the PF decreases (Low PF), this condition occurs in peak demand only. When the load in Low (Low DF) then the PF is high (High PF), this condition occurs during the light load conditions. Low DF and Low PF condition does not occur in the day. This condition is assumed for analysis only. The load data for Jeevakona feeder is shown in Table 2. The load flow calculations are performed to get the voltages at each bus and & the total power losses for 5 conditions. To evaluate the reliability of a real time system here we have considered the 24-node 11kv Jeevakona urban radial distribution feeder is selected. Line data for this feeder is shown in Table 3.

Table 2. Load data for Jeevakona radial feeder

Bus No	P (KW)	Q (KVAR)	Bus No	P (KW)	Q (KVAR)
1	0	0	13	32.4	9.45
2	259.17	125.52	14	312.45	185.4
3	159.53	66.51	15	80.78	41.39
4	256.44	152.16	16	209.58	95.49
5	67.5	19.69	17	30	8.75
6	207.16	86.37	18	111.87	40.6
7	164.88	68.74	19	126.74	46
8	212.89	88.75	20	153.41	63.96
9	236.19	98.47	21	208.25	94.88
10	10	2.03	22	30.82	8.99
11	48.6	17.64	23	0	0
12	36.93	21.91	24	0	0

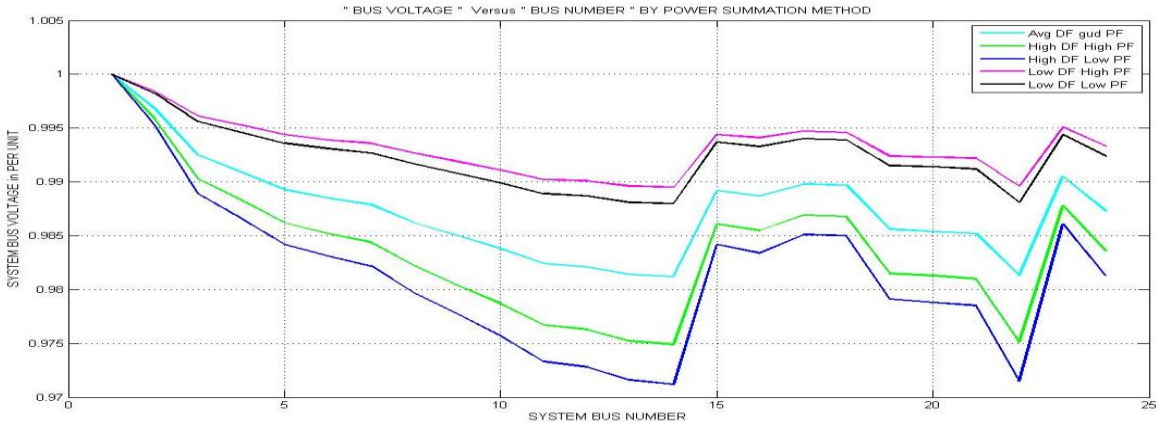


Figure7. Voltage profiles for five different categories by power summation method

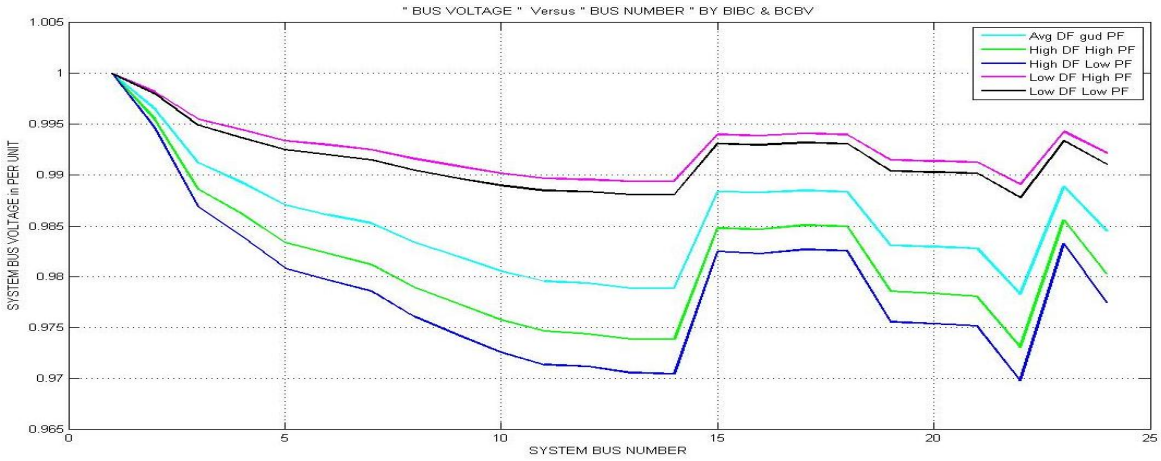


Figure 8. Voltage profiles for five different categories by BIBC and BCBV

Table3. Line data for Jeevakona radial feeder

From node	To node	Distance between nodes (KM)	R (ohm/KM)	X (ohm/KM)	R (ohms)	X (ohms)
1	2	0.2	0.55	0.351	0.1100	0.0702
2	3	0.3	0.55	0.351	0.1650	0.1053
3	4	0.12	0.55	0.351	0.0660	0.0421
4	5	0.2	0.55	0.351	0.1100	0.0702
5	6	0.1	0.55	0.351	0.0550	0.0351
6	7	0.1	0.55	0.351	0.0550	0.0351
7	24	0.1	0.55	0.351	0.0550	0.0351
24	8	0.2	0.55	0.351	0.1100	0.0702
8	9	0.3	0.55	0.351	0.1650	0.1053
9	10	0.4	0.55	0.351	0.2200	0.1404
10	11	0.5	0.55	0.351	0.2750	0.1755
11	12	0.1	0.55	0.351	0.0550	0.0351
12	13	0.3	0.55	0.351	0.1650	0.1053
13	14	0.1	0.55	0.351	0.0550	0.0351
4	23	0.1	0.55	0.351	0.0550	0.0351
23	15	0.2	0.55	0.351	0.1100	0.0702
15	16	0.2	0.55	0.351	0.1100	0.0702
23	17	0.3	0.55	0.351	0.1650	0.1053
17	18	0.4	0.55	0.351	0.2200	0.1404
24	19	0.6	0.55	0.351	0.3300	0.2106
19	20	0.1	0.55	0.351	0.0550	0.0351
20	21	0.2	0.55	0.351	0.1100	0.0702
13	22	0.5	0.55	0.351	0.2750	0.1755

(c) Results and Discussion

The load flow calculations are performed by using two methods, one by Power summation method and another by BIBC & BCBV method. The voltage magnitudes and the power losses are obtained by using BIBC and BCBV, Power summation method. The voltage profiles at each bus are plotted in blow figure 7 and 8 for both method and losses respectively for Jeevakona feeder at different conditions is shown in above table 4 The voltages magnitudes at nodes are equal in both the methods. The losses are similar for both the methods. The nodes which are close to the source are having the higher voltage magnitude is the nodes that are far-away from the source are of lower voltage magnitude (due to higher drop in voltage). This Jeevakona feeder is already installed by 18 KVAR capacitor bank at each Distribution Transformer (DTR) in LT side with pole mounted. So, there are no nodes having voltages less than 0.95 p.u. Hence, there is no need of capacitor placement. The real time losses are shown in Table 4. These losses are compared with losses obtained by using both methods. Energy losses are computed for Jeevakona feeder by real time energy consumed data by the feeder from substation. It is observed that the computed energy losses closely match with the calculated energy (real time data) losses. The details of the distribution system real time losses computation are shown in Table 6.

There are 4 interruption cases during the year Jan 2011- Jan 2012 (Table 9). When the feeder was not provided with isolators, 6 load points got affected during the 4 interruptions. The Distribution System Reliability Indices are calculated and results are tabulated in Table 10 and the percentage of indices is represented in pie chart as shown in Figure 9.

Table 4. Real Time system losses for Two Different Methods

Power Summation method			**BIBC & BCBV**		
Avg DF gud PF			**Avg DF gud PF**		
TLP =	31.6737	KW	TLP =	41.6907	KW
TLQ =	20.2526	KW	TLQ =	26.6831	KW
TL =	51.9263	KW	TL =	68.3738	KW
High DF High PF			**High DF High PF**		
TLP =	53.6482	KW	TLP =	67.2592	KW
TLQ =	34.3041	KW	TLQ =	43.0359	KW
TL =	87.9523	KW	TL =	110.295	KW
High DF Low PF			**High DF Low PF**		
TLP =	68.9335	KW	TLP =	86.6164	KW
TLQ =	44.0785	KW	TLQ =	55.4092	KW
TL =	113.0121	KW	TL =	142.026	KW
Low DF High PF			**Low DF High PF**		
TLP =	9.0865	KW	TLP =	10.7679	KW
TLQ =	5.8111	KW	TLQ =	6.891	KW
TL =	14.8976	KW	TL =	17.6589	KW
Low DF Low PF			**Low DF Low PF**		
TLP =	11.5259	KW	TLP =	13.606	KW
TLQ =	7.3714	KW	TLQ =	8.7054	KW
TL =	18.8973	KW	TL =	22.3114	KW

VII. REAL TIME LOSSES CALCULATION

Table 5. Peak Power Loss (PPL) Sheet

Section	DTR KVA	Current in sec	Resistance Ohm/KM	Length of Sec In KM	R of sec. Ohm	PPL
23	40	2.1	0.55	0.5	0.275	0.0036
22	100	5.25	0.55	0.2	0.11	0.0091
21	200	10.5	0.55	0.1	0.055	0.0182
20	300	15.75	0.55	0.6	0.33	0.2456
19	100	5.25	0.55	0.4	0.22	0.0182
18	200	10.5	0.55	0.3	0.165	0.0546
17	100	5.25	0.55	0.2	0.11	0.0091
16	200	10.5	0.55	0.2	0.11	0.0364
15	400	21	0.55	0.1	0.055	0.0728

14	100	5.25	0.55	0.1	0.055	0.0045
13	240	12.6	0.55	0.3	0.165	0.0786
12	303	15.9075	0.55	0.1	0.055	0.0418
11	343	18.0075	0.55	0.5	0.275	0.2675
10	383	20.1075	0.55	0.4	0.22	0.2668
9	483	25.3575	0.55	0.3	0.165	0.3183
8	583	30.6075	0.55	0.2	0.11	0.3092
7	883	46.3575	0.55	0.1	0.055	0.3546
6	983	51.6075	0.55	0.1	0.055	0.4395
5	1083	56.8575	0.55	0.1	0.055	0.5334
4	1183	62.1075	0.55	0.2	0.11	1.2729
3	1743	91.5075	0.55	0.12	0.066	1.6580
2	1843	96.7575	0.55	0.3	0.165	4.6342
1	1943	102.0075	0.55	0.2	0.11	3.4338
Total				**5.6**		**14.081(KW)**

Table 6. Technical Losses calculation from Substation

Units sent out from the 11k.v. System for one month					**783000**	UNITS	
Average Demand					1315.5242	KVA	
Peak Demand During The Month(100Amp)					**1905.2559**	KVA	
Load Factor Of The Month					0.6904711		
Distribution Transformer In The 11Kv System							
	No.s	**Rating**		**Total**			
	1	160	KVA	160			
`	**16**	100	KVA	1600			
	1	63	KVA	63			
	3	40	KVA	120			
Total KVA				1943			
Iron losses when the demand is equal to total transformer capacity							
160	KVA	1	NO.s	720	Watts	720	
100	KVA	16	NO.s	450	Watts	7200	
63	KVA	1	NO.s	350	Watts	350	
40	KVA	3	NO.s	180	Watts	540	
Total Iron Losses						8810	
Copper losses when the demand is equal to total transformer capacity							
160	KVA	1	NO.s	3200	Watts	3200	
100	KVA	16	NO.s	2000	Watts	32000	
63	KVA	1	NO.s	1320	Watts	1320	
40	KVA	3	NO.s	800	Watts	2400	
Total Copper Losses						**38920**	
11Kv Line Losses As Per PPL Statement					**14081**	**Watts**	
Maximum demand during the month					1905.2559	KVA	
Total transformer capacity					1943	KVA	
Ratio of maximum demand to the tr capacity					0.9805743		
Transformer Cu Losses(corrected to demand)					37422.591	Watts	
LINE Cu Losses(corrected to demand)					13539.247	Watts	
Least loss factor							
LLF=0.8x(LF*LF)+0.2(LF)					0.5194945		
Corrected Tr. Cu Losses(Actual Loading Condition)=						19440.83	Watts
corrected line Cu losses(Actual Loading Condition)=						7033.565	Watts
Units Handled During The Month=						783000	Units
Units Billed During The Month=						**688000**	Units
Actual Losses In 11KV line,tr =						95000	Units
Total Tr.Losses=IRON LOSSES+COPPER LOSSES=						46232.59	Watts
Total Tr.Losses For One Month=Total Tr lossesx24x31days=						34397.05	Kwh
%of Transformer Losses=						4.39	%

Total 11KV Line Losses=	7033.57	Watts
11KV Line Losses For One Month=Total 11kv lossesx24x31days=	5232.97	Kwh
%of 11KV Line Losses=	0.67	%
Total Loss=Tr. LOSS+11KV Line Loss =	**5.06**	**%**

Table 7. Losses comparison between Load Flow Methods and PPL Sheet

JEEVAKONNA FEEDER					
BCBV Method			**Power Summation Method**		
Avg DF gud PF			**Avg DF gud PF**		
TLP =	41.6907	KW	TLP =	41.0289	KW
TLQ =	26.6831	KW	TLQ =	26.1839	KW
TL =	68.3738	KW	TL =	67.2128	KW
Energy Loss =(TLP*24*31)=	31018	Units	**Energy Loss =(TLP*24*31)**	30526	Units
=	3.96	%	=	3.90	%
Energy Loss as per PPL Sheet=			5.06% of 783000	39619.8	Units
			=	5.06	%

VIII. INTERRUPTION DATA

Table 8. Details of Distribution System

Load Points	No of Customers	Total Connected Load(KW)	Average Connected load(KW)
1	0	0	0
2	589	740.48	1.2572
3	309	398.82	1.2907
4	648	854.80	1.3191
5	43	75.00	1.7442
6	330	345.27	1.0463
7	383	412.21	1.0763
8	476	354.82	0.7454
9	492	393.65	0.8001
10	10	10.00	1.0000
11	49	54.00	1.1020
12	1	41.03	41.0300
13	30	36.00	1.2000
14	1359	1249.81	0.9197
15	173	201.96	1.1674
16	480	523.96	1.0916
17	6	30.00	5.0000
18	237	279.69	1.1801
19	123	149.10	1.2122
20	424	438.31	1.0338
21	356	347.09	0.9750
22	34	36.26	1.0665
23	0	0.00	0
24	0	0.00	0
Total	6552	6972.26	

Table 9. Interruption effect in a Calendar Year (without Isolator)

Interruption Case	Load Point Affected	Duration (hrs)	Cause of Interruption
1	16	2	Failed Due to OverLoad
2	3	1.5	Enhancement of DTR capacity from 40 to 100 KVA
3	7	3	Failed Due to Internal Fault

4	19	6	Shifting of DTR from one place to another place
	20	6	
	21	6	

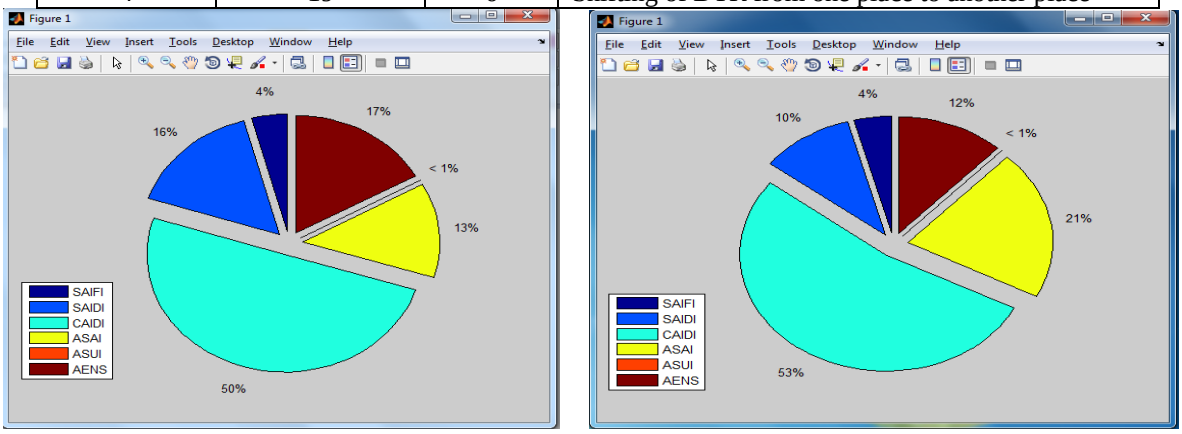
Table 10. Distribution System Reliability Indices (without isolator)

Distribution System Reliability Indices
SAIFI=0.317 interruptions/customer
SAIDI=1.220 hrs/customer
CAIDI=3.851 hrs/customer interruption
ASAI=0.999861
ASUI=0.000139
AENS=1.296 KWh/customer

When the feeder is provided with isolator at 19th node, the load point 19 will only be affected and the load points affected are reduced from 6 to 4 during 4 interruption cases. Distribution Reliability Indices are shown in Table 11. The percentage of indices is represented in pie chart as shown in Figure 10

Table 11 Interruption effect in a Calendar Year (with Isolator at 19th node)

Interruption Case	Load Point Affected	Duration (hrs)	Cause of Interruption
1	16	2	Failed Due to Overload
2	3	1.5	Enhancement of DTR capacity from 40 to 100 KVA
3	7	3	Failed Due to Internal Fault
4	19	6	Shifting of DTR from one place to another place



(a) (b)

Figure 9 Percentage of Indices representation in Pie chart

Table 12.Distribution System Reliability Indices (With Isolator)

Distribution System Reliability Indices
SAIFI=0.198 interruptions/customer
SAIDI=0.505 hrs/customer
CAIDI=2.556 hrs/customer interruption
ASAI=0.999942
ASUI=0.000058
AENS=0.577 KWh/customer

When the feeder is not provided with isolator the Average Energy Not Supplied (AENS) is 1.296 KWh/Customer. When the feeder is provided with isolator at 19th node the Average Energy Not Supplied (AENS) is reduced to 0.577 KWh/Customer.

IX. CONCLUSIONS

In this paper, a direct approach for distribution power flow solution was explained. Two matrices, which are developed from the topological characteristics of distribution systems, are used to solve

power flow problem. The BIBC matrix represents the relationship between bus current injections and branch currents, and the BCBV matrix represents the relationship between branch currents and bus voltages. These two matrices are combined to form a direct approach for solving power flow problems. Test results show that the proposed method is suitable for large-scale distribution systems. This Jeevakona feeder is already installed by 18 KVAR capacitor bank at each Distribution Transformer in LT side with pole mounted. So, there is no node having voltages less than 0.95 p.u. Hence, there is no need of capacitor placement for this feeder.

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