Indian J.Sci.Res. 17(2): 21-28, 2018

ISSN: 0976-2876 (Print)
ISSN: 2250-0138(Online)

REAL TIME ANALYSIS OF POWERLOSSES OF 33KV SUB-TRANSMISSION NETWORK

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Abstract:Sub-transmissionis part of an electric power transmission system that runs at relatively lower voltages. It is uneconomical to connect all distribution substations to the high main transmission voltage, because the equipment is larger and more expensive. Typically, only larger substations connect with this high voltage. It is stepped down and sent to smaller substations in towns and neighborhoods. While sub-transmission circuits are usually carried on overhead lines, in urban areas buried cable may be used. The lower-voltage sub-transmission lines use less right-of-way and simpler structures; it is much more feasible to put them underground where needed. Higher-voltage lines require more space and are usually above-ground since putting them underground is very expensive. Transmitting electricity at high voltage reduces the fraction of energy lost to resistance, which varies depending on the specific conductors, the current flowing, and the length of the transmission line. This paper presents the real time valuation of radial 33kV sub-transmission three phase networkof Tirupati town with a goal of reducing the power losses of the substations caused by overloading of the feeders and maintaining the Bus voltage standards even in the loading conditions by performing the Distribution load flow using BIBC and BCBV matrix method.

Keywords**:-**Sub-Transmission system, Radial Distribution network, Load flow studies, BIBC and BCBV matrix method

I. Introduction

Power is generated for the consumer utilization. From when power is generated it is transmitted through transmission lines via grids & then distributed to the consumer. Power distribution is the final and most crucial link in the electricity supply chain and most visible part of the electricity sector, according to Power Grid Corporation of India Limited current distribution losses is about 30%.

Distribution losses can be caused by theft of Electricity, low metering levels and poor financial health of utilities with low cost recovery, which generally causes power quality issues and increase in the cost to electricity supply. Loss of power in Distribution sector also causes increase in cost to produce more power, and the global warming concerns. Distribution losses can be classified into categories of technical losses and non-technical losses. The technical losses are most visible losses because it is related to material properties and its resistance to the flow of current that is also dissipated as heat. The technical losses can be clearly classified as the losses in power dissipated in distribution lines and transformers due to their internal resistance.

The deregulation and privatization are posing new challenges to the distribution systems. System elements are going to be loaded up to their thermal limits, and wide-area power trading with fast varying load patterns will contribute to an increasing congestion. About 30 to 40 % of total investments in the electrical sector go to distribution systems, but nevertheless, they have not received the technological impact in the same manner as the generation and transmission systems. Nevertheless, there is an increasing trend to automate distribution systems to improve their reliability, efficiency and service quality. Ideally, losses in an electric system should be around 3 to 6%. In developed countries, it is not greater than 10%.However, in developing countries, the percentage of active power losses is around 20%; therefore, utilities in the electric sector are currently interested in reducing it in order to be more competitive, since the electricity prices in deregulated markets are related to the system losses. In India, collective of all states, in 2008 the technical and non-technical losses are accounted as 23% of the total input energy. To manage a loss reduction program in a distribution system it is necessary to use effective and efficient computational tools that allow quantifying the loss in each different network element for system losses reduction.

Energy losses occur in the process of supplying electricity to consumers due to technical and commercial losses. The technical losses are due to energy dissipated in the conductors and equipment used for transmission, transformation, sub- transmission and distribution of power. These technical losses are inherent in a system and can be reduced to an optimum level. The losses can be further sub grouped depending upon the stage of power transformation & transmission system as Transmission Losses (400kV/220kV/132kV/66kV), as Sub transmission losses (33kV /11kV) and Distribution losses (11kV/0.4kv). The commercial losses are caused by pilferage defective meters, and errors in meter reading and in estimating unmetered supply of energy. In India, average

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Transmission and Distribution losses, have been officially indicated as 23 percent of the electricity generated. However, as per sample studies carried out by independent agencies including TERI, these losses have been estimated to be as high as 50 percent in some state. The officially declared transmission and distribution losses in India have gradually risen from about 15 percent up to the year 1966-67 to about 23 percent in 1998-99. The continued rising trend in the losses is a matter of serious concern and all out efforts are required to contain the them. According to a study carried out by Electric Power Research Institute (EPRI) of the USA some time back, the losses in various elements of the T&D system usually are of the order as indicated in Table I.

Table I

The losses in various elements of the T&D system

Supply System	Power losses
Minimum Maximum Step-up transformers & EHV transmission system	0.5- 1.0
Transformation to intermediate voltage level, transmission system & step down to sub-transmission voltage level	1.5- 3.0
Sub-transmission system & step-down to distribution voltage level	2.0 - 4.5
Distribution lines and service connections	3.0 - 7.0
Total Losses	7.0 - 15.5

The losses in any system would, however, depend on the pattern of energy use, intensity of load demand, load density, and capability and configuration of the transmission and distribution system that vary for various system elements.

II. Distribution Network

The primary distribution networks are electrical circuits with three-phase wire (three phase), connected at distribution substation and are usually built in classes of voltage of 11kV & 33kV. The levels of voltage: 11 kV and 33 kV are standardized by law; the other levels exist and continue to operate normally. Primary distribution networks are installed with distribution transformers, fixed on poles, whose function is to lower the voltage level to the primary side voltage level (e.g., for download from 11 kV to 230 Volts). The secondary distribution networks are electrical circuits with three-phase four wires (three phases and neutral), typically operate at voltages (phase - phase / phase - neutral) 11kV/440 volts, 11kV/230 volts. These networks are connected consumers, including residences, bakeries, shops, and so on, and also the fixtures for street lighting. These networks serve the large consumption centres (namely, population and large industry, among others). In some cases, the tension between supplies is 1100/230 volts or 1100/440 volts. The entire distribution system is protected by a system composed by circuit breakers at the substations where the primary networks are connected, and with key fuse in distribution transformers, which in case of short circuit switch off the power grid.

A. Occurrence of losses:

- ✓ Sub Transmission Lines
- ✓ Distribution Lines
- ✓ Station transformer
- ✓ Secondary Service to Customer

BReasons for occurrence of losses:

- ✓ Inadequate investment on transmission and distribution, particularly in sub-transmission and distribution.
- ✓ Haphazard growths of sub-transmission and distribution system with the short-term objective of extension of power supply to new areas.
- ✓ Large scale rural electrification through long 11kV and LT lines.
- ✓ Too many stages of transformations.
- ✓ Improper load management.
- ✓ Inadequate reactive compensation
- ✓ Poor quality of equipment used in agricultural pumping in rural areas, cooler
- ✓ air-conditioners and industrial loads in urban areas.

C.Remedial action to be taken:

- ➢ Resizing of Conductors
- ➢ Installation of capacitor banks
- ➢ Relocation of distribution transformers.
- ➢ Ensuring a constant Power Factor to industrial users.
- ➢ Avoiding overloading of transformers.
- ➢ Construction of a substation using underground cables at loading point if necessary.

III. Load Flow Studies

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 order to evaluate the performance of a power distribution system and to examine the effectiveness of proposed modifications to a system in the planning stage, it is essential that a load flow analysis of the system is to be repeatedly carried-out. It basically gives the steady state operating condition of a distribution system corresponding to a specified load on the system. Certain applications, particularly in the distribution automation (i.e., VAR planning, state estimation, etc.) and optimization of power system require repeated load flow solutions.

Load flow studies are the back bone of power system analysis and design. It gives the steady state solution of a power system network for normal operating condition which helps in continuous monitoring of the current state of the system. It is also employed for planning, optimization and stability studies. Hence an efficient and fast load flow method is required. Load Flow Studies (LFS) are needed to be conducted to evaluate the voltage at each bus, branch currents, system losses and to verify whether the conductors and transformers are overloaded or not. As the distribution system has a topological characteristic like high R/X and unbalanced loads, the frequently used LFS methodologies are not applicable such methods are GS, NR and decouple methods. So in order to overcome all these difficulties and efficient and powerful method which suits for radial structure are developed. This type of methodologies requires new data format and some data manipulations are needed to be performed.The methods which suits for radial distribution system LFS are

1) Power Summation Method

2) Single Line Equivalent Method

3) Very Fast Decouple Method

4) BIBC and BCBV Matrix Method

5) Forward and Backward Method.

In this respective research the BIBC and BCBV matrix method was adopted, due to its easy implementation and fast convergence characteristics and better performance. In this method two matrices Bus injection to branch currents (BIBC) and Branch Current to Bus Voltage (BCBV) are needed to be developed. The step by step methodology for conducting BIBC and BCBV matrix method was discussed.

A. Algorithm for BIBC and BCBV Matrix Method:

Step-1: Read the line and load data of System.

Step-2: BIBC Matrix can be formulated using above steps. The relationship can be expressed as

[B]=[BIBC][B]

Step-3: BCBV Matrix can be formulated using above steps. The relationship can be expressed as

$[\Delta V] = [BCBV][B]$

Step-4: Form the DLF matrix

$[DLF]=[BIBC][BCBV]$ $[\Delta V] = [DLF]\,[I]$

Step-5: Set iteration k=0

Step-6: Iteration k=k+1

Step-7: Update the voltages by using,

$[\Delta V] = [DLF]\,[I]$

Step-8: If V>Tolerance go to step-6.

Step-9: Calculates final voltage at each bus.

Step-10: Print bus voltages.

IV.Study of 33kV Network

A.Test system I:

Radial 33kV Sub-Transmission network was taken for validating the results to evaluate the performance of load flow studies. Base MVA=100, Conductor type=ACSR(AluminiumConductor Steel reinforced) DOG,Basevoltage=33kV,Resistance=0.55ohm/kM,Reactance= 0.351ohm/kM.The 21 Bus system has 20 branches with the total load of 89.43 MW and 27.636 MVAR shown in Figure 1.Table 1 and 2 indicates the Linedata and Load data of 21 Bus system. The single linediagram of 21 Bus system was represented in Figure1

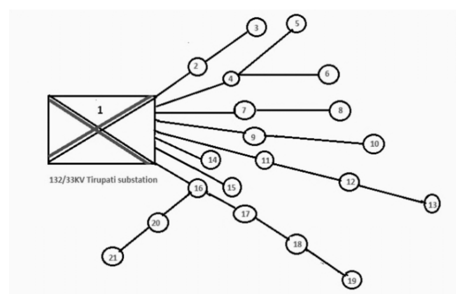


Figure1: Radial 33kV 21-Bus system

Table 1: Line data of 21-Bus system

Branch No.	Sending End Node	Receiving End Node	Resistance R (ohms)	Reactance X (ohms)
1	1	2	0.561	0.525
2	2	3	1.021	0.955
3	1	4	1.798	1.683
4	4	5	0.822	0.77
5	4	6	3.1603	2.957
6	1	7	0.1309	0.1225
7	7	8	0.8976	0.84
8	1	9	0.5984	0.56
9	9	10	1.0846	1.015
10	1	11	2.6554	2.48
11	11	12	0.5984	0.56
12	12	13	0.748	0.7
13	1	14	0.0187	0.0175
14	1	15	1.5334	1.435
15	1	16	1.3838	1.295

16	16	17	1.0846	1.015
17	17	18	0.7106	0.665
18	18	19	1.084	1.015
19	16	20	2.244	2.1
20	20	21	1.3464	1.26

Table 2: Load data of 21-Bus system

Bus No.	Real power (MW) P	Reactive power (MVAr)Q
1	0	0
2	4.33	0.639
3	5.3	1.03
4	0	0
5	3.7	1.6855
6	3.1	1.501
7	4	0.812
8	6.2	1.258
9	8.25	1.675
10	6.65	1.350
11	3.46	8.64
12	3.83	0.276
13	5.0	1.97
14	7.25	1.033
15	15.15	2.158
16	0	0
17	2.66	0.772
18	2.06	0.287
19	1.3	0.324
20	3.58	1.04
21	3.61	1.186

B.Test system II:

This involves a new 132/33kV substation named *ALIPIRI SUBSTATION*connecting four feeders which of the three feeders previously fed by 132/33 KV Tirupati SS and newly added three 33/11kV buses. It has total load of 30.99 MW and 5.298MVar.The remaining feeders of the town are fed by 132/33kV Tirupati SS.

Figure (a):11-Bus system.

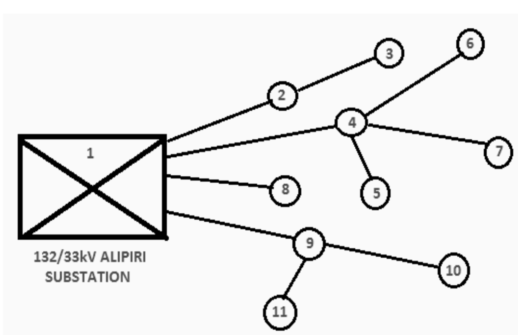


Figure (a): 11-Bus system.

Table (a): Line data of 11-Bus system

Branch No.	Sending End Node	Receiving End Node	Resistance R (ohms)	Reactance X (ohms)
1	1	2	1.122	1.05
2	2	3	0.4488	0.42
3	1	4	1.87	1.75
4	4	5	0.561	0.525
5	4	6	0.748	0.7
6	4	7	0.3366	0.315
7	1	8	1.496	1.4
8	1	9	0.5984	0.56
9	9	10	0.561	0.525
10	9	11	0.7854	0.735

Table (b): Load data of 9-Bus system

Bus No.	Real power (MW)	Reactive power (MVAR)
1	0	0
2	2.1	0.411
3	4.1	0.703
4	3.8	0.478
5	4.4	0.594
6	6.85	1.174
7	0.5	0.070
8	3.2	0.677
9	2.25	0.523
10	1.9	0.338
11	1.8	0.33

Remaining feeders fed by 132/33kV Tirupati substationand it has total load of45.38MWand10.95MVar.

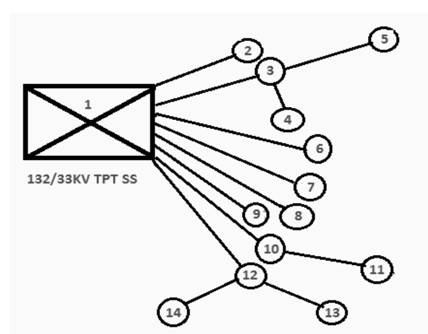


Figure (b): 14-Bus system.

Table (a): Line data for 14-Bus system

Branch No.	Sending End Node	Receiving End Node	Resistance R	Reactance X

			(ohms)	(ohms)
1	1	2	0.7293	0.6825
2	1	3	1.122	1.05
3	3	4	0.3366	0.315
4	3	5	0.4114	0.385
5	1	6	0.561	0.525
6	1	7	0.0187	0.0175
7	1	8	0.2805	0.2625
8	1	9	1.5708	1.47
9	1	10	3.6278	3.395
10	10	11	1.3464	1.26
11	1	12	1.7989	1.6835
12	12	13	0.8228	0.77
13	12	14	3.1603	2.9575

Table (b): Load data for 14-Bus system

Bus No.	Real power (MW) P	Reactive power(MVar) Q
1	0	0
2	6.2	1.225
3	0	0
4	1.9	0.438
5	4.8	0.933
6	3.93	1.132
7	7.34	1.016
8	3	0.875
9	6.16	0.861
10	2.95	1.046
11	3.55	1.144
12	0	0
13	3	1.275
14	2.55	1.005

V. Results and Discussions

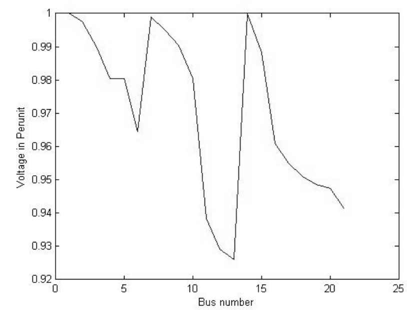
Load flow studies are performed on both the Test systems above using BIBC and BCBV matrix method solution .The losses due to overloading of the feeders are compared by addition of a new 132/33kV substation .The voltage profiles and powerlosses are shown in tables.

Load flow study performed on First test system:

It has Radial Network consists of 21 buses and 8 feeders. Each feeder has two (or) more connecting substations. Load flows are performedwith the system involving multiple connections from Slack bus (i.e. Reference bus).Incoming supply is taken from 132kVRenigunta,It is stepped down to 33kVVoltage.132/33kVTirupati SS is taken as reference bus (Slack bus).The output is as follows:

Power loss of the 132/33kV Tirupati Substation in KW = **2.36MW**

Voltage profile of the system at each bus:



Load flow study on second Test system:

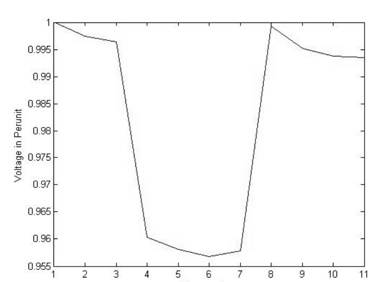
Division of some of the feeders from 132/33kV TPT SS is made. Those feeders are connected to 132/33kVAlipri SS and the remaining feeders are as usually fed by TPT SS itself. Analyzing the load flows of these two substations gives that the power loss of the Tirupati substation gets decreased by 70% of the previous system losses.132/33kV Tirupati substation has total load of 52.73MW and 12.194MVar.The outputs of the two substations are as follows:

Power loss of the 132/33kV Alipiri substation in KW=0.41MW

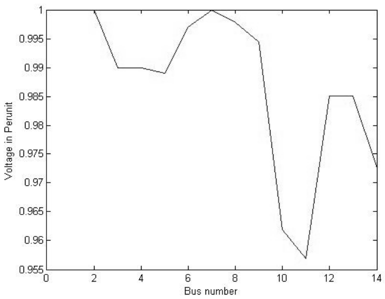
Power loss of the 132/33kV Tirupati substation in KW=1.00MW

One can analyze from the Load flow study of the two systems that the burden on the substation due to overloading hasbeen decreased compared toloadedsystem. The distance and length of the line is reduced. The voltage profile and power factor is up to standards. The system improved its reliability and stability in transmitting power.

Voltage profile of the Alipiri substation



Voltage profile of Tirupati substation



Two case studies have been studied in this paper. Increment and decrement of loads on the systems are studied.

Case study-I:

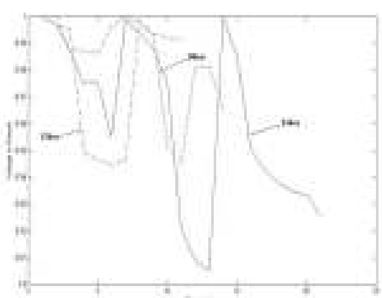
In the first case study 25% of load is added to the existing load. The load flow study is performed on the system. The power loss and the voltage profiles of the above three systems are shown below.

Power loss of the 21-Bus system=3.80 MW

Power loss of the 14-Bus system =1.59 MW

Power loss of the 11-Bus system =0.66 MW

Comparing the graphs of Voltage profiles of three systems are shown below



Case study-II:

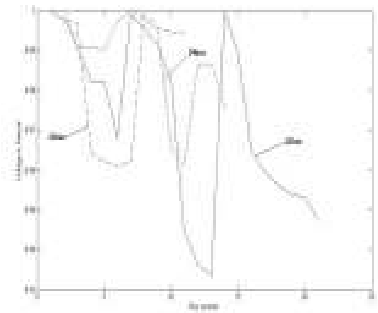
In the second case study 10% of the load is decreased to the existing load. The load flow study is performed on the system. The power loss and the voltage profiles of the above three systems are shown below:

Power loss of the 21-Bus system =1.90 MW

Power loss of the 14-Bus system =**0.81 MW**

Power loss of the 9-Bus system =**0.33 MW**

Comparing the graphs of Voltage profiles of three systems are shown below



VI. Conclusion

Table (a): From the study analysis

132/33kV Alipiri Substation			
132/33kV Alipirisubstation (with addition of new 33/11 kV substation)	Power loss (MW)	Vminimum (P.u)	Vmaximum (P.u)
	0.41	0.9568 (at 6th bus)	0.9992 (at 8th bus)

For Unmodified system	Power loss (MW)		Vminimum (p.u)	Vmaximum (p.u)
	2.36		0.9261 (at 13th bus)	0.9999 (at 14th bus)
For Modified system (after addition of new 33/11kV substation)	Power loss (MW)	% Improvement	0.9567 (at 11th bus)	0.9999 (at 7th bus)
	1.00	57.6%		
132/33kV Tirupati Substation				

%Voltage Regulation of lengthiest feeder of unmodified system at tail end is 2.14%

Table(b): %Voltage Regulation of 132/33kVTirupati substation

%Voltage Regulation at the tail ends of the feeders of 132/33kV Tirupati Substation	
Feeder No.	*%V.R*
1	0.49

2	0.99
3	0.25
4	0.01
5	0.08
6	0.77
7	0.58
8 (Lengthiest feeder)	1.03

Table(c): %Voltage Regulation of 132/33kV Alipiri substation

%Voltage Regulation at the tail ends of the feeders of 132/33kV Alipiri Substation	
Feeder No.	*%V.R*
1	0.25
2 (Lengthiest feeder)	0.55
3	0.54
4	0.27

Table(d): From the case studies

132/33kV Tirupati Substation							
	For Unmodified system			For Modified system			
	Power loss (MW)	V minimum (p.u)	V maximum (p.u)	Power loss (MW)	% Improve-ment	V minimum (p.u	V maximum (p.u
For 25% increment of load	**3.80**	**0.9051**	**0.9999**	**1.59**	**58.15%**	**0.9451**	**0.9999**
Base load case (for 100 % load)	**2.36**	**0.9261**	**0.9999**	**1.00**	**57.62%**	**0.9567**	**0.9999**
For 10% decrement of load	**1.90**	**0.9336**	**0.9999**	**0.81**	**57.36%**	**0.9612**	**0.9999**

132/33kV Alipiri Substation			
	Power loss(MW)	V minimum (P.u) (at 6th bus)	V maximum (P.u) (at 8th bus)
For 25% increment of load	**0.66**	**0.9449**	**0.9990**
Base load case (for 100% load)	**0.41**	**0.9568**	**0.9992**
For 10% decrement of load	**0.33**	**0.9611**	**0.9993**

From the above test systems, in the first test system the feeders are on one substation and in the second test system (a) a new substation is added with some feeders and remaining feeders are fed by test system (b).Because of the division of the feeders one can see that 57.6% of the power loss of first test system has been reduced in the second test system (b).Test system (a) has negligible power loss and is in stable operation.

From the above mentioned two case studies when the load is 25% increased the voltage profile of the test system-I has 0.905p.u as minimum and test system-II(a) has 0.9451p.u as minimum and test system-II(b) has 0.9449p.u as minimum. When we see the base case the voltage profile of the test system-I has 0.925p.u as minimum and test system-II(a) has 0.9567p.u as minimum and test system-II(b) has 0.9568p.u .When the load is decreased by 10% the voltage profile of the test system-I has 0.934p.u as minimum and test system-II(a) has 0.9612p.u as minimum and test system-II(b) has0.9611p.u as minimum voltage.So,when we compare the three cases when the load is decreased the voltage profile of the systems are got improved and the power loss of the systems got reduced. The results are also graphically shown.Further one can add one more substation with latest technology and with optimal capacity equipment's in order to meet the Demand and to get rid of the overloading on the feeders if necessary.

Acknowledgement

Our sincere thanks to A.PTRANSCO for giving me permission to do this project.

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