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ABSTRACT: Power distribution network in India is the weakest link in the entire power system chain. Despite of impressive growth in power sector, the presently available sub-transmission and distribution network is not adequate to deliver the power to the ultimate consumers with reliably and up to their satisfaction. It is mainly due to low investment in this sector and poor financial health of various SEBs. Study indicates that about 55% of energy generated is billed and balance is lost. This paper discusses various technical, commercial and administrative measures that need to be taken immediately to reduce the losses and improve the reliability of power supply to the consumers with quality. A case study with reference to one of the distribution circles was described. Results indicate that proposed measures would yield substantial reduction in various losses, improvement on reliability as well as increase in revenue collection efficiency. This would ultimately makes the distribution sector commercially viable unit and thus helps in accelerating overall economic growth of our country.

I. INTRODUCTION

Electric power is the basic infrastructure for economic development of any developing country like India. In Indian power system, phenomenal expansion has taken place since last five decades. For example, generation capacity has grown at an average rate of 9% and reached to a level of more than 100,000 MW as of today. The development of transmission network has also closely followed the growth of generation facilities. With a meager transmission network, with 132kV as the highest transmission voltage at the time of independence, today, besides HVDC lines, we have 765kV as the highest transmission voltage level, five regional grids under operation and formation of a National Grid interconnecting all the regional grids is under progress.

In the sub-transmission and distribution sector also, substantial expansion has taken place and State Electricity Boards (SEBs), more or less, have been able to fulfill the objectives of Government in terms of expanding the electricity network to rural areas. Out of total 587,258 inhabited villages in the country as per 1991 census, more than 86% villages have been electrified. 13 states have declared 100% electrification of feasible villages. However, despite impressive growth, the presently available sub-transmission and distribution network is not adequate to deliver the power to the ultimate consumers with reliably and up to their satisfaction. In fact, distribution is the weakest link in Indian power system chain and its expansion did not, for the past many years, keep pace with generating capacity expansion. It is mainly due to low investment in this sector and poor financial health of various SEBs.

Due to above reasons coupled with mushrooming/unplanned growth of the network, Indian distribution system is characterized by inefficiency that results into to high losses (technical and commercial), frequent interruptions and poor voltages in the power supply and dissatisfaction to the consumers. It is estimated that out of total energy generated, approximately 55% is billed and only 41% is realized. Further, the gap between average revenue realization and average cost of supply has been increasing constantly. During the year 2000-01, the average cost of supply from SEBs was 304 paisa per unit while the average revenue realization was 212 paisa per unit. Therefore, to accelerate the overall growth of Indian power system and the economy as a whole, efficient functioning of distribution system both in technical and financial terms is the need of the hour.

In this paper, important factors responsible for making the existing distribution sector inefficient are discussed. A few aspects for improvement of efficiency in the distribution system in terms of quality power supply to the consumers, financial turnaround of SEBs etc. are also deliberated with specific reference to Sindhudurg distribution circle in Maharashtra State.

II. CHARACTERISTICS OF PRESENT DISTRIBUTION SYSTEM

In the initial stages of power development in our country, power supply facilities and T&D system were built mainly catering to urban areas/towns to feed mostly domestic and commercial loads. With the thrust of rural electrification programme and large-scale energisation of pump sets from the third five-year Plan onwards, the sub-transmission and distribution networks were expanded rapidly. While extension to the high voltage transmission system in the country (from 110kV and above) has been made on the basis of systematic load flow and system studies, the extensions in the sub-transmission and distribution systems (66kV and below) have been made to meet immediate requirements without a proper planning and system studies to evolve optimal network, size, location of substations, adequacy of back-up network etc. Instead, the distribution network has developed in an unplanned and haphazard manner. This has characterized the existing distribution system as follows:

- Development of distribution system dominated by radial networks. Due to radial nature, various problems emerged
  - For example, in many parts of our country, like Bihar, U.P, Maharashtra (Konkan area) etc., almost a radial link right from 132kV and below feeds supply to a large number of areas. Thus a fault at any part of the radial link would disrupt the supply to entire area, hence, makes unreliability in power supply.
As discussed earlier, to improve the distribution system revenue collections, improved customer satisfaction etc. achieved only through reduction in losses, improvement of distribution system efficiency. It can be made the distribution system financially viable through retarding the growth. Therefore, attentions need to be paid to increased losses. The huge losses are the major drain on the attention has not been given to compensate this reactive element – the most value added stage in the entire power sector. The cost of energy at the distribution stage is about Rs. 2.75 per unit – the most value added stage in the entire power sector. In fact, due to absence of meters, in most of the present there is no accounting. This is primarily on account of absence of adequate metering arrangement at strategic locations. In fact, due to absence of meters, in most of the cases, there is no clue on the areas that are incurring maximum losses. This information is very vital to devise special corrective measures to alleviate the problem of high losses. Therefore, to contain this loss, following measures are considered:

- Augmentation/strengthening of overloaded 33/11kV substation.
- Creation of new 33/11kV substations to reduce the length of 11kV feeder as well as overload of 33kV lines and 33/11kV transformers
- Re-conductoring of overloaded and old feeders.
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- Computerised load flow studies for long-term strengthening of sub-transmission and distribution systems in a systematic manner.

Commercial Interventions

It was found that out of total losses of 40-50% in sub-transmission and Distribution system (ST&D), major portion (about 20-30%) constitutes commercial losses for which presently there is no accounting. This is primarily on account of absence of adequate metering arrangement at strategic locations. In fact, due to absence of meters, in most of the cases, there is no clue on the areas that are incurring maximum losses. This information is very vital to devise special corrective measures to alleviate the problem of high losses. Therefore, to contain this loss, following measures are considered:

- Provision of 100% temper proof and high precision metering of all category of consumers.
- Proper energy accounting and auditing at all levels so that energy received, energy billed and losses at various stages of transformation can be accurately accounted.
- Consumer mapping and indexing to bring all consumers on record maintaining status profile of indexed consumers by periodic survey.
- Creation of data base of consumers with past consumption pattern.

Administrative Interventions

Administrative interventions are required for improvement of billing, revenue collection efficiency, customer satisfactions etc. for which following actions are considered:

III. EFFICIENCY IMPROVEMENT – A FEW ASPECTS

As discussed earlier, to improve the distribution system efficiency, technical, commercial and administrative interventions would be required.

Technical Interventions

The very purpose of technical interventions is to reduce the technical loss up to the manageable level. The target and maximum tolerable technical loss levels for each distribution voltage levels are as given in Table-1 below:

<table>
<thead>
<tr>
<th>Voltage level</th>
<th>% Target level</th>
<th>% Tolerable level</th>
</tr>
</thead>
<tbody>
<tr>
<td>33kV/66kV</td>
<td>1.5</td>
<td>3.0</td>
</tr>
<tr>
<td>33/11kV</td>
<td>2.25</td>
<td>4.5</td>
</tr>
<tr>
<td>transformation &amp; 11kV</td>
<td></td>
<td></td>
</tr>
<tr>
<td>LT</td>
<td>4.0</td>
<td>7.0</td>
</tr>
<tr>
<td>Total</td>
<td>7.75</td>
<td>14.5</td>
</tr>
</tbody>
</table>

Various measures for technical loss reduction are:

- Development of long LT lines: Distribution network all over the country uncharacteristically have mesh of long low voltage (LT) lines with inadequate transformer capacity. This leads to substantial voltage drop, high technical losses, unreliability in supply etc.
- Inadequacy in system: Due to non-systematic planning for growth of the network without considering long-term requirement, many parts of the sub-transmission and distribution network are loaded heavily without adequate redundancies. This inadequacy causes frequent tripping as well as high technical losses.
- Difficulties in voltage regulation: As per the guidelines, sub-transmission and distribution voltage need to be regulated within ±10 to ±6% depending upon the voltage level. However, during peak times, due to huge power flows over long radial link, substantial voltage drop beyond permissible limits occurs. On the contrary, during off-peak times (when demand reduces), shunt capacitors used for load compensation remain connected in the network and thus leads to higher voltages.
- Absence of proper energy accounting system/audit: This makes actual estimation of losses and ratio of technical and commercial losses difficult, thus high loss areas, specific elements etc. remain unidentified.
- Poor quality of equipment and lack of proper maintenance, accounts for the high level of technical losses at the distribution stage. Further, improper load management and inadequate reactive compensation at load points also lead to high losses.

In addition to above, distribution system is also suffering from high level of commercial losses due to poor billing, revenue collection etc. and theft of power by various users. These constitute a large component of overall losses. There are also losses on account of defective/slow energy meters, burnt meters, no meters etc. In fact, energy loss in EHV transmission system is only around 4-5%, whereas, about 40-45% of the total energy loss takes place in sub-transmission and distribution system. This is the most crucial area as the cost of energy at the distribution stage is about Rs. 2.75 per unit – the most value added stage in the entire power sector. Further, the rise in industrial and agricultural pumping loads increased the reactive power requirements. Adequate attention has not been given to compensate this reactive demand, which resulted in poor voltage conditions and increased losses. The huge losses are the major drain on the revenue stream deteriorating the financial health of SEBs thus retarding the growth. Therefore, attentions need to be paid to make the distribution system financially viable through improvement of distribution system efficiency. It can be achieved only through reduction in losses, improvement in revenue collections, improved customer satisfaction etc.
• Establishment of computerized billing centers minimum at circle level with WAN/Web connectivity upto at least sub-division level.
• Verification of consumer energy meters and replacement wherever defective.
• Adoption of at least hand held logging units for meter reading
• Provision of voluntary disclosure scheme of declaring connected load in each year for providing opportunity to consumers for declaring their increased load.
• Strengthening of customer complaint redressal system through computerization.
• Taking prompt action for disconnection and reconnection.
• Reduction of outage rate and improvement of supply reliability with quality.
• Introduction of effective Management Information System (MIS) to ensure effective flow of information at various levels for quick decision making purpose.
• Adoption of DMS/SCADA system for collection of various information and generation of reports automatically.
• Introduction of suitable incentive and disincentive schemes for motivating the employees to perform their duties.
• Initiation of punitive actions to stop theft of energy.

IV. A CASE STUDY
Considering different specific requirements of various geographical areas, scattered works, nature and volume of field data required, Indian power distribution system is divided into 436 nos. of distribution circles spread over 593 districts. This demarcation is in consonance with responsibility and network structure in the field covering both urban and rural areas correspond to the circle which is headed by a Superintending Engineer and generally covers 66kV/33kV/11kV/0.4kV radial network. However, for the sake of simplicity studies were carried out for efficiency improvement of distribution system in Sindhudurg distribution circle in the State of Maharashtra. It is one of the important tourist district in Konkan area of Maharashtra and is located in south-west part of the state, having Sahyadri terrain in east, Arabian sea at west, Ratnagiri district in north and Goa state in south.

The circle is spread over an area of 5087 sq. kms with a population over 8 lakh. It has the distinction of having 100% electrification with all the towns and villages connected to source of power supply. Like other circles in our country, distribution system of this circle is suffering from unreliability, poor voltage at consumer ends, overloading of distribution transformers, high losses etc.

Features of the Circle
The circle has one division and further divided into eight sub-divisions. Peak demand is about 67 MW. The circle receives power supply through a lone 220/132kV substation. The distribution network spreads over 19 nos. of 33/11kV substations having 18 nos. of 33kV feeders, 56 nos. of 11kV feeders average length 25 kms) with LT and HT ratio as 2.67. Power map of the circle upto 33kV level is shown at Fig.1.

86% of the consumers are domestic category that consumes about 60% of energy. About 55% of the energy received is being metered while 15% is assessed, thus making the total losses as 30% out of which technical loss as estimated is about 18%. The energy flow chart and technical losses at various voltage levels is given at Fig. 2.
**Improvement of overall Efficiency**

It was observed that the technical loss in the circle is about 18% while commercial loss is about 29%. Studies were carried out for reduction of both commercial and technical losses.

**Reduction in commercial loss**

Following aspects were studied:

a) Provision of 100% static/high precision energy meters at all consumers and system levels

It was found that most of the meters at consumers are electro-mechanical type which were reportedly sluggish and have more scope for manipulation. About 13% and 5% of un-metered consumers are domestic and commercial category respectively. Hence, in the study energy meters of all the consumers were replaced by the static/high precision meters including un-metered consumers. Study reveals that with this modification the metered energy would be increased from the level of 55% to 70%.

 Provision of meters at 33kV, 11kV and distribution transformer levels were considered for proper energy accounting and to pen down the areas that are more prone to theft by comparing the energy received at distribution transformers vis-à-vis energy metered at consumer ends. Study indicates that provision of 1000 nos. of meters on Distribution transformers out of total 1550 nos., would increase metered energy by 5%.

The monetary benefit on the account of increased metered energy, hence reduction in commercial loss estimated as Rs. 420 lakh per annum (assuming cost of power supply as Rs. 3.5 per unit).

b) Establishment of computerized billing centers

Presently meter reading is done at sub-divisional level and billing is done at zonal level and bills are issued to the sub-divisional level for further distribution which takes longer time. To avoid such delay, computerized billing centers at sub-division level were considered that would improve the efficiency in billing as well as collection.

c) Detection and control of theft

To reduce the loss due to pilferage, setting up of vigilance squad were studied.

**Reduction in technical loss**

Following aspects were studied:

a) Establishment of new 33/11kV substations and re-configuration of 11kV feeders

Study indicates that voltage regulation at different 33/11kV substations is as high as 11% with 2.88% as energy loss at 33kV feeders. In case of 11kV feeders, the voltage regulation estimated as high as 25% with 7.5% loss. Therefore, to reduce the loss and to contain the voltage regulation, establishment of new 33/11kV substations, re-configuration of 11kV feeders were studied. It was observed that establishment of at least six nos. of substations along with re-configuration of 11kV feeders having high voltage regulation and loss would result into improvement in voltage regulation by 10-15% and loss reduction by about 2%. This measure would extend annual monetary benefit of about Rs. 190 lakh.

b) Re-conductoring of 11kV feeders

In Sindhudurg circle, most of the 11kV feeders are built with weasel conductor. It was found that few feeders, even though length is comparatively small, but due to very high loading, voltage regulation is poor. In such situation, re-conductoring is a good option. Hence, studies were carried out for re-conductoring of two feeders which result in loss reduction by about 0.5%.

c) Installation of Capacitors

Installation of fixed capacitors at the distribution transformer LT side (0.4kV) is one of the solutions for improvement of voltage profile by improving the power factor of the loads and reduction of losses. From the studies it was observed that with the installation of about 6 MVAR capacitor banks (i.e about 10% of the existing total distribution transformer capacity-100 kVA and above), the load p.f would improve from existing 0.80 to 0.95. This causes reduction in technical loss by about 0.2%. Losses will further reduce with the installation of shunt capacitors at 11kV level.

d) Establishment of new Distribution Centers (DTC)

The ratio of LT and HT network in the circle is about 2.67, which attributed high loss in the LT system. It was also found that LT system voltage is also very poor. Therefore, to reduce the loss and improvement of voltage, establishment of additional DTCs along with 11kV interconnecting lines were studied. Study reveals that establishment of 300 nos. of DTCs (200 nos. 63kVA and 100 nos. of 100 kVA) in various sub-divisions would lead to improvement in the ratio of LT and HT to 2.3 and reduction in technical loss by about 4%.

Therefore, with the above measures, technical loss would reduce by about 8%. Total monetary benefit on this account is estimated as Rs. 390 lakh per annum (assuming purchase price as Rs. 2.6 per unit).

**Improvement of revenue collection efficiency**

One way of improvement of Revenue collection efficiency is improvement of customer satisfaction. This can be
achieved by improving the reliability of supply, computerized customer complaint centers, quick redressal of complaints etc.

33/11kV substations are the backbone of power distribution system, and any failure in the substation results into darkening of a large area thus affecting the supply reliability. Therefore, priority needs to be given to make the substation fault-free to the extent possible. Study indicates that in many substations, number of equipment like circuit breakers, isolators, instrument transformers, auxiliaries, lightning arrestors, protection devices etc. are not in working conditions. Maintenance of substations, DTCs are also not in order. Based on the data, studies were carried out for revamping of substations and augmentation of transformation capacity in the overloaded stations. Studies indicate that with proper R&M of substations and distribution transformer centers would improve the failure rate from existing level of 18% to 9%, thus improve reliability. This leads to the increase in annual revenue by about Rs. 70 lakh (2% increase) by way of increased energy consumption.

It was found that with all the above measures, total loss in the circle would reduce to about 18% from present level of 30%.

V. GOVERNMENT INITIATIVES

The initiatives of Government of India hitherto were confined to setting up of SERC, tariff rationalization, unbundling of SEBs and private participation in generation, transmission & distribution. However, these initiatives that are predominantly fiscal, financial and policy oriented alone could not make much effect in bringing about commercial viability of SEBs, which is the main factor for inefficient distribution system. For example, the initiatives on tariff rationalization and removal of subsidies have resulted in tariff increases without any improvement in quality, reliability and availability of power supply. This led to increased consumer resistance apart from lack of sustained investments in the Sector.

Non-viability of the SEBs on account of inadequacies of distribution sector, wherein the maximum losses occur, has not allowed for the desired results in the power sector reform initiatives and there was a need to integrate the above measures and initiatives and provide for a focused approach towards improving the sustainability and financial viability of the SEBs.

A national programme has been launched that covers the entire country in the next three to five years to strengthen the sub-transmission and distribution network, restructures the utilities at the distribution circle level, adopts project mode and which seeks in the first instance to reduce outages and interruptions and reduce Aggregate Technical & Commercial (AT&C) losses to fifteen percent. Therefore, Government of India launched a nationwide programme called Accelerated Power Development and Reform Programme (APDRP) in February, 2001 by providing 50% fund as grant to the States for upgradation and strengthening of ST&D system. To begin with, 63 nos. of distribution circles were identified all over the country to develop them, as “Model” that will be replicated in rest of the circles. Works in this direction has already started.

VI. CONCLUSION

Power is the single largest sector that would determine the course of infrastructure reforms and revival of our economy. Indian power sector is at cross roads. Time has come for taking drastic measures. Commercial losses are estimated at about Rs. 33,000 crore during 2001-02. Gross subsidy estimated at about Rs. 43,060 crore in 2001-02. Industrial and commercial consumers are charged tariffs higher than the average cost. All these result into inefficiency in the distribution sector. Hence, there is a need to halt this trend and reverse it with corrective steps. Various technical, commercial and administrative interventions that are required to reduce losses, improvement in billing and revenue collection efficiency in the distribution sector are discussed. Effect of proposed measures with specific reference to Sindhudurg circle in the Maharashtra state is also quantified. It was found that with the proposed measures, the losses in the circles would reduce by 12% with an investment having payback period of about four years.

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