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Estimation of Technical Losses in Power Distribution System Using Top-Down Bottom-Up Method

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ABSTRACT
The developing country like India faces shortage of electrical power. Power distribution utilities in India are facing many problems like commercial loss due to various inefficiencies, and high technical losses. This has a very bad effect on the economic growth of our country. Power system losses comprises of technical losses, non-technical losses & revenue losses. This research paper aims at the estimation and computation of technical losses in the distribution system based on the top-down and bottom-up approach when a complete set of data is not available.

KEYWORDS: *technical losses, power distribution system, distribution transformer (DT), bottom-up, top-down, transmission and Distribution (T&D), etc.*

I. INTRODUCTION

In India the percentage of transmission and distribution losses has been quite high. The term distribution losses refers to the difference between the amount of energy delivered to the distribution system and amount of energy consumer billed. Distribution losses are of two types: technical and non-technical. India is the fifth largest producer and consumer of electricity in the world, however, 24x7 power supply still remains a dream unfulfilled.

Electricity grids in the developed markets expect losses below 15%, but the losses by India's state utilities, over the past five years, were as high as 30% equal to about 1.5% of the country's GDP[1-3]. About one-third of that loss is technical, but the rest is either given away for free or at subsidized rates to farmers, or lost to pilferage. Utility generation companies have little control over that; the losses are mainly due to the distribution companies which are mostly state owned enterprises.

These distribution companies also conduct regular load shedding and intentional blackouts in certain areas to manage demand, as revenue collection doesn't always cover the bills to power generators. Although India has almost doubled its energy generation in the past decade, its old and inefficient distribution and transmission network lose more than 10 GW of this generated power.

For the proper and accurate measurement of power losses in the power distribution utilities, one must identify and found different power losses like technical and non-technical losses. This is the today's need of our developing country is more important where total T&D loss % loss are very high. The power distribution utilities should estimate the losses where the data for computing the technical and non-technical losses are generally not available. The top-down and bottom-up approach is used for estimating and calculating the losses for primary and secondary distribution system.

The paper provides a brief description of technical and non-technical losses in Section-2. Section-3, 4 & 5 give the methodology for estimating losses with top-down bottom-up approaches. Section-6 &7 reports the case study and its results. Conclusions are put forth in Section-8.

II. TECHNICAL & NON-TECHNICAL LOSSES

Total system losses may be disaggregated into transmission and distribution losses as follows[4,7]:

Total Losses = $T_{LT}+T_{LNT}+D_{LT}+D_{LNT}$

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Where T_{LT} and T_{LNT} are the technical and nontechnical transmission losses, respectively, And D_{LT} and D_{LNT} are technical and non-technical distribution losses, respectively. Above equation assumes that generation injections are net-rather than gross-quantities. Otherwise, that equation can be modified in the obvious manner. Nontechnical losses in transmission systems are often associated with inaccuracies with the metering system at the points where electricity is purchased or sold at a wholesale level (rather than with theft). Thus, for all practical purposes, non-technical transmission losses are negligible, and as a result, can be simplified as follows:

Total Losses = $T_{LT}+D_{LT}+D_{LNT}$

Accurate estimates of technical losses in transmission systems are generally on hand, given that both data and software tools are typically available.

2.1 Technical Losses in Distribution Systems (D_{LT})

The technical losses in distribution systems are contributed by the high voltage (HV) to medium voltage (MV) substation transformers as well as by the MV distribution circuits, the MV to low voltage (LV) transformers, the LV circuits, the customer service drops, and the end-user meters [5]. Technical losses were estimated using the well-known LF and LLF for transformer and for the feeder. These included the load losses in the HV to MV substation transformers as well as the losses contributed by the MV distribution circuits and the load losses of the MV to LV transformers. Loss ratios in the LV circuits, customer service drops, and end-user meters were estimated as approximately less than 3% by calculating the technical loss we can easily find out the non-technical losses and we can find measure for reducing the losses and we can improve the system performance.

2.2 Non-technical Losses in Distribution Systems (D_{LNT})

In distribution systems, the sources of nontechnical losses are

- deficiencies in the commercial cycle, including unread or improperly read meters and/or inaccurate logging of readings;
- non-metered supply, due to a lack of meters (in these cases, consumption is often estimated);
- inaccurate meters;
- meter tampering and meter bypass;
- Illegal connections (theft), i.e., energy diverted by illegal taps in the network.

Nontechnical losses in distribution systems generally occur in the LV network, although sometimes, they are also originated in the MV system. In this last case, nontechnical losses are normally associated with meter inaccuracy or meter tampering or, more properly, with tampering with the measurement transformers, especially the current transformers (CTs). Once total distribution losses (D_L) and the technical distribution losses (D_{LT}) are known, non-technical losses (D_{LNT}) are easy to compute, as follows:

$$D_{LNT} = D_L - D_{LT}$$

Carlos A Dortolina and Ramon Nadira [6] proposed a top- down/ bottom-up approach for accurately estimating technical losses in power distribution system when a complete set of modelling data is not available. According to them, result yielded by top-down bottom- up approach must be in agreement with each other. Otherwise additional analyses need to be conducted to reconcile the difference.

III. METHODOLOGY FOR ESTIMATING DISTRIBUTION LOSSES

Approaches that are used to calculate the technical loss in the distribution system are broadly classified in following two categories: 1) top-down 2) bottom-up as shown in fig.3.1

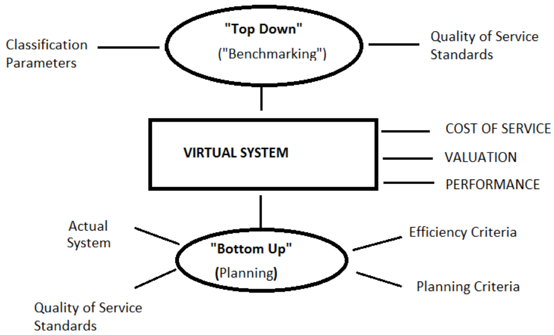

Fig.3.1 Top-Down/Bottom-Up Approach

The result, calculated from the top-down and bottom-up approach must be in agreement with each other. Otherwise, additional analysis needs to be conducted in order to reconcile the differences.

IV. TOP-DOWN APPROACH

The top-down analysis is applied to estimate the technical and non-technical losses for incomplete set of data.

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The top-down approach to estimate the technical and non-technical losses in a power distribution network consists of three steps as:

Step 1: Functional Variables: This step gives the valuation of functional variables, i.e., variable that contain appropriate information to describe the performance evaluation of the power distribution system at the HT and LT feeder. For example, in case of HT feeder, the functional variables are (i) the units consumed per consumer (ii) the number of consumers per length of feeder whereas in case of secondary distribution system, the variable is the units consumed or the no. of consumers per length of feeder.

In a primary distribution system based on the category of the consumers, the technical loss % is variably dependent upon the units consumed per consumer and the number of consumers per length of feeder [6]. For the same no. of consumers, the technical loss % is different for high load consumption vs. medium/low load consumption. For example, the technical loss % is different for industrial consumers vs. domestic/commercial consumers depending upon various parameters like connected load, consumption, utilization factor etc.

The technical loss % is therefore different in case of these two categories. However, the functional variable describes that the higher units consumed per consumer and/or the higher the number of consumers per length of feeder, the smaller should be the technical loss %.

In case of secondary distribution system, if the units consumed or the no. of consumers per length of the feeder is higher, the technical loss % is higher as shown in fig. 4.4

Step 2: Formulation of clusters: This step Involves the formulation of clusters in terms of functional variables, i.e., the determination of "closeness" of the specific distribution system under consideration to other distribution system whose characteristics are almost similar. The clusters are formed as per table No. 4.2

Step 3: Estimation of losses: this step assumes that similar distribution system have comparable technical losses (on percentage basis). As such technical losses of the distribution system under consideration are estimated from those of the system close to it (close to same cluster).

Top down approach is basically based on "benchmarking". So this approach following points should be taken care of:

1. The two distribution networks don't perform in a similar manner so, formulation of clusters should be properly done although in some cases it is not valid.
2. Benchmarking analysis tends to be broad rather than specific.

We took examples to illustrate the functional variables for both industrial and domestic/commercial consumers. Fig. 4.1 shows the relationship between the no. of consumers per kilometer of HT feeder and the technical loss % for industrial and domestic/ commercial consumers.

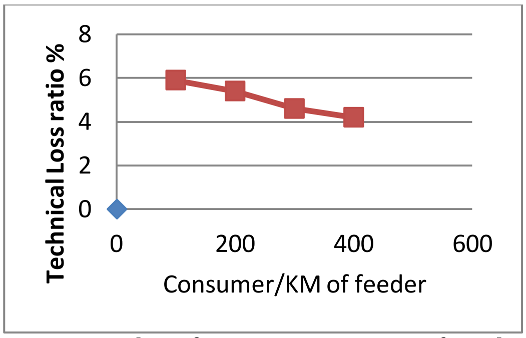

Fig. 4.1Number of Consumers per KM of Feeder versus Technical loss ratio for domestic/commercial consumers

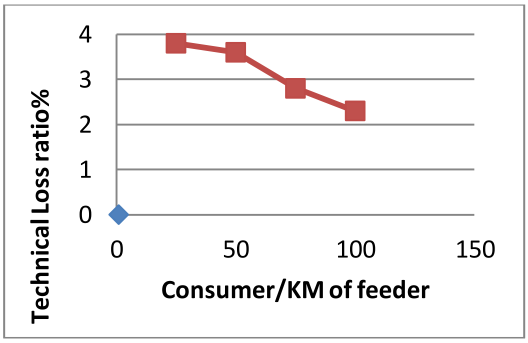

Fig. 4.2Number of Consumers per KM of feeder versus Technical loss ratio of industrial feeder

Fig. 4.3 & 4.4 shows the relationship between the no. of KWH/consumer versus technical loss ratio % industrial and domestic /commercial consumers.

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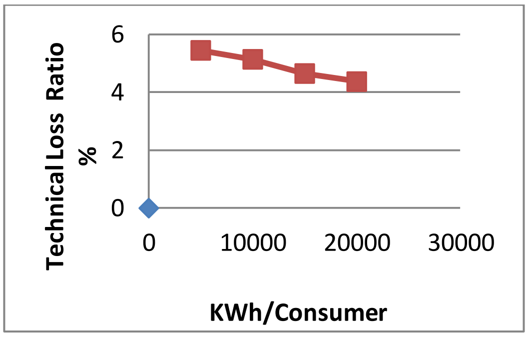

Fig. 4.3 Technical loss ratio v/s KWH/consumer for commercial / domestic consumer

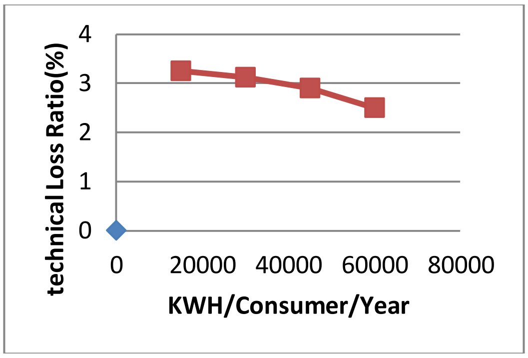

Fig. 4.4 Technical loss ratio versus KWH/consumer for industrial consumer

An example to illustrate the functional variable for secondary distribution system is shown in Fig. 4.5.It shows the relationship between the no. of consumers per kilometer of LT feeder and the technical loss %

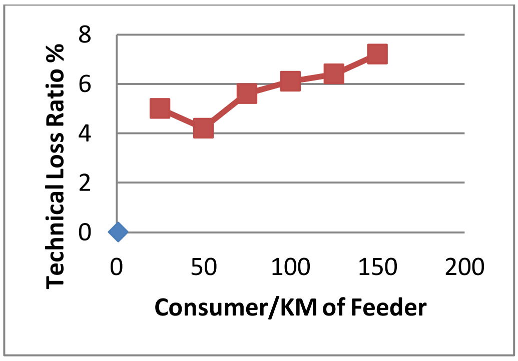

Fig. 4.5Number of Consumer per KM of Feeder versus Technical loss ratio For LT

V. BOTTOM-UP METHOD

In bottom up approach, firstly, complete and detailed distribution system data is required. Then, specific analysis is conducted to bring the performance of the distribution company. The bottom –up analysis calculated the actual system losses and improved the performance of the distribution system by bringing the losses to a given (predetermined) level.

The methodology used for bottom- is as:

1. Identification of feeder/DT data
2. Consumer tagging.
3. Generation of T&D loss %
4. Analysis
5. Action taken report to bring losses to a given level

The DTs of Mayapuri industrial area (MIA) are being considered and the DT energy of theses 7 DT's are given in table no. 5.1

NAME OF DT (MYP)	DT CAPACITY(KVA)	DT ENERGY (March)	DT ENERGY (April)
A-15	990	258112	254272
A-43	1000	431728	480968
Shopping Center	1000	224352	232992
Lumax	1000	250000	284960
WH-49	1000	216480	224864
B-32	1000	365568	391808
B-132	1000	145280	136260

Table no. 5.1 DT Energy Detail of MIA for Month of March and April

The next step in this approach is to do consumer tagging. The consumer tagging of only two DTs are shown in table no. 5.2

S. No.	Meter no.	March	April
1	27115299	1893	2386
2	27065154	1317	1369
3	E-993902	39	39
4	27065252	1967	1434
5	24147462	593	930
6	27016428	1232	1232
7	29001037	3472	3680
8	27045327	6469	5470
9	13468687	25S2	392
10	27038175	1057	1250
11	29001065	1968	2320
12	27036094	1261	1114

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13	27037778	1269	1601
14	29001063	3820	4024
15	DVBO3625	7581	8116
16	DVB03624	2396	3178
17	27016430	800	800
18	23822551	53	73
19	22137976	177	177
20	13090358	165	195
21	23833429	18	18
22	24157859	24	24
23	9825087	993	993
24	27110120	1223	988
25	27068494	1265	1296
26	27074855	2769	4556
27	27049235	4077	4489
28	27024217	1856	1856
29	27063169	1033	1153
30	27036503	2978	4287
31	DVB02920	31209	27602
32	27063243	212	275
33	27063308	175	268
34	29001038	4132	4024
35	DVB02921	12625	11098
36	29001035	1096	1280
37	29001034	1864	1752
38	22034943D	1816	1628
39	27016837	706	706
40	22078151	277	177
41	29001036	1788	1476
42	23767192	124	124
43	29001029	280	232
44	27063097	335	702
45	22396747	143	143

Table No. 5.2 Consumer Tagging Data

Then, the T&D loss% is calculated that includes both technical and non-technical losses for these 7 DT's. The summary of T&D loss % of these 7 DT along with consumer data are shown in table no. 5.3

T&D % SUMMARY REPORT OF MAYAPURI INDUSTRIAL AREA					
				March	April
1	KVA rating	990	Consumer Energy	224558	223760
	DT Name	A-15	DT Energy	258112	254272
	DT Meter No.	29509479	% Loss	13%	12%
				March	April
2	KVA rating	1000	Consumer Energy	328114	351107
	DT Name	A-43	DT Energy	431728	480968
	DT Meter No.	29502536	% Loss	24%	27%
				March	April
3	KVA rating	1000	ConsumerEnergy	204161	200374
	DT	SHOPP	DT	2243	232

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	Name	ING CENTER	Energy	52	992
	DT Meter No.	29504407	% Loss	9%	14%
				March	April
4	KVA rating	1000	ConsumerEnergy	232500	259314
	DT Name	LUMAX	DT Energy	250000	284960
	DT Meter No.	29502534	% Loss	7%	9%
				March	April
5	KVA rating	1000	Consumer Energy	192668	202378
	DT Name	WH-49	DT Energy	216480	224864
	DT Meter No.	29502537	% Loss	11%	10%
				March	April
6	KVA rating	1000	ConsumerEnergy	314389	350873
	DT Name	B-32	DT Energy	365568	391808
	DT Meter No.	29502166	% Loss	14%	10%
				March	April
7	KVA rating	1000	ConsumerEnergy	133317	128547
	DT Name	B-125	DT Energy	1,45,280	136260

Combined T&D loss % of 7 DT's		March	April
	ConsumerEnergy	1640314	1724849
	DT Energy	1,89,1520	2,00,6124
	Total Loss %	13%	14%

Table No. 5.3 Summary of T&D loss % of DT's

VI. CASE STUDY

The utility taken for our case is BSES Rajdhani power limited, a power distribution company that supply power to west and south Delhi. BSES Rajdhani power limited is broadly divided into west and south circle. Here, the Janakpuri division of west circle, BSES Rajdhani power limited is considered. The Janakpuri division includes various categories of consumer like, industrial, domestic and commercial. This division serves approx. 1,24,000 consumers with consumption of around 470 units per consumer per month for domestic and commercial consumers and around 3000 units per industrial consumer per month. The Janakpuri division consists of a 11 KV Mayapuri Industrial Area Phase-I that serves nearly 820 consumers.

There is good scope to enhance the system performance by reducing the T&D loss percentage. The historical peak load of Janakpuri has been reported at around 600MW (approx.). The load demand of this division generally reaches its maximum level between June and July of every year. Presently, T&D loss % that includes including technical and nontechnical losses, appear around 14%.

Firstly a top-down method is conducted and assumed that the energy consumption (in terms of kilowatt hours per consumers per year) and consumer density (in terms of number of consumers per kilometer of primary feeder) are functional variables with respect to technical loss percentage. Then, formulation of clusters based on "closeness" to each other in terms of functional variables and characteristics.

In this case study of Janakpuri division, the four clusters, namely, Domestic, Commercial, Domestic + Commercial, and industrial were sufficient to divide the space into coherent groups. This is illustrated in Fig. 6.1. The primary distribution voltage in this distribution system of Janakpuri division system is 11 KV. The groups

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are formed based on the consumers per km of feeder versus KWh/ consumer/Year

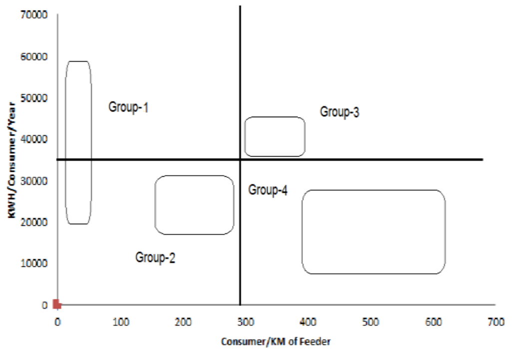

Fig. 6.1 Clustering of 64 HT feeders into four Groups

From fig. 6.1 from the four groups so formed, group 1 consists of industrial consumers only whereas other groups, i.e., 2, 3 & 4 comprises of mixed category of consumers.

In bottom-up approach, firstly, complete and detailed distribution system data is required. Then, specific analysis is conducted to bring the performance of the distribution company. In bottom –up analysis, the actual losses are calculated that helps in improving the performance of the distribution system by bringing the losses to a given (predetermined) level.

The actual T& D losses of the DT given in table no. 5.3 is represented in the form of Bar graph as shown in fig. 6.2for easy visualization of losses in the DT's

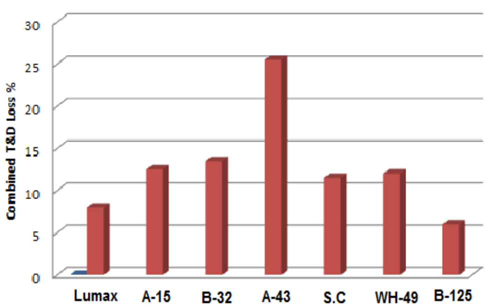

Fig. 6.2 T&D Loss in Distribution System

Then, the technical losses are for these 7 DT's are calculated. Firstly, the DT losses are taken and line losses in conductor/cables are assumed to be 1.3% to 2.4% depending upon the DT energy, loading, length of the line etc. then the total technical losses in the secondary distribution system are again represented in the form of bar graph as shown in fig. 6.3

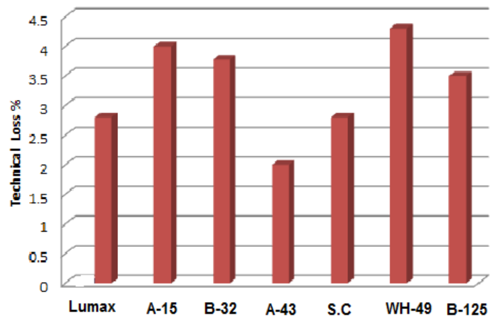

Fig. 6.3 Total Loss in Feeder and corresponding DT

VII. RESULTS

Results obtained by the top-down approach are shown in table. For Industrial area, there are about 20 number of consumer per kilometer of primary feeder and an intensity of consumption is approximately 48,536kWh/consumer/year. Similarly, for Domestic/Commercial area, there are about 225 number of consumer per kilometer of primary feeder and an intensity of consumption is approximately 12310 kWh /consumer /year.

Table nos. 7.1 &7.2 gives the Estimated Technical Loss% (Top-Down Approach) for primary distribution system, i.e., 11 KV feeders.

Consumer Type	Consumers/ km	Technical Loss %
Domestic/Commercial	225	5.9
Industrial	20	3.8

Table No. 7.1 Technical loss % w.r.t. Consumer/KM

Consumer Type	KWh/Consumer/Year	Technical Loss %
Domestic +Commercial	12,310	5.45
Industrial	48,536	3.25

Table No. 7.2 Technical Loss % w.r.t KWh/Consumer/Year (Top-Down Approach)

By using bottom-up approach, the actual T&D loss % are estimated in table no. 5.3 and then segregate these losses into technical and non-technical losses. Based on these losses action plan should be proposed to reduce these technical and non-technical losses to a given (pre-determined) value. Table 7.3 gives the estimated technical loss % using bottom-up approach.

Component of Loss Ratio	Loss %
Technical	3.9
Non-Technical	9.6
Total	13.5

Table No. 7.3 Estimate of Technical Loss% by Bottom-Up Approach

VIII. CONCLUSION

In India, the T&D loss% of the power distribution utilities is very high. The power utilities are facing power shortages, huge amount of losses in terms of money, poor and unreliable power etc. Power system losses comprises of technical losses, non-technical losses & revenue losses. The top-down and bottom-up approach is used in this paper to estimate the technical losses in the power distribution system. This approach not only helps in identification of technical and non-technical losses but also helps to reduce these losses and improve the overall health of the power distribution utilities.

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