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A Review of Losses in Distribution Sector and Minimization Techniques

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ABSTRACT: This paper presents a comprehensive analysis of aggregate technical and commercial losses(AT & C) occur in Power Distribution Sector with special focus on loss reduction and efficiency improvement of power supply. Different major aspects of technical and non-technical losses have been identified and on the basis of that a number of remedial measures have been suggested for loss reduction and to facilitate the improvement of overall efficiency of the power distribution system. The main objective of this paper is to implement a distribution system having negligible Non Technical Losses (NTL).Some case studies (CESC,NDPL) have also been made to reflect the viability of the loss reduction techniques which have been already implemented. This may provide further strategy to energy planners and managers.

KEYWORDS: Aggregate Technical and Commercial Losses (AT & C), Distribution Sector, Loss Minimization, CESC, NDPL, APDRP

I. INTRODUCTION

Distribution Sector, the revenue generating link in the Generation - Transmission - Distribution chain is clearly the weakest link in the power sector value chain and is threatening to derail the entire process of power sector reforms. While the power generation sector in the Country is struggling to meet rising demand, the Distribution sector has been reeling under losses and has been in focus with various measures being taken by the Government of India to make the State DISCOMs/Utilities viable.

Distribution provides the crucial last mile connectivity and has disparate, numerous and varied consumers. Though most of the SEBs have been unbundled, distribution is still largely under the control of Government Utilities. Post unbundling, their operations on sound commercial principles under the regulatory supervision has not yielded the desired results. Worsening financial condition of power distribution utilities owing to high Aggregate Technical & Commercial (AT&C) losses, inability to revise tariffs strictly in principle and spirit, increasing Subsidy burden, cross subsidization by the industry to domestic consumer and farmers, billing inefficiencies and more importantly need to buy expensive power to tide over short-term deficits are eating away the benefits of the policy initiatives. The gap between their Average Cost of Supply (ACS) and Average Revenue Realized (ARR) is increasing and has crossed ` 1.50 per Kwh, resulting in further erosion of the net worth of these utilities.

To reduce the losses and to improve the system efficiency, a policy has been made [1]. The Policy initiatives for Distribution Reforms are aimed at system up-gradation, loss reduction (aggregate technical and commercial losses), theft control, consumer orientation, commercialization, decentralized distributed generation and supply for rural areas, introducing competition [2].

II.VARIOUS LOSSES

Power system losses can be divided into following categories:

Technical Losses : Technical Losses are naturally occurring losses (caused by actions internal to the power system) and consist mainly of power dissipation in electrical system components such as transmission lines, power

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transformers, measurement systems, etc. Technical losses are possible to compute and control, provided the power system in question consists of known quantities of loads. Technical losses are easy to simulate and calculate. Improvements in information technology and data acquisition. have also made the calculations and verifications easier.

Non Technical Losses (NTL): Non Technical Losses , on the other hand, are caused by actions external to the power system, or are caused by loads and conditions that the technical losses computation failed to take into account. NTL are more difficult to measure because these losses are often unaccounted for by the system operators and thus have no recorded information.
T & D losses: The sum of Transmission & Distribution losses is termed as T&D losses.

Aggregate Technical and Commercial Losses (AT & C): The aggregate of T & D loss and loss due to non-realization of billed demand is termed as Aggregate Technical and Commercial Losses (AT & C loss).
AT & C loss (%) = [(Energy input – Energy realized) × 100] / Energy input
Energy realized = [Energy billed X Collection efficiency]
Collection efficiency (%) = [Amount Realized X 100] / Amount billed
AT & C loss is a transparent measure of the overall efficiency of the distribution business as it measures technical as well as commercial losses.

III.WHY LOSS MINIMIZATION IS ESSENTIAL?

All energy supplied to a distribution utility does not reach to the end consumer. A substantial amount of energy is lost in the Transmission and Distribution system by way of Technical and Non Technical Losses. The distribution system accounts for highest technical and non technical losses in the power system. The Transmission and Distribution Losses in our country, which were around 15% up to 1966-67, increased gradually to 28.36 % by 2011-12[3]. Total Transmission and Distribution Losses are about 30-50%. The major part of the loss is taking place only in distribution sector which accounts for 80-90% of total T&D losses. Cost of power theft is Rs 20,000 Crores / year and the total loss incurred by all State Electricity Boards is Rs 26,000 Crores per year in India.

The Transmission and Distribution losses in advanced countries of the world have been ranging between 6 to 11%. Even in many developing countries, T & D losses are less than the level obtaining in India. As per the T & D losses issued by CEA, taking into consideration the Indian conditions, it would be reasonable to aim for containing T & D losses within 10 to 15% in different States [3],[4]. The aggregate losses accumulated by all utilities from 2006-07 to 2010-11. The losses (on accrual basis) of all the utilities increased from Rs 24,796 crores in the year 2008-09 to Rs 30,466 crores in 2009-10. In the year 2010-11, the aggregate losses of all utilities decreased to Rs 29,701 crores [5].

With the setting up of State Regulatory Commissions in the country, accurate estimation of T&D Losses has gained importance as the level of losses directly affects the sales and power purchase requirements and hence has a bearing on the determination of electricity tariff of a utility by the commission. Higher AT & C losses have severe impact on tariff as well as economy. So, minimization of this losses is utmost essential.

IV.REASONS BEHIND AT&C LOSSES

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The following are the major reasons for high *technical losses* in our country: -

- Inadequate investment on transmission and distribution, particularly in sub-transmission and distribution. While the desired investment ratio between generation and T&D should be 1:1, during the period 1956 -97 it decreased to 1:0.45. Low investment has resulted in overloading of the distribution system without commensurate strengthening and augmentation.
- Haphazard growths of sub-transmission and distribution system .
- Short-term objective of extension of power supply to new areas.
- Large scale rural electrification through long 11kV and LT lines.
- Too many stage of transformations, improper load management and inadequate VAR compensation
- Poor quality of equipment used in agricultural pumping in rural areas,
- Cooler air-conditioners and industrial loads in urban areas.

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Theft and pilferage account for a substantial part of the high transmission and distribution losses in India. Theft / pilferage of energy is mainly committed by two categories of consumers i.e. non-consumers and bonafide consumers. Some of the modes for illegal abstraction or consumption of electricity are given below:

- Making unauthorized extensions of loads, especially those having "H.P." tariff.
- Tampering the meter readings by mechanical jerks, placement of powerful magnets or disturbing the disc rotation with foreign matters.
- Stopping the meters by remote control.
- Wilful burning of meters, bypassing the meter.
- Changing the sequence of terminal wiring.
- Changing C.T . ratio and reducing the recording.
- Errors in meter reading and recording.
- Improper testing and calibration of meters.

V. LOSS MINIMIZATION TECHNIQUES

A. Technical Loss Reduction

The causes of high technical losses[6] are varied and require different remedial measures to be implemented to bring them down to acceptable levels.

Short-term Measures :

The immediate improvement and reduction of losses[6],[8] in the technical system are based upon sample studies, statistical scrutiny/ analysis of the information/ data collected from the existing system detail. These are:

i. Network Reconfiguration – It gives an option to handle the increased demand and increases system reliability

ii. Conductor Replacement in Network –A lower conductor size can cause high ohmic losses and high voltage drop which causes a loss of revenue as consumer's consumption and hence revenue is reduced. The recommended practice is to find out whether the conductor is able to deliver the peak demand of the consumers at the correct voltages, that is, the voltage drop must remain within the allowed limits specified in Electricity Act, 2003.

iii. Preventing Leakages at Insulators - Cracking of insulator and flashover across insulators often cause outages and result in loss of revenue. Use of appropriate material for insulators, depending on the nature of pollution, and designed protected creep age path helps in reducing insulator failure. Preventive actions are regular inspection and hot line washing.

iv. Automatic Voltage booster – it is similar to that of the series capacitor as an on-load tap changer it boosts the voltage at its point of location in discrete steps. This, in turn, improves the voltage profile and reduces the losses in the section beyond its point of location towards the receiving end. It has a total voltage boosts of 10% in four equal steps and the loss reduction is directly proportional to voltage boosts.

v. Better Management of Distribution Transformers – the following measures can be taken in this regard:

- Augmentation/ addition of distribution transformers and relocation of distribution transformers at load centres.
- Low voltage (less than declared voltage) appearing at transformers consumers terminals
- Guarding against loss in transformers through oversized transformers operating at low loading, undersized transformers, unbalanced loads in secondary side, connector at bushings, low oil level/ oil leakages, hot spots in core, use of energy efficient distribution transformers(DT).

vi. Load Balancing and Load Management – if the loads on each of the three phases of a distribution lines or among feeders are redistributed, the losses will be reduced. The best method to identify load balance is to construct current duration curves for all three phases. Distribution automation along with SCADA (Supervisory Control and Data Acquisition System) is an important tool for load management which should be introduced.

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vii. Capacitor Installation – the use of capacitors to correct for poor power factor is a well established and cost effective means of reducing distribution system losses and maximizing the revenue. In most LT distribution circuits, it is found that the power factor (PF) ranges from 0.65 to 0.75. Overall improvement in the operating condition can be brought about by reducing the system reactance. This can be done by the application of shunt capacitor in the following ways – across individual customers, advantage points on LT and 11 kV feeders, at distribution transformers and at 33kV/11 kV sub stations.

viii. Improving joints and connections – Improper joints are a source of energy loss in both overhead and underground systems. The conductivity of joints should not be less than an equivalent length of the conductor. Joints should be capable of carrying maximum fault current without failure or deterioration for the time required for the protective system to operate.

ix. Increase in HT/LT ratio – It is well known that for high HT/ LT ratio, the losses will be low. The losses for a given quantum of power supplied by a line are inversely proportional to the square of its operating voltage. Higher the operating voltage, lower will be the line losses. Therefore, by increasing the HT lines the losses will be reduced.

x. Adoption of High Voltage Distribution System (HVDS) – Adoption of HVDS by converting existing LVDS to HVDS reduces the technical losses appropriately.

xi. Preventive and regular maintenance – Care should be taken to optimize preventive maintenance, because each shutdown due to preventive maintenance is also a source of revenue loss. It can be minimized by careful design and healthy installation practices. The activities that can be undertaken for preventive maintenance are maintenance of overhead lines, rewinding transformer, monitoring transformer tank temperature, use of protective devices, improved bushings, transformer oil testing, repairing of broken parts.

Long-term Measures:

Long-term measures include upgrading, strengthening and improvement of the sub-transmission and distribution system in a circle to meet the future load demand for the next *five to ten* years. The activities for preparation of a long term plan are listed below:

i. Data collection regarding existing loads, operating conditions, forecast of expected loads, etc. from grid sub-station upto consumers level.
ii. Mapping and analysis of existing system.
iii. Load forecast and plan for upgrading the network .
iv. Technology options including integration of features for modernization of system.
v. Evaluation of various alternatives for least cost optimal solution.
vi. Preparation of cost estimation and phasing of works and their cost.
vii. Financial analysis.

B. Commercial loss reduction :

The measures for reducing commercial losses[6] depend on the factors that cause them. These are:
i. Measures for controlling direct tapping by non-customers and customers – Stopping theft by direct taping; Use of aerial bunched cables/ partial insulated LT lines; Public relation and awareness campaigns by utility

ii. Measures for controlling pilferage of energy by existing customers –

- The energy meter should be housed in a separate box sealed and made inaccessible to the consumers. The fuse cut-outs should be provided after the meter
- Multi-core PVC cables should be used as service mains instead of single core wire
- Severe penalties may be imposed for tampering with metering seals, etc.
- Theft of electricity should be publicized as a social and economic crime and people should be informed of the provisions in electricity laws in this regard.

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iii. Measures for reducing defective metering – stuck up meters, constant nil consumption cases reported without any comment, progressive readings recorded in disconnected service, no relation between the meter capacity and the load, adoption of wrong multiplication factors (MF) for billing as the change in MF in not intimated to the billing agency etc.

iv. Meter installation –
It is often considered as a low skill, labour oriented activity. It must be given due importance to against revenue loss. Certain installation practices to prevent this include

- Having a visually traceable and joint free incoming cable, shrink wrapped sealed joint
- Having clearly visible and accessible seals that can be subjected to easy inspection
- Mounting the meter and CTs inside a box with a clear window
- Ensuring height and location of installation for easy readability of meters
- Locating meters in public domain in full public view

v. Measures for improvement in billing and collection –
Correct billing and timely delivery of bills go a long way in improving the revenue collections. The normal complains viz. non-receipt / late-receipt of bills, wrong bills, wrong reading status, wrong calculations etc. should be avoided.

vi. Users‟ Associations, Panchyats and Franchisees in Billing and Collection –
The electricity Act, 2003, visualizes the role of users‟ associations, co-operatives, panchayats and franchisees in electricity.

vii. Legal Measures for Reducing Commercial Losses –
The Electricity Act, 2003, has brought radical changes in all the facets of the electricity sector. The relevant Sections of the Act are 55, 126, 127, 135, 138, 145, 150, 151, 152, 153, 154, 156, 157, 168, 169, 170 and 171.

VI.CASE STUDIES

A. NDPL(North Delhi Power Limited):

By 2001, Transmission &Distribution losses in New Delhi had reached 53%. A large part of these losses was due to theft. The *Delhi Vidyut Board* had run heavy losses for a long time, and only survived due to fiscal support. Delhi's government invited bids for the purchase of a 51% stake in the utility. These bids were not to be based on the utility's asset levels, but rather electricity loss reduction targets, which would form the basis for tariff determination. The private sector company that quoted the largest reduction in electricity loss levels would win the auction. Tata Power, one of India's largest private sector utility companies, won the auction and took a 51% stake in the company. The remaining ownership was retained by the Government of Delhi. Tata subsequently employed professionals at top-level management; empowered use of IT enabled services; and cracked down on electricity theft by installing meters and tracking consumption trends. As a result, Tata Power brought down transmission and distribution losses from 52% in 2002 to 18.5% in 2008[7].

B. CESC(Calcutta Electricity Supply Corporation):

The combination of lacking law and order infrastructure (in relation to power market theft control) and inefficient management by state electricity board(SEB) staff causes theft to be high. However, it is not just the poor that steal electricity. SEBs have been inefficient at maintaining computerized records of their customers and maintaining operating meters. Especially, agricultural or rural customers are not metered. In Orissa, for example, 40% of the meters were not read until its SEB was privatized in the 1990s. In Karnataka also, 40% of the electricity supplied is unmetered. Measures that can be taken to control theft in the power sector by way of this case study. This case study Surveys actions of CESC, a privately held company that owns utilities in Kolkata and Noida. The owner Of CESC, RPG Group, undertook a series of measures[7] to reduce electricity theft that can be replicated in the rest of the Country. The measures include the following:

- The first thing is installation of 100% metering ,even in hut.
- Replacement of all faulty meters with new ones.

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- Rotation of meter readers in order to avoid rent seeking and bribery.
- Random checking at large consumption centre.
- Setting up two group-assessor group(responsible for collecting information and reports abnormal consumption) and disconnection group(replaces faulty meters ,regularise illegal connections and disconnections)
- Setting up rewarding scheme for division managers with predefined low theft level.
- Assigning unique identification number for each customer and billing record through management information system(MIS).

These measures were instrumental in bringing down electricity losses in both Noida and Kolkata stand at 7%and 13.2%, respectively [7].

VII.GOVERNMENT INITIATIVES

The Government of India initiated various reforms in the Power Sector with an objective of bringing about commercial viability to the State Power Utilities.

A. APDRP:

In order to achieve commercial viability, Ministry of Power launched Accelerated Power Development Programme (APDRP)[9] in the year 2000-01. The programme had *investment* component only. However, on recommendation of Deepak Parikh Committee on State Specific Reforms, *incentive* component was also included with an emphasis and the programme was renamed as Restructured Accelerated Power Development and Reform Programme (RAPDRP) in 2002-03.It comprises of two parts:

Part-A - This part provided assistance to states for preparing the base-line data for using new technology tools in project areas having more than 4 lakh people and annual input energy of the order of 350 MU.

Part-B- This part provided assistance for renovation, modernization and strengthening of 11 kV level Substations, Transformers/Transformer Centres, and re-conducting of lines at 11kV level. In exceptional cases, where sub-transmission system is weak, strengthening at 33 kV or 66 kV levels was also to be considered.
To get assistance under the scheme, the states were required to constitute the State Electricity Regulatory Commission, and achieve the target of AT&C loss reduction of 3% per year for utilities that have AT&C loss above 30% and 1.5% for utilities having AT&C loss below 30%.

The Government had approved the programme with a budget provision of Rs. 40,000 Crore [9] during Xth Plan, out of which Rs. 20,000 Crore was allocation under Investment component and Rs. 20,000 Crore under Incentive component. However, the Government actually allocated only Rs. 12,322 Crore under the investment component, Ministry so far sanctioned 583 projects with overall estimated outlay of Rs. 19180.46 Crore. However, the Utilities were able to complete only about 50% work amounting to Rs. 9730.48 Crore. Under incentive component of APDRP, 19 states submitted their incentive claims to the Ministry amounting to Rs. 10,795.69 Crore, since launch of the programme. However, on scrutiny by independent evaluators, only 8 states were found eligible for incentive. Total incentive amounting to Rs. 1536.62 Crore was released among these states.

B. POLICY:

Different policy[3] and schemes like Rajiv Gandhi Grameen Vidyutikaran Yojana (RGGVY, apr-2005), Rural Electricity Distribution Backbone (REDB),Village Electrification Infrastructure (VEI), Decentralised Distributed Generation (DDG) , National Electricity Fund(NEF)[3] etc have been adopted by GOI to promote distribution as well as whole power sector. The amount of Rs. 22,000 crore has been estimated for 12th Plan under NEF, assuming an average interest subsidy of 5% per annum which is expected to be provided from the funds allocated for distribution.

VIII.RECOMMENDATIONS

Some recommendations for loss minimization are proposed below

- Setting up of special courts and special police stations to deal exclusively the cases of pilferage of electricity.

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- Strengthening SLDC/NRLDC etc and providing autonomy to CERC,SERC etc.
- Metering: 100% metering of feeders, distribution transformers and consumers.
- Energy Accounting and Auditing on real time basis, employing AMR etc.
- 100% billing / collection efficiency and adoption of *prepaid meter* in some cases(non bonafide customer).
- Development of adequate distribution infrastructure by constructing new lines/ substations and augmentation /up gradation of existing distribution infrastructure.
- Systematic Planning & Development of distribution infrastructure using the system development techniques/software and do away with the present practice of haphazard / casual and ad-hoc practice.
- Adequate and proper maintenance of distribution infrastructure as per the best practices all over the world.
- Adoption of *Automatic Power Factor Controller (APFC)* which is capable of automatic turn on and off, *Anytime Payment Centre(ATP), E- billing, customer care centre,*.
- It should be made obligatory for all the big industries as well as the utilities to carry out energy audit of their system to identify high loss areas and take remedial measures to reduce the same.
- Schemes for *incentive awards* to utilities who are able to reduce T&D losses beyond a certain pre-fixed limit.
- The financial institutions should be encouraged to provide easy loans to utilities for taking remedial measures to reduce the T&D losses.
- Publicity campaigns should be carried out to make the consumer aware of the high penalties on the unauthorized use of electricity.
- *Liberalization of electricity market*:

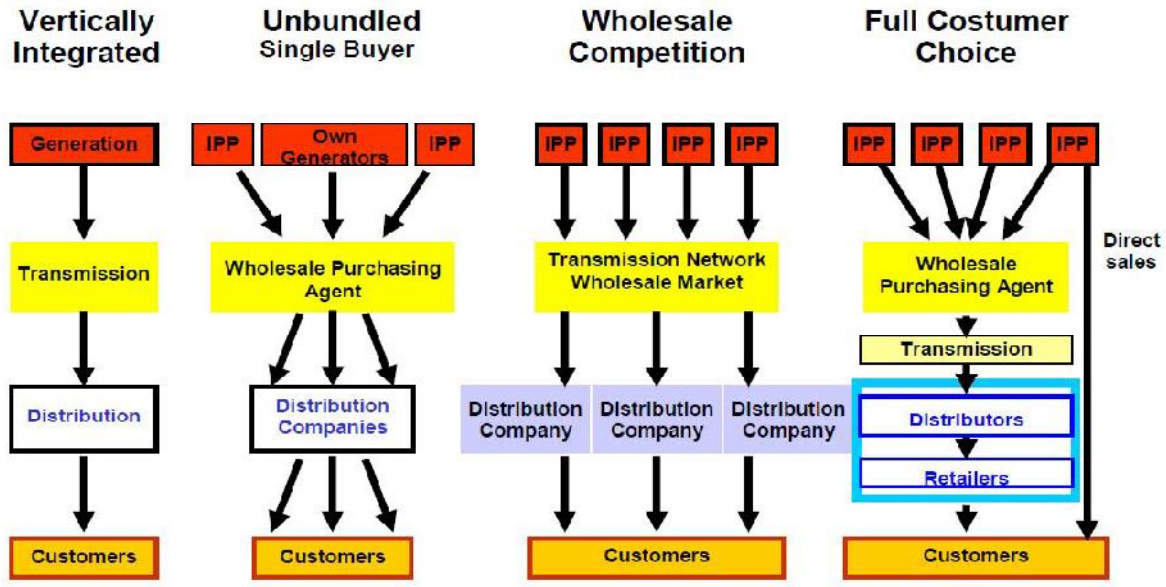

Figure 1: Liberalization of Electricity Market and enhancement of customer choice

- *Tariff rationalization*:
  Since T&D losses are not uniform across a state, consumers in an area that has a high default rate should be charged more compared with those consumers in the areas of lesser default.
- *Reducing cross subsidization*:
  The agriculture and household sectors are cross-subsidized [3] ,[5]by above-cost tariffs for commercial and industrial customers and railways. In fact, Indian industry pays a much higher price for the power it consumes in comparison with even developed nations such as the US, Germany and the UK, with just the Japanese counterparts paying more.
- *Promote use of CDM(Clean Development Mechanism) and Renewable Energy:*

- Perform, Achieve and Trade Scheme of the National Mission for Energy Efficiency
- Provisions for T&D losses in UNFCCC
- Energy Access through Off-Grid technologies for Agriculture

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- Optimal use of ***distributed generation***
- ***Outsourced call centres*** for whistle-blowing
- Utilities should prepare realistic power *Master Plans* for their systems to develop a strategy to meet the targeted loss level.

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 below

. TABLE 1:Elementwise accepted level of T& D loss

System Element	Power Losses (%)	
	Minimum	Maximum
Step-up transformer & EHV Transmission system	0.5	1.0
Transformation to intermediate voltage level, Transmission system and 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 & service connections	3.0	7.0
Total	7.0	15.5

IX.CONCLUSION

From the above discussions it is found that there are various factors responsible for AT & C losses which need to be eliminated. As it is extremely difficult to eliminate all the causes simultaneously in our country, strategically measures should be taken to reduce or marginalize the major causes of losses. The distribution losses can be reduced by proper selection of distribution transformers, feeders, proper re-organization of distribution network, placing the shunt capacitor in appropriate places, theft control, adoption of upgraded technology etc. HVDS should be implemented at a faster rate. Training of the operating personal would result in improved system operation. The distribution companies should be ready for initial investment keeping in view of future savings in energy.

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