Reliability Evaluation and Improvement in Voltage Profile of Distribution System

Rashmi Kannur
Dept. of EEE
SDM College of Engineering and Technology
Dharwad-580002

Shivaleela Kori
Dept of EEE
Acharya Institute Of Technology
Bangalore-576107

Dr. S. G. Ankaliki
Professor, Dept. of EEE
SDM College of Engineering and Technology
Dharwad-586002

Arathi Sunkara
Dept of EEE
SDM College of Engineering and Technology
Dharwad-586002

***Abstract*-In this paper an effective approach of real time evaluation of radial distribution system is done. A power flow solution with an objective of determining the reliability indices, improving the voltage profile and reduction of power loss by placement of shunt capacitor is carried out. In this approach an analytical method is used to calculate the load and system indices for existing distribution system. To demonstrate the effectives of the proposed method, a 110/11KV substation is selected for analyzing the performance. From the result it is observed that by placement of shunt capacitor in the distribution system there is improvement in voltage profile and reduction in total loss.**

Keywords: Radial distribution system, Reliability indices, Voltage profile, Total loss.

I. INTRODUCTION

Power system efficiency depends on distribution system. Distribution system provides link between transmission system and actual customers. A distribution system normally consists of main feeder or primary feeder and laterals. The primary feeder starts from substation and passes through the major loads. Laterals connect between individual load and main feeder with distribution transformers. Radial distribution systems are popular because of their simple design and low cost.

The main function of power system is to feed loads with electric energy as economically as possible with a reasonable level of reliability and power quality. Distribution system is one of the main part of power system. It is responsible for transferring electrical energy to its end users. A distribution system is relatively cheap and outages in this part of the system have a very localised effect compared with generation and transmission system. However, analysis of the customer failure statistics of most utilities indicates that the distribution system makes the greatest individual contribution to the unavailability of supply to a customer.

Distribution system performance evaluation usually relies on reliability index to evaluate system operation. Hence, important aspects form system operations such as voltage profile, line/transformer, over loadings are normally assessed for scenarios. Recently, some researchers have focused on improving distribution system performance assessment. For that in [1] the probability distributions from the distribution system reliability indices are evaluated using a Sequential Monte Carlo simulation (SMCS) approach from the service adequacy perspective. In [2], DG peaking and standby modes are represented in an analytical approach for distribution system reliability assessment. In [3], an analytical technique for distribution system reliability is developed, where the probability of successful islanding is taken into account. In [4], the stochastic nature of the system operation with parallel connected customer controlled DG units is evaluated from the adequacy point of view.

Capacitor placement has been discussed in technical literature since 1980's as the distribution system planning and operation started. Shunt capacitors are commonly used in distribution systems to reduce the power losses, to improve the voltage profile and to increase the power flow. The [6] method of placement of capacitor done by considering some constraints like load constraints and operational constraints are presented and simulated annealing is used to solve this optimization. A [7] new and fast energy loss calculation technique is presented in this literature. The optimal placement of capacitors using loss minimization as the object is presented in lot of literatures. The energy loss calculation method is changed to make it faster. Genetic algorithm is used to solve the optimal placement problem Here [1].There are two types of switches in primary distribution systems: normally closed switches which connect line sections, and normally open switches on the tie-lines which connect two primary feeders, or two substations or loop-type laterals.

II. RELIABILITY INDICES

The distribution system operation can be assessed using analytical and Monte Carlo Simulation techniques. The reliability indices that have been evaluated using classical concepts are the three primary ones of average failure rate, average outage duration and average annual unavailability or average annual outage time. These indices will be generally referred to as failure rate, outage duration and annual outage time. Analytical technique are usually applied to compute mean value of the failure rate λi, average outage duration ri and average annual outage time Ui for each load point i of a distribution system. Although the three primary indices are fundamentally important, they do not always give a complete representation of the system behaviour and response in order to reflect the severity or significance of a system outage. Additional reliability indices can be and frequently evaluated. The load point information is further utilized to compute the mean values of additional system reliability indices such as SAIFI, SAIDI, CAIDI, ASAI, ASUI using the following equalities. The customer and load orientated indices described are very useful for assessing the severity of system failures in future reliability prediction analysis. They can also be used, however as a means of assessing the past performance of a system. In fact, at the present time, they are probably more widely used in this respect than as measures of future performance. Assessment of system of system performance is a valuable procedure for three important reasons:

(a) It establishes the chronological changes in system performance and therefore helps to identify weak areas and the need for reinforcement.
(b) It establishes existing indices which serve as a guide for acceptable values in future reliability assessments.
(c) It enables previous predictions to be compared with actual operating experience.

The evaluation of system performance indices has be illustrated by considering a real radial distribution system having 15 load point feeders. The number of customers and average load connected to this system are shown in table below.

1. System average interruption frequency index, SAIFI

$$SAIFI=\frac{\text{Total number of customer interruptions}}{\text{Total number of customer served}}=\frac{\sum \lambda iNi}{\sum Ni}$$

Where, λ_i is the failure rate and N_i is the number of customers of load point i.

2. System average interruption duration index, SAIDI

$$SAIDI=\frac{\text{Sum of customer interruption durations}}{\text{Total number of customer}}=\frac{\sum UiNi}{\sum Ni}$$

Where, U_i is the annual outage time and N_i is the number of customers of load point i.

3. Customer average interruption duration index, CAIDI

$$CAIDI=\frac{\text{Sum of customer interruption durations}}{\text{Total number of customer interruptions}}=\frac{\sum UiNi}{\sum \lambda iNi}$$

Where, λ_i is the failure rate, U_i is the annual outage time and N_i is the number of customers of load point i.

4. Average service availability index, ASAI

$$ASAI=\frac{\text{Customer hours of available service}}{\text{Customer hours demanded}}=\frac{\sum Ni*8760-\sum UiNi}{\sum Ni*8760}$$

Where, 8760 is the number of hours in a calendar year.

5. Average service unavailability index, ASUI

$$ASUI=\frac{\text{Customer hour of unavailable service}}{\text{customer hours demand}}=1-ASAI$$

III. LOAD FLOW

The power system is a large interconnected system, where various buses are connected by transmission lines. At any bus, complex power is injected into the bus by the generators and complex power is drawn by the loads. Of course at any bus, either one of them is not present. The power is transported from one bus to other via transmission lines. Load flow studies are important in planning and designing future expansion. Load flow studies give steady state solution of the voltage at all the buses, for a particular load condition. Different steady state solution can be obtained for different operating conditions to help in planning, design and operation of the power system.

Algorithm for capacitor placement:

1. Run the load flow program and find the value of (i) Voltages at all nodes (ii) total real power loss (iii) total reactive power loss.
2. Using these voltages and power at all nodes calculate the capacitance current I_c. Using the equation $V_R=V_S-[IR\cos\varphi + (I\sin\varphi-I_c)X]$
3. Find the capacitive reactance by $I_c=V/X_c$.
4. Calculate $B_c=1/X_c$ and
5. Find the capacitor value in Mvar.
6. Connect this capacitor at that particular node where the voltage is minimum.
7. Run the load flow program again and now compute the new values of voltage, total real power loss and total reactive power loss.

IV. CASE STUDY

The distribution network of Bijapur substation is shown in the figure 1.This station is fed from Bijapur 220/110KV receiving station. The area of study for the analysis of Bijapur distribution station region where number of customers are within one lakh and type of customers include residential, commercial or industrial. This system is used to evaluate the performance of distribution system. A real radial distribution system of Bijapur District has been considered with 15 feeders, 3 transformers as shown in fig (1).

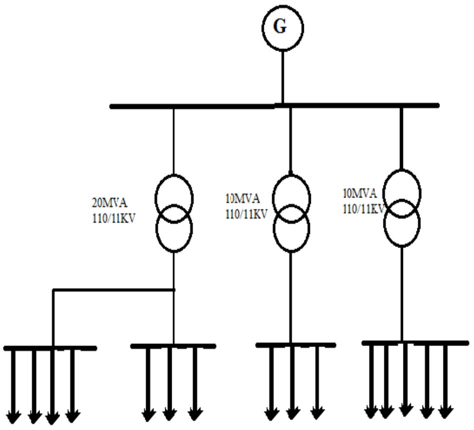


Fig (1): Single Line Diagram of Bijapur Distribution Station

Table (1): Load point reliability indices:

Sl No	Feeder	No of Customers	λ_i (f/yr)	U_i (hr/yr)	r_i (hr)
1	Atallati	500	0.0711	0.0495	0.6966
2	Jumanal	3000	0.0334	0.0151	0.4539
3	Hitanhalli	2500	0.0302	0.0123	0.4075
4	Ganesh Nagar	3000	0.0385	0.0133	0.3461
5	Jalanagar	5000	0.0239	0.0093	0.3904
6	Badikaman	8000	0.0323	0.0105	0.3250
7	Honaganahalli	800	0.0627	0.0318	0.5072
8	Power House	6000	0.0312	0.0116	0.3722
9	Indira Nagar	3000	0.0712	0.0176	0.2484
10	Meenaxi	6000	0.0364	0.0107	0.2946
11	Torvai	3000	0.0481	0.0141	0.2938
12	Water Tank	7000	0.0576	0.01553	0.26931
13	Akashvani	12000	0.0375	0.0114	0.3039
14	VijayCollage	6000	0.0321	0.0106	0.3297
15	Siddeshwar	7500	0.0333	0.0237	0.7123

Table (2): System reliability indices:

Sl No	Index	Analyt
1	SAIFI	0.6403
2	SAIDI	1.258
3	CAIDI	1.965
4	ASAI	0.9999
5	ASUI	0.0001

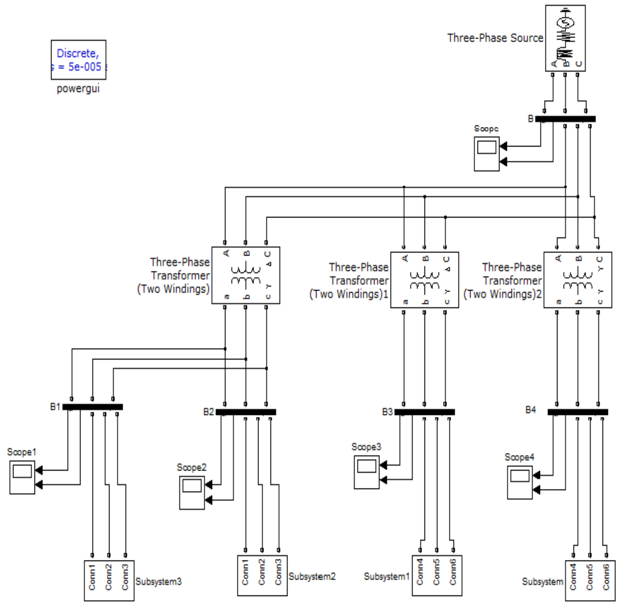
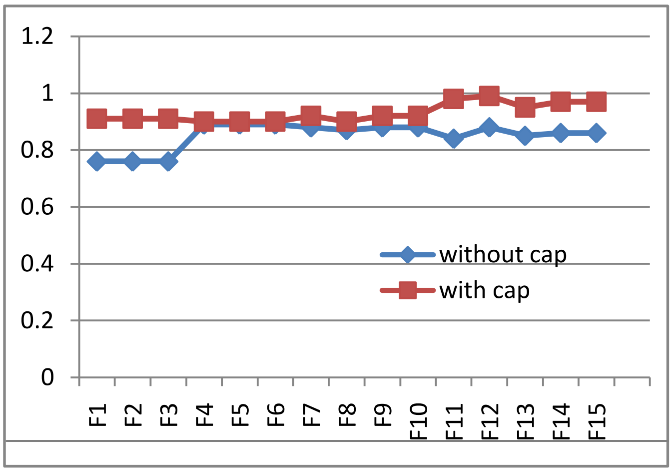


Fig (2): Simulink model of distribution system

Table (3): System data

Feeder No	Line Voltage	Length in Km	R+jX Ohm/km	Load (MW)	Pf
1	11	8	0.9116+j0.314	2.753	0.85
2	11	9	0.9116+j0.314	2.753	0.85
3	11	10	0.9116+j0.314	2.753	0.85
4	11	2	0.5449+j0.301	2.753	0.85
5	11	1	0.5449+j0.301	2.753	0.85
6	11	2	0.5449+j0.301	2.753	0.85
7	11	16	0.9116+j0.314	2.753	0.85
8	11	4	0.5449+j0.301	2.753	0.85
9	11	3	0.5449+j0.301	2.753	0.85
10	11	2	0.5449+j0.301	2.753	0.85
11	11	6	0.5449+j0.301	2.753	0.85
12	11	2	0.5449+j0.301	2.753	0.85
13	11	4	0.5449+j0.301	2.753	0.85
14	11	3	0.5449+j0.301	2.753	0.85
15	11	3	0.5449+j0.301	2.753	0.85



Fig(3): Bus voltage with and without capacitor

V. RESULT AND CONCLUSION

Fig.3 shows the bus voltages with and without capacitor placement at optimum locations it is observed there was improvement in voltage profile at respective buses where capacitor is placed. With the improvement in bus voltages, the overall system losses were reduced with MVAR compensation at various locations. It is seen that the optimum location obtained is feeder 1, 2, 3 and 11 by placing shunt capacitors and at this location the voltages at these buses are improved with decrease in overall losses in system. Before capacitor placement, the voltages at feeder 1, 2 ,3 and 11 were 0.76 p.u and 0.84 pu. The losses were 2.31 MW and 6.22 MVAR. After placing the shunt capacitors at these buses the voltages were improved to 0.91, 0.98 p.u and the losses were reduced to 2MW and 6MVAR. And also an analytical method is used to calculate load point and system indices. Finally, simulation results for Bijapur distribution system are presented.

VI. REFERENCES

[1] A. M. Leite da Silva, A. M. Cassula, L. C. Nascimento, J. C.Freire, C. E. Sacramento, and A. C. R. Guimaraes Chronological monte carlo-based assessment of Distribution system reliability. *9th PMAPS Proceedings*, Jun. 2006.

[2] In-Su Bae and Jin-O Kim. Reliability evaluation of distributed generation based on operation mode. *IEEE Transactions on Power Systems*, 22(2):785 . 790, May 2007.

[3] Y.M. Atwa and E.F. El-Saadany. Reliability evaluation for distribution system with renewable distributed generation during islanded mode of operation. *IEEE Transactions on Power Systems*, 24(2):572 .581, May 2009.

[4] Y.G. Hegazy, M.M.A. Salama, and A.Y. Chikhani. Adequacy assessment of distributed generation systems using monte carlo simulation. *IEEE Transactions on Power Systems*, 18(1):48 . 52, Feb. 2003.

[5] Roy Billinton and Ronald N. Allan, '*Reliability Evaluation Of Power Systems'* second edition-1996.

[6] H. D. Chiang, J. C. Wang, O. Cocking, and H. D. Shin, "Optimal capacitors placements in distribution systems, part I: A new formulation of the overall problem," *IEEE Trans. Power Del.*vol. 5, no. 2, pp.634–642, Apr. 1990.

[7] G. Levitin, A. Kalyuzhny, A. Shenkman, and M. Chertkov, "Optimal capacitor allocation in distribution systems using a genetic algorithm and a fast energy loss computation technique," *IEEE Trans. Power Del.*, vol. 15, no. 2, pp. 623–628, Apr. 2000.

[8] M. A. Kashem, V. Ganapathy and G. B. Jasmon "Network Reconfiguration for Enhancement of Voltage Stability in Distribution Networks" IEE Proc-Generation, Transmission distribution, Vol.147, No.3, PP171-175, May 2000.

[9] B.Venkatesh, Rakesh Ranjan "Optimal Radial Distribution System Reconfiguration Using Fuzzy adaptation of Evolutionary Programming", Electrical Power and Energy Systems, No. 25, PP 775-780, 2003.

[10] P. J. Lagace "Network Voltage Profile Correction by Discrete Shunt Compensation", Mathematics and Computers in Simulation, No. 63, PP 461-469, 2003.

[11] D. Das "Reactive Power Compensation For Radial Distribution Network Using Genetic Algorithm", Electrical Power and Energy Systems, No. 24, PP 573-581, 2002.

[12] C. Bhargava, P.S.R. Murthy and k.Alekhya " Assessment of Reliability for Distribution Feeders on the Basis of Cost Analysis." Bonfring International Journal of Power Systems and Integrated Circuits, Vol. 1, Special Issue, December 2011.