Loss Reduction in Distribution System using Best Practices

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Abstract. This paper talks about the implementation of the best practices to reduce the losses related to Transmission and Distribution (T&D) system. Distribution system is one of the major areas where the distribution companies (DisComs) face huge losses, therefore, reduction of T&D losses may bring profit to the DisComs. In this work, various technical losses are identified and tackled accordingly. This paper also discusses the measures to be taken to reduce the losses and hence increase the overall efficiency of the network.

1. Introduction
Energy is the basic requirement and necessity for overall development of the nation. Electric power utilities face rapidly increasing power demand. Distribution system is the last point to deliver power to the end consumer. So, it becomes necessary to keep and maintain the health of our distribution system. But sadly, in India the growth of the distribution network has happened in a very haphazard manner and it is due to this reason it is facing poor monetary health and poor efficiencies. Over the years this approach had resulted into high Transmission and Distribution (T&D) losses or high Aggregated Technical and Commercial (AT&C) losses. Thus, the focus over the years has been on developing the strategies to reduce the T&D or AT&C losses using the best practices. And that is why various reforms are being carried out at the distribution level to improve its condition and health i.e., minimizing the overall losses at distribution level.

2. Problem formulation
The DisComs face a lot of issues and challenges when it comes on T&D losses. The DisComs also face the finance and monetary related issues due to the energy which is lost in the network. The T&D losses are bifurcated into two components i.e. Permanent/Fixed type losses and Variable losses [1, 2]. Permanent losses that occurs in the system are identified as heat and noise but not directly related with current. These losses occur for the time when the transformer remains energized. Permanent or the fixed type losses can be generated in many forms in the system. Some of them can be mentioned as:
- Losses due to Corona
- Losses due to leakage current
- Dielectric Losses
- Losses due to open circuit
- Losses that happens due to measuring elements continuous load

Variable losses are the losses which vary directly with the current. These losses vary in direct proportion to square value of the current and also known as $I^2R$ losses. These losses also depend on lines and cables cross-sectional area. So cross-sectional area can be increased to reduce these losses. Mains reasons of these losses are:
2.1. Long distribution lines
Lines/cables/conductors are stretched over long distance to feed the loads in rural areas. This increases the resistance of line and ultimately increases the $I^2R$ losses in the lines. The root causes of such practice are the growth of distribution and sub-transmission system in a very haphazard manner. Therefore, rural electrification is developed using long 11 kV lines and LT lines.

2.2. Distribution transformers installation distant from the consumption point
In most of the cases, DTs are placed far away from the location of customers. Due to this reason the length of the service cable increases and hence problem of low voltage arises. The line losses tend to increase due to low voltage level at the consumer end. The solution for this type of problem is to install DTs at the load centers.

2.3. Low power factor
In distribution network, power factor is observed to be vary from 0.65 to 0.75. This low value of power factor also results in high distribution losses. For low power factor, the current flowing would be more and hence $I^2R$ losses in the network tend to increase. Thus, line losses that occur in distribution system due to poor power factor can be minimized by using means of power factor improvement. One such mean is shunt capacitor. It can be connected either at various point of distribution line or on secondary side (11 kV side) of the 33/11 kV power transformers to improve the system performance. For a distribution system, the optimum rating of capacitor banks is considered to be two-third of the average kVAR requirement of that system. The more appropriate method is to connect the shunt capacitors across the customer’s premises that uses inductive loads. It is observed that the connection of capacitors across individual loads reduces the losses up to 4 to 9% and it depends upon the extent of power factor improvement.

2.4. Feeder phase current and load balancing
Simplest ways to reduce the losses in any distribution system is to do current balancing in 3-phase circuits. Balancing in feeder phases also help in reducing the voltage drop problems which further decreases the voltage unbalancing conditions for 3-phase customers. Amperage magnitude at the substation does not give surety for load balancing for throughout the length of feeder. Unbalancing may vary with time i.e. throughout the day and seasons-wise. Feeders are usually considered to be balanced when phase current magnitudes are within 10. In similar way, if load balancing is also done at the distribution feeder level it can also help in reducing the losses.

2.5. Effect of the load factor
Load factor is calculated by taking the ratio of average load to peak load for a specified time period. Let us understand this with an example:
In a month of 30 days (720 hours), suppose a feeder having peak load of 10 MW. If the feeder supply 5000 MWh in total, the load factor of the month will come out to be $5000 \text{ MWh} / (10 \text{ MW} \times 720 \text{ hrs}) = 0.69$
Energy losses can be curtailed by increasing the load factor value. The load factor could be increased by offering the “Time of Day” (TOD) rates to the consumers.

3. Solution technique
The solutions to the above listed problems are:

3.1. Size of conductor
A conductor size of low value can increase the $I^2R$ losses and can also cause the low voltage problem. The adequate size of the conductor was identified and hence the losses in this category were reduced.
3.2. Keeping regular check on insulators
Flashover across insulators and cracking of them can cause power outages. All the damaged or the deteriorated insulators were immediately replaced with the appropriate ones. The preventive action which was implemented is to keep a regular check on them and their regular inspection.

3.3. Distribution transformers
Relocation of the DTs at regular intervals. Regular maintenance of DTs. Sealing of DTs wherever there was scope of theft.

3.4. Installation of the shunt capacitors
Where there is need of correction of poor power factor, the installation of shunt capacitors may be cost-effective and best method to decrease the distribution losses.

3.5. Regular maintenance
The maintenance work of all the DTs and LT line is done on regular intervals in order to keep the losses under control. Following are the activities which are undertaken on regular basis:
- Overhead lines maintenance
- Bent poles corrections
- Oil testing of transformer
- Repairing of any broken part
- Proper crimping of lugs on the cables of DT panel box
- Keeping a check on load unbalancing conditions

3.6. Laying of new service cables and installation of new smart meters
Under this project, all the household as well as industrial electricity meters were replaced with the smart meters. As there was a wide and large scope of theft and meter tampering. New service cables were also installed as the I2R losses are comparatively less in new cables.

3.7. DT metering
DT metering was done on every DT present in the city. This not only helped in maintaining the regular data of the energy consumption but also helped in knowing the status of phase balancing as the meters which were installed are all smart meters. Apart from this, it also helped in restricting the theft to some extent as the DT meter reading is matched with the consumption of the consumers who are connected to the DT.

3.8. Boundary metering
The utilities need to ensure that their operational area is electrically fenced. Ring fencing is necessary for measuring the net input energy of the DISCOM i.e., difference of energy entering and leaving. For this purpose, it should be make sure that proper import/export meters are installed at the boundary of those lines which feed the outside as well as inside area of operation so that import and export energy could be measured properly. These lines may originate from sub-stations located within or outside the Utility’s operational area.

3.9. Online data collection
Earlier the data collection process was manual. Using various tools and software this process was made online. The process has now been made a lot simpler as this process was really time consuming. The system generated data for energy auditing is the time efficient as well as the cost-effective method as not only it saves time in collecting the required data, but it also saves the conveyance charges.

3.10. Feeder to DT metering
Electronic Trivector are connected at the input side of HT (11 kV feeders sending end) and LT (distribution transformers output) which were missing earlier. Feeders record the energy supply at every half hour interval by the feeder. The date and time stamp for each data is also recorded. The memory of
energy meter is adequate to store the data for minimum period of 36 days in most of the cases. At the end of a month, the data that has been stored is downloaded. It is downloaded at site into Common Meter Reading Instruments (CMRI) in online mode. A continuous check is being kept on the Feeder to DT metering. The energy consumption by the feeder is matched with all the DTs connected to the Feeder to find out the overall losses in this area [6].

Apart from the above measures, the following strategies were formulated and implemented on field. These are the practices which were not followed earlier but came into existence afterwards.

- Installation of Energy meters on all incoming feeders of 33 kV & 11 kV sub-stations located inside Metering Billing & Collection (MBC) network area.
- Installation of Energy meters on all incoming feeders of 33 kV and 11 kV that feed power to the HT/LT customers inside MBC network area.
- Installation of export/import meters in dedicated feeders connected to sub-stations inside project area but feeding power to outside MBC network area.
- Segregation of rural HT (11 kV) feeders according to their categories which includes agricultural, commercial, domestic etc.
- Meter data analysis which includes consumption pattern analysis of household consumers, malls, hospitals, cold storage plants, RO plants etc.
- Phasor diagram study along with the study of events using Meter Reading Instrument (MRI).
- Updating all sorts of Transformers, Poles and Household Customers data on GIS.
- New DT installation proposal to Nigam (AVVNL) if the conductor length is found to be excessive in length, to reduce the line losses.
- Shift the excessive number of DTs to another feeder.
- Informing AVVNL if there are any tree touching cases on HT line.

The other factors also include:

- Checking the multiplying factor of the consumer
- Checking the multiplying factor of DT and HT consumer
- Welding of the Super transformer (SDT) for restricting the theft practices
- In the theft prone areas, a single DT was replaced by single phase transformers (one transformer for 3-4 homes)
- Complex monitoring and society monitoring: Analyzing how many customers are connected to single DT and what is the loss level.
- 33 kV to 11 kV daily energy mismatch data
- LT network maintenance
- Shifting of the excess load from the transformers which are overloaded
- Meter data analysis of Domestic Consumers (event data, day and night consumptions)
- Verification of tagging of Distribution Transformers
- Analysis of DT and Feeder tripping report and providing improvement action plan

3.11. Data analysis:

Now a days, more emphasis is given on data analysis rather than going directly for the site verification. Consumer’s day and night energy consumption are analyzed on daily basis and after establishing a trend in their consumption pattern the site visit is done for suspected theft cases. Except for the Non-Domestic Consumers (shops, complexes, factories etc.) if any consumer’s night consumption is zero then site visit is done for vigilance to restrict the theft cases.

More emphasis is also given on DT to consumer losses which is also being done through data analysis. Through data analysis we have rectified following cases:

1. Load balancing phase wise
2. Low output voltage in case of DT failure or CT (Current Transformer placed on transformer’s LT bushing) failure.
3. Replacement of high kVA rating transformers with negligible load w.r.t kVA rating with the lower kVA rating transformers.
4. Simulation results and discussions

For calculation of T&D losses the data for net input energy and the total sold energy in lac units (LU) was collected for the given months and hence the corresponding T&D losses were calculated. For AT&C losses calculation, billing efficiency and collection efficiency both plays a very crucial role and should be considered to calculate these losses. Figure 1 shows the level of T&D and AT&C losses level from March 2018 to February 2020.

![Figure 1. T&D and AT&C loss level data.](image)

The 33 kV to 11 kV energy flow is monitored regularly and it is being analyzed periodically. Proper metering is done at the 33 kV as well as 11 kV feeder to keep a check. The yellow line which represents the calculated energy at 11 kV and the blue line which represents measured energy at 11 kV seem to coincide. Figure 2 shows the data for energy flow monitoring from 33 kV to 11 kV input.

![Figure 2. Energy flow data between 33kV and 11kV.](image)

Daily monitoring and regular analysis are done for energy mismatch between 33 kV and 11 kV for loss minimization techniques. Figure 3 shows the trend of energy mismatch between the two. The energy consumption at the 33 kV feeder and 11 kV feeder is being collected with the help of smart meters. The green line shows the LSL which stands for Lower Standard Limit and the red line USL stands for Upper Standard Limit. The LSL and USL are set at 0.3% and 0.8%, respectively.
The energy gap between 11 kV feeder and DTs are shown in figure 4. The target is to achieve 2% variation in this case. And for five consecutive months, the trend shows that the variation was very close to 2%. The term USL is the abbreviation used for Upper Standard Limit.

Figure 5 shows the cumulative trend of the energy mismatch between 11kV to DT and HT consumers. The trend is a cumulative graph as the energy consumption of the previous months are added into the next successive months. We have managed to keep the percentage variation close to 3% throughout.
Figure 6 shows the cumulative losses at the LT network which includes the energy consumption by Distribution Transformer and Super Transformer, percentage variation between 11 kV and DT and at LT consumer level. The trend is a cumulative graph as the energy consumption of the previous months are added into the next successive months so as to get the overall view of the level of losses month wise as well as year wise at the end of a financial year.

![Cumulative LT losses](image)

**Figure 6.** Cumulative LT losses.

5. Conclusions
In this paper, the various measures that are taken at the distribution level for the reduction of T&D losses have been discussed thoroughly. The factors which are responsible for current loss have also been represented. It can be seen and observed that some of the reasons mentioned in this paper are the common causes with almost every distribution network. Implementation of various measures mentioned here have proved to be effective and helped in bringing down the overall level of the losses. If the losses are reduced, then the distribution network will become more efficient, more reliable and more stable. If these losses at LT level are reduced then the Discom might think on providing the electricity at lower rates, this will surely bring a sense of relief to the consumers. Over the years a lot of research and studies have been carried out to reduce the T&D and AT&C losses but it is also true that all the losses cannot be completely wiped out as there are fixed losses also present in the network. In the present scenario, T&D system is the center of focus for many of the utilities and various reforms have been carried out. But the need of the hour is to implement the planned strategies and calculative measures and for that utilities need to come up with the permanent solution to the existing challenges. All this will ultimately contribute towards the process and development of our nation.

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