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Challenges Faced in performing Energy Audit of 11kV Feeder and Distribution Transformer: A Study on Energy Management

Narasimha Pandit, Ezhilarasan Ganesan
Dept. of EEE, Faculty of Engineering and Technology, Jain Deemed to be University, Kanakapura, Karnataka
panditnarasimha63@gmail.com, g.ezhilarasan@jainuniversity.ac.in

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Abstract

Background: After notification of the Electricity Act, 2003, the Indian power sector has undergone a major transformation in bringing competition, in the development of electricity industry as a whole, protecting interest of consumers, ensuring supply of electricity to all, reduction of losses and rationalization of electricity tariff, etc. Enough generation capacity has been added, 'Power for All' has been implemented in true terms, and both transmission and distribution network has been strengthened considerably.There is still enough work to be done in terms of 100 % metering, and reduction of line losses and commercial losses. Transmission and Distribution (T&D) losses are a percentage of energy lost in the power grid in the process of transporting electricity from generating stations to points of consumption. It is important to measure and understand the source of losses before tackling them. Energy audit of 11 kV lines and Distribution Transformers (DTs) comes into picture here. This paper discusses the challenges in performing the Energy audit in distribution sector and proposes few remedies for the same.

Objectives: To understand the difference between the Technical loss, Commercial loss and AT&C loss in power distribution companies; To find out various ways of finding/calculating technical loss, commercial loss and AT&C loss in power distribution companies; To know the significance and method of calculating the Energy Audit of 11 kv feeders and Distribution Transformers; To list out the challenges faced in finding out the Energy Audit of 11 kv feeders and Distribution Transformers; To explore remedies to perform effective energy Audit.

Methods: In this paper, various methods of finding out the 11 kv feeder energy audit are discussed. The challenges faced in performing such audit are also listed out. Few remedies to do the audit in a better way is also discussed.

JOURNAL OF ALGEBRAIC STATISTICS
Volume 13, No. 3, 2022, p. 5351-5366
https://publishoa.com
ISSN: 1309-3452

Key words:*AT&C losses, Challenges,Energy Audit, Metering, T&D losses, , Sub-station.*

1. Introduction

The power sector is a combination of three important stages, viz., Generation, Transmission and Distribution. It is a chain of activity from Generation to Distribution. Hence the chain is only as strong as the weakest link. The distribution stage serves electric power to the end consumers, and happens to be the weakest link in this chain[3].

Fig 1. Power Value Chain

But the distribution is the most vital and challenging linkin all 30 States/ Union Territories of India. There are 60 state-owned Distribution companies (Discoms), and 10 major private Discoms, with a customer base of over 220 million.

For the power sector to be financially viable, the health of the distribution sector is most important. Presently, the health of Indian distribution sector has a major challenge in bringing down the high aggregate technical and commercial (AT&C) loss, as it is severely affecting the health of the sector.

1.1 AggregateTechnical and Commercial loss (AT&C)

Both technical loss and commercial loss together is called the Aggregate technical and commercialloss. It is obtained by deducting the energy for which revenue is actually realized from the consumer, from the energy input. The technical loss or Transmission and Distribution loss (T&D) occurs due to flow of energy into transmission and distribution network and is the difference between the energy input and the energy billed to the consumer. The T&D loss is being brought to an optimum levelby Technological advancements. The commercial loss usually occurs due toinefficient billing and collection of the energy supplied, theft, illegal connections, meter tampering, and pilferage, etc.

JOURNAL OF ALGEBRAIC STATISTICS
Volume 13, No. 3, 2022, p. 5351-5366
https://publishoa.com
ISSN: 1309-3452

Table 1 Comparison of Technical and Commercial losses in a distribution system

Sl No	Technical losses	Commercial losses
1	11 kV line losses	Theft by direct tapping the lines
2	Distribution transformer (iron and copper losses)	Theft by tampering meters CTs and PTs
3	LT line losses	Non-performing meters
4	Losses due to loose jump connections	Under performing meters
5	Short circuit and earth fault losses	Meters not read
6	Losses in service mains and energy meters	Mistakes in billing

1.2 Action taken to reduce losses

After the Indian power sector reforms were taken up in 1991, restructuring and unbundling of State Electricity Boards (SEBs) were done to form separate companies for generation, transmission and distribution segments. The Government of India (GoI) took up further reforms, after the Electricity Act 2003 was enacted, to strengthen the power sector. The GoI has also taken up various initiatives for reduction of losses

Over the past 12-13 years, after notification of Electricity Act 2003, the power distribution utilities/stateel ectricity boards have reduced their Transmission and Distribution losses(T&D) and Aggregate Technical and Commercial loss(AT&C) to a significant extent through multiple initiatives such as augmentation/up gradation of network, installation of electronic energy meters, relocation of energy meters outside consumer premises, technology up gradation like implementation of High Voltage Distribution Systems(HVDS) and low voltage distribution systems(LVDS), installation of Low Tension Aerial Bunch Conductors (LTABC), putting in place measures to control losses and theft etc.

1.3 Literature Review

Many papers have been written on energy audit of buildings, but very few on feeder and transformer energy audit. Actually, a lot of research is required in this field because,

JOURNAL OF ALGEBRAIC STATISTICS
Volume 13, No. 3, 2022, p. 5351-5366
https://publishoa.com
ISSN: 1309-3452

Power distribution companies are finding it difficult to conduct an effective energy audit in their companies. The Discomsof Karnataka state leads other state Discoms in conducting regular audit of feeder and distribution transformer.

After going through various papers, magazines, blogs and newspapers, on Energy Audit, it is felt that deep study is required on the actual problems faced by the field staff in Discoms. Hence this paper is written to through light on the problems and possible solutions to the problems.

In the 'Maha Energy Audit'[1], the authors have mentioned briefly regarding necessity of energy audit, constraints in carrying out energy audit, and computer application in energy audit. They have also conducted the audit on 220 kv feeders of Amaravati Receiving Station. But more attention is required on 11 kv feeders as all types of problems occur at this level. Authors have not given any feasible solutions also.

The paper 'Challenges faced by Indian DSO's and future developments'[2], the author has touched upon Vicious cycle in Indian distribution sector, Challenges-Discoms, Government of India initiatives, Gradual evolution of smart grid in Indian Power Distribution Sector, and opportunities and way forward. The author has focused more on general problems of power sector and IT initiatives by Government, rather than specific energy audit problems and solutions.

NITI Ayog has published 'Turning Around The Power Distribution Sector- Learnings and Best practices from reforms'[3], which discusses in detail status of discoms, distribution sector reforms, structural reforms, regulatory reforms, operational reforms, solutions for RE integration, managerial reforms, and best practices and recommendations. Though energy audit problems are briefly mentioned, a detailed analysis is not given here.

2. Objectives

To understand the difference between the Technical loss, Commercial loss and AT&C loss in power distribution companies; To find out various ways of finding/calculating technical loss, commercial loss and AT&C loss in power distribution companies; To know the significance and method of calculating the Energy Audit of 11 kv feeders and Distribution Transformers; To list out the challenges faced in finding out the Energy Audit of 11 kv feeders and Distribution Transformers; To explore remedies to perform effective energy Audit.

JOURNAL OF ALGEBRAIC STATISTICS
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3. Methods

3.1 Energy Audit for a Discom

Energy auditing, as perEnergy Conservation Act, 2001, isthe "verification, monitoring, and analysis of use of energy including submission of technical report containing recommendations for improving energy efficiency with cost benefit analysis and an action plan to reduce energy consumption" (Ministry of Law, Justice and Company Affairs, 2001). Energy audit is useful in identifying the AT&C loss in the distribution network. Due to AT&C loss alone, around 1 lakh crore is lost in the power distribution segment, as per Ministry of Power (MoP). Since this is a huge sum, if the AT&C losses are high, it has to be reduced to make the sector financeable viable. To reduce AT&C loss, energy audit is performed, and then, corrective actions like tagging in a correct manner, reduction in theft, timely meter reading etc.

To perform the energy audit, all the feeder meters of a substation are accurately measured. This forms the input side of the energy audit. The energy output is measured by taking the meter reading of all the consumers connected to each feeder separately. The difference of the energy input and the output gives the loss in each feeder.

Arrangement of a 33 kV sub-station with two 11 kV lines and six transformers is shown in fig. 2

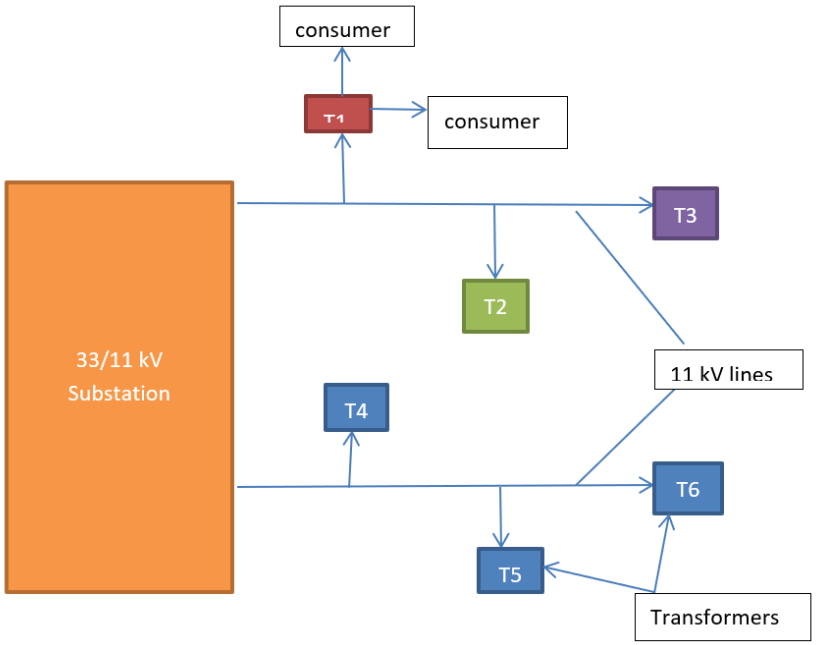

Fig2. Arrangement of a 33 kV sub-station with two 11 kV lines and six Transformers

JOURNAL OF ALGEBRAIC STATISTICS
Volume 13, No. 3, 2022, p. 5351-5366
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Energy Input (IP) = (FR – IR) x MC

Where,

IP= Energy input to the feeder from the substation

FR = Final meter reading of current month

IR = Initial meter reading of current month

MC = Meter constant

The energy output (OP) is the sum of the energy consumption of all the consumers connected to the feeder. The difference between the energy input and energy output is the energy loss (EL) in the system.

This energy loss can be segregated into technical and commercial loss as follows:

Technical Loss (TL) = Technical loss in 11 kV feeder (TF) + Technical loss in DTs (TD)

TL can be calculated with the formula

Technical loss = (0.105 X D2 X L X R X LLF)/ (LDF X DF2 X 2), Where,

D = Connected load (in kVA), L = Total length of the feeder (in km)

R = Resistance of the conductor per km (ohm/km)

Load Factor (LF) = Energy input to the feeder/ (Peak load X number of hours during the period)

Loss load factor (LLF) = k x LF + (1-k) x LF2, Where,

k = 0.2 for medium voltage feeders and distribution substation

Diversity Factor (DF) = Connected load (kVA)/Peak load (kVA)

Load Diversification Factor (LDF) =

Connected capacity of DTs (kVA) x Length of the feeder (km)/ (kVA x km)

KVA x km = sum product of the total load incident on each section of the feeder multiplied by its length.

Table 2 Technical Loss in 11 KV feeders of typical sub-divisions.

Name of the sub-division	No.of feeders	Energy loss in Percentage			
		< 5%	5-10 %	10 -15%	-ve loss
A	21	6	14	0	1
B	17	9	7	0	1
C	16	1	15	0	0

JOURNAL OF ALGEBRAIC STATISTICS
Volume 13, No. 3, 2022, p. 5351-5366
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D	17	3	13	1	0
E	23	3	19	0	0
F	9	1	8	0	0
G	3	3	9	1	0

3.1.1 Technical Loss in the DTs

A distribution transformer has two types of losses, one is core loss and the other is the copper loss.Core loss occurs due to magnetic properties of the transformer core. Copper loss occurs because of heat dissipation due to current passing through the windings of the transformer.

Technical loss in DTs = Total core loss (kWh) + Total copper loss (kWh)

The commercial loss is the difference between total energy loss (R) and the total technical loss:

Commercial loss = Energy Loss - Technical Loss

The loss calculated in this way is then compared with the standard values of technical and commercial loss. DISCOMs then undertake suitable corrective measures to reduce these losses through network improvement and effective monitoring mechanisms.

3.1.2 Alternate way of finding out the losses:

By calculating the Billing Efficiency and Collection Efficiency, The AT&C losses and T&D losses can be found out, as follows –

i) Calculation of Billing Efficiency:

Billing efficiency gives a clear picture of how much of energy has been billed (includes both metered and unmetered sales) to consumers out of the energy supplied to that particular area.

Billing Efficiency = Total Energy Billed to Consumers (kWh) / Total Energy Input (kWh)

ii) Calculation of Collection Efficiency

All the consumers who have received the electricity bill may not pay the bill within the stipulated date. This means that the company is expecting the collection to be a certain value, but will not actually achieve that much collection.

JOURNAL OF ALGEBRAIC STATISTICS
Volume 13, No. 3, 2022, p. 5351-5366
https://publishoa.com
ISSN: 1309-3452

Collection efficiency gives a picture of how much has been collected from consumers out of the amount billed to them.

Collection Efficiency = Revenue Collected (INR)/ Billed Amount (INR)

Then, AT&C Lossescan be calculated using formula

AT&C Losses = {1 – (Billing Efficiency X Collection Efficiency)} X 100

The Aggregate Technical and Commercial losses is illustrated in Fig. 3

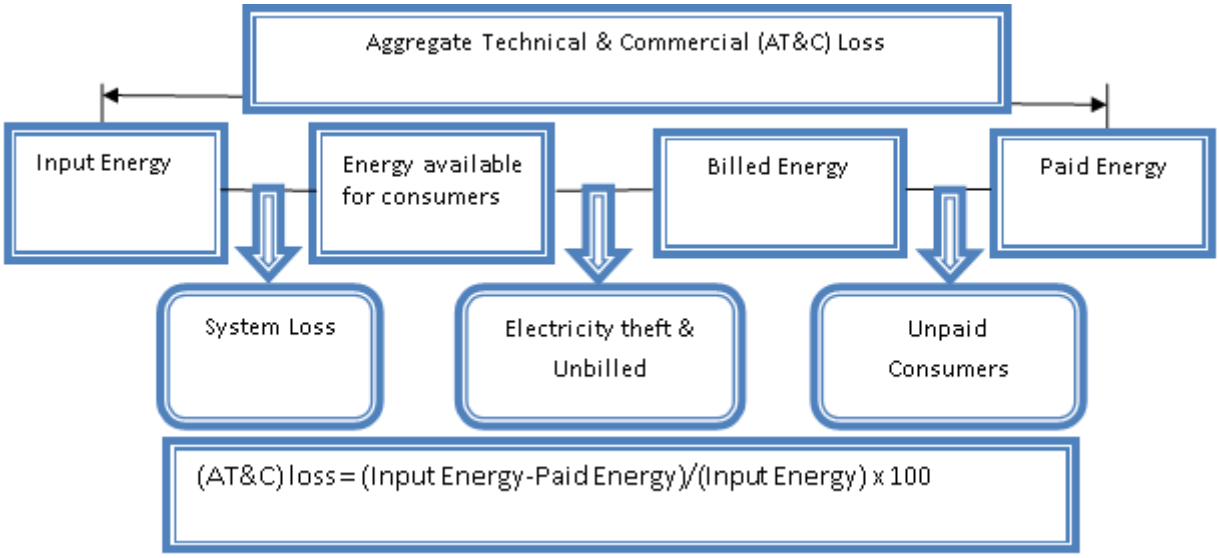


Fig 3. AT&C losses

3.1.3 Segregation of technical and non-technical losses:

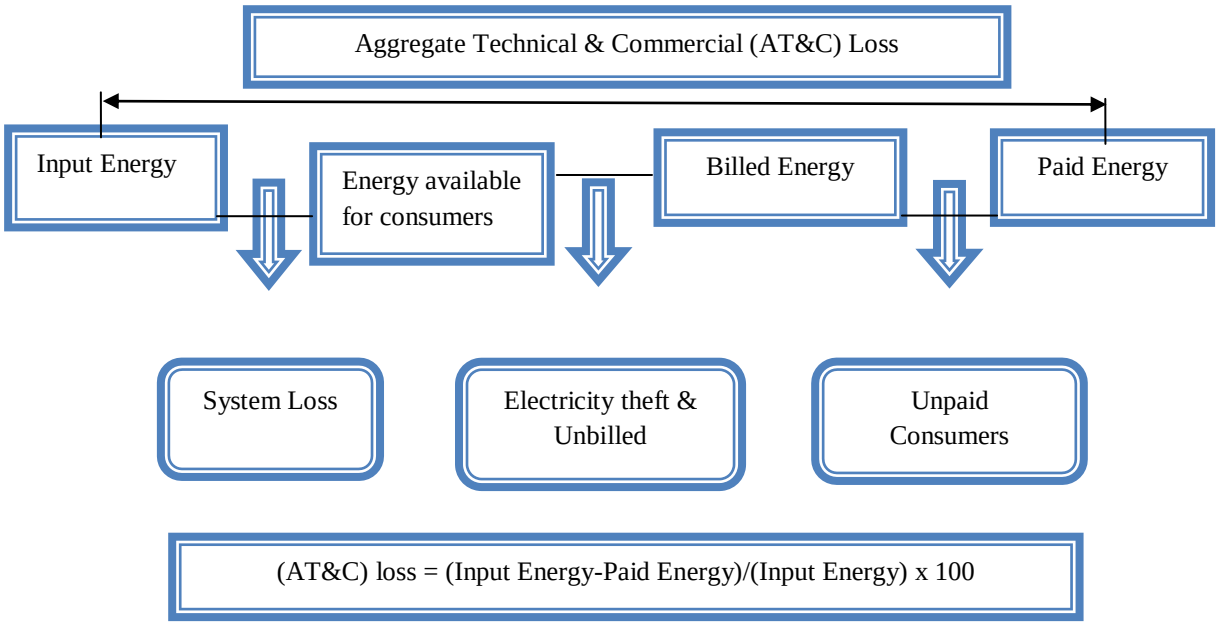
Technical loss: They arise because of current flowing in the electrical network, and mainly comprises of Copper losses. Major reasons for technical losses are:

- **Harmonics distortion**: The power supplied through the electric network doesnot comprise of pure sine wave. When it is distorted and comprises of harmonics, it leads to heating in the network and hence losses.
- **Long single-phase lines**: Many houses are supplied power with long single phase line creating more electrical load on single wire causing more copper loss. It also leads to low voltage at the tail end.
- **Unbalanced loading:** In the actual power distribution network lot of single phase loads are there. These single phase loads are serviced without checking the actual load on the individual phase. This leads to

JOURNAL OF ALGEBRAIC STATISTICS
Volume 13, No. 3, 2022, p. 5351-5366
https://publishoa.com
ISSN: 1309-3452

unbalanced load on the system. Then, the overloaded phases are stressed leading to more losses.

- **Losses due to overloading and low voltage**: Many lines are overloaded; causing more load losses.



Non-technical loss (Internal): The internal non-technical losses may arise from the following:

- **Connection management**: These arise due to not managing the correct database of new and existing consumers. There are cases of releasing a new connection without fixing the meter. Then there will be mismatch between the demand and sales, and eventually it leads to losses.

- **Meter reading**: If the meters are not read on the specified date, if they are not read accurately, it will lead to losses. Many a times, the reading is not taken by the meter reader due to meter being fixed in an inaccessible position, the premises has a dog, the premises gate as well as the door is locked, etc.

- **Billing**: Due to erroneous billing, delayed billing, meter not recording, meter slow/fast, etc, accurate bill is not generated, leading to huge loss to the company.

- **Non-technical loss (External):**

When the revenue dues are not collected in time, they lead to the external non-technical losses This arises because of government arrears not paid, not enough follow ups from the concerned officers, not disconnecting the installation, etc.

JOURNAL OF ALGEBRAIC STATISTICS
Volume 13, No. 3, 2022, p. 5351-5366
https://publishoa.com
ISSN: 1309-3452

3.2 Conditions for perfect Energy Audit

The schematic representation of the losses in a distribution system including the distribution transformer is as shown in fig. 4. The energy auditing can be efficiently planned and executed with the help of this diagram

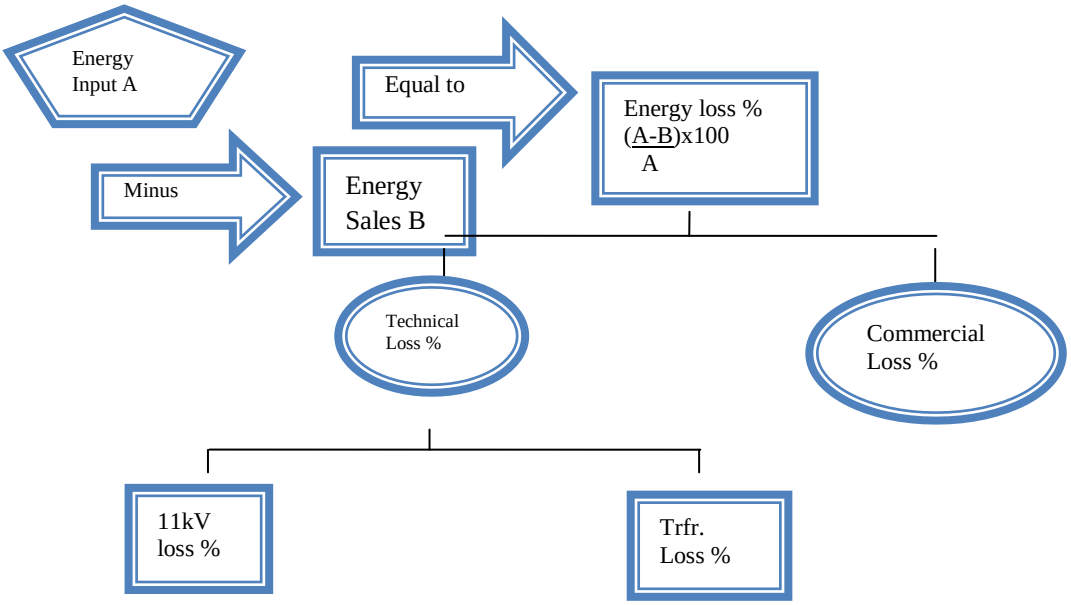


Fig 4. Schematicrepresentation of energy auditing

The condition to be fulfilled for an energy audit in the 11 kV distribution system inclusive of distribution transformers is given in the Table 3. To perform the audit, these conditions are to be met with.

Table 3 Basic condition to be met with for an energy audit

1	Metering has to be done to all the consumer installations.
2	Meter readings have to be taken correctly and timely.
3	The secondary side of distribution transformers has to be provided with Electronic tri-vector meters.
4	The accuracy class of energy meters has to be same .

JOURNAL OF ALGEBRAIC STATISTICS
Volume 13, No. 3, 2022, p. 5351-5366
https://publishoa.com
ISSN: 1309-3452

Table 4. DTC (Distribution Transformer Centre) Energy Audit.

Sub div	DTC existing	DTC Metered & Audited	Meters not recording, not communication, burnt etc	% age loss				%age audit
				0-5%	5-10%	10-15%	>15%	
A	1354	1252	833	142	265	12	0	92.54
B	1196	1192	628	313	131	117	0	99.66
C	1774	1133	865	111	157	0	0	63.86
D	1146	1003	768	48	114	73	0	87.52
E	687	125	69	12	22	22	0	18.19
F	1295	1124	844	127	80	59	1	86.79
G	844	692	169	187	177	159	0	81.99

3.3 Issues and challenges in Energy Audit

a) Energyloss segregation:Right now, in most of the DISCOMs,energylossiscalculated forfeeders. But segregation of losses into technical and commercial losses not performed.

b) Faultydataentry:In many utilities, the meter readings are not entered in the data base accuratelyleading toincorrectcalculationofAT&Closs.This may be because of outsourcing of meter reading, data entry etc who have less knowledge and commitment towards the assigned work.

c) Consumer meter readings are taken on staggered dates: For accurate energy audit, both input reading and output reading should be taken on same day. But in all utilities, input reading is taken on first of a month, and output readings are noted on different dates throughout the month. This creates lot of inaccuracy.

d) Not using Load Flow Methods: Majority of discoms do not use any load flow method to perform the energy audit. These are done randomly.

e) Regular updating of network not done: Whenever new lines and transformer are added to the system, they are to be included in the system immediately, which is not done in most discoms.

f) Incremental tagging:For accurate

JOURNAL OF ALGEBRAIC STATISTICS
Volume 13, No. 3, 2022, p. 5351-5366
https://publishoa.com
ISSN: 1309-3452

energy audit, every consumer has to be tagged to corresponding transformer, and the transformer to feeder and the feeder to the 33 kv station. If this is not done regularly, energy audit will not be accurate.

g) Accuratemetering of distribution transformer:This is most important. Usually, most transformers are not metered, or the meter is not recording, or the meter is abnormal/subnormal, or it is burnt. A regular monitoring of transformer metering is required for accurate energy audit.

3.4 Recommendations for an effective Energy Audit

It is noticed that failure to monitor various process in the audit process is the main reason for erroneous results. The discoms can adopt the following procedures for an effective audit:

a) Which loss is the main culprit: The discoms have to find out whether the loss is high due to technical or managerial issues. Then, discoms can take suitable measures regarding network strengthening or serious monitoring ways.

b) Correct Data entry: The concerned staff of the utility must see that the data collected from the field are entered in the data base accurately. The meter reading by outsourced men has to be regularly monitored by the utility for its authenticity

c) Regular and compulsory Tagging:The consumer tagging to respective transformer and that transformer tagging to respective feeder has to be regularly done.

d) 100% DT metering and regular maintenance: All the transformers need to be metered with high accuracy remote reading meters and need to monitor them regularly. If the meters become not reading, burnt they need to be replaced immediately

e) Installation of boundary meters: Boundary meters have to be installed at the end of section, subdivision and divisions to know the energy import and export from different areas. Regular monitoring

f) Energy audit process streamlining: Every discom should take the energy audit seriously and should form two groups, one of assessor and another is of monitoring. The assessor group should concentrate on fetching the data and enter them in the data base. The monitoring group must see that meters

JOURNAL OF ALGEBRAIC STATISTICS
Volume 13, No. 3, 2022, p. 5351-5366
https://publishoa.com
ISSN: 1309-3452

are working in good condition and the data entry is made correctly.

3.5 Remedies

- Calibration of energy meters in all Sub-stations and consumer premises: There should be continuous monitoring regarding the calibration of meters, both in the Sub-station (Input side) as well as the consumer end (output side). High energy consuming consumer meters should be given first priority.
- Energy meters should be of same class: In the high energy consumer category, many times, there will be only one consumer connected to one 11 kV feeder. In such cases, if the accuracy class of the input side and the output side are different, the loss figures will be erroneous. Hence, all effort should be done to keep the energy meters of same class in sub-station and consumer end.
- Accurate assessment of un-metered category of consumers: Usually Irrigation pumpsets(IP sets)are not metered in many states. Even when they are metered, they are not read as they are in large numbers located in the remote fields. In such cases, several predominantly feeding IP set Transformers are metered in a sub division and these readings are taken as the representative reading of all IP sets.Hence, the predominantly feeding IP DTs should be chosen in a correct way.
- Usage of static meters: Static meters are programmable; they are more reliable, accurate and sensitive.

4. Results:

Energy audit is a major task to be done in power distribution. It gives the amount of energy losses occurring in lines and distribution transformers connected to the distribution system. Once the quantification of energy losses at various stages is done, action can be taken to reduce the losses. But, due to various reasons, the Indian distribution companies are not able to perform the energy audit in the right way. An attempt is made in this paper, to highlight the challenges faced in doing effective energy audit in power distribution sector and few remedies are also recommended to overcome the challenges

5. Discussions

Energy audit of 11 feeders and distribution transformers is an

JOURNAL OF ALGEBRAIC STATISTICS
Volume 13, No. 3, 2022, p. 5351-5366
https://publishoa.com
ISSN: 1309-3452

essential and important task to be done regularly in any power distribution company. Many a times the audit is done routinely and the results will be totally erroneous. This result will be kept as it is or adjusted to suit the desired value. The reason for the erroneous result is the difficulty in finding the exact consumption of various categories of consumers connected to the feeder. Many installations like irrigation pump sets are not metered in many parts of the country, as the power is given free to the farmers. These consumptions are arrived by assessment. Many meters are not read properly because of door lock, negligence of meter readers or meter not recording. Energy audit, in this way is a challenging task, requiring lot of attention by officers and field staff of escoms.

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