**Losses in Power Distribution**

**Introduction:**

* Power generated in power stations pass through large & complex networks like transformers, overhead lines, cables & other equipments and reaches at the end users. It is fact that the Unit of electric energy generated by Power Station does not match with the units distributed to the consumers. Some percentage of the units is lost in the Distribution network. This difference in the generated & distributed units is known as Transmission and Distribution loss.
* Transmission and Distribution loss are the amounts that are not paid for by users.
* T&D Losses= (Energy Input to feeder(Kwh)-Billed Energy to Consumer(Kwh)) / Energy Input kwh x100
* Distribution Sector considered as the weakest link in the entire power sector. Transmission Losses is approximate 17% while Distribution Losses is approximate 50%.
* There are two types of Transmission and Distribution Losses

1. Technical Losses
2. Non Technical Losses (Commercial Losses)

**(1) Technical Losses:**

* The technical losses are due to energy dissipated in the conductors, equipment used for transmission Line, Transformer, sub- transmission Line and distribution Line and magnetic losses in transformers.
* Technical losses are normally 22.5%, and directly depend on the network characteristics and the mode of operation.

The major amount of losses in a power system is in primary and secondary distribution lines. While transmission and sub-transmission lines account for only about 30% of the total losses. Therefore the primary and secondary distribution systems must be properly planned to ensure within limits.

* The unexpected load increase was reflected in the increase of technical losses above the normal level
* Losses are inherent to the distribution of electricity and cannot be eliminated.
* There are two Type of Technical Losses.

**(a)   Permanent / Fixed Technical losses:**

* Fixed losses do not vary according to current. These losses take the form of heat and noise and occur as long as a transformer is energized.
* Between 1/4 and 1/3 of technical losses on distribution networks are fixed losses. Fixed losses on a network can be influenced in the ways set out below.
* Corona Losses.
* Leakage Current Losses.
* Dielectric Losses.
* Open-circuit Losses.
* Losses caused by continuous load of measuring elements
* Losses caused by continuous load of control elements.

**(b) Variable Technical losses**

* Variable losses vary with the amount of electricity distributed and are, more precisely, proportional to the square of the current. Consequently, a 1% increase in current leads to an increase in losses of more than 1%.
* Between 2/3 and 3/4 of technical (or physical) losses on distribution networks are variable Losses.
* By increasing the cross sectional area of lines and cables for a given load, losses will fall. This leads to a direct trade-off between cost of losses and cost of capital expenditure. It has been suggested that optimal average utilization rate on a distribution network that considers the cost of losses in its design could be as low as 30 per cent.
* joule losses in lines in each voltage level
* impedance losses
* Losses caused by contact resistance.

**Main Reasons for Technical Losses:**

**(1) Lengthy Distribution lines:**

* In practically 11 KV and 415 volts lines, in rural areas are extended over long distances to feed loads scattered over large areas. Thus the primary and secondary distributions lines in rural areas are largely radial laid usually extend over long distances. This results in high line resistance and therefore high I2R losses in the line.
* Haphazard growths of sub-transmission and distribution system in to new areas.
* Large scale rural electrification through long 11kV and LT lines.

**(2) Inadequate Size of Conductors of Distribution lines:**

* The size of the conductors should be selected on the basis of KVA x KM capacity of standard conductor for a required voltage regulation but rural loads are usually scattered and generally fed by radial feeders. The conductor size of these feeders should be adequate.

**(3) Installation of Distribution transformers away from load centers:**

* Distribution Transformers are not located at Load center on the Secondary Distribution System.
* In most of case Distribution Transformers are not located centrally with respect to consumers. Consequently, the farthest consumers obtain an extremity low voltage even though a good voltage levels maintained at the transformers secondary. This again leads to higher line losses. (The reason for the line losses increasing as a result of decreased voltage at the consumers end Therefore in order to reduce the voltage drop in the line to the farthest consumers, the distribution transformer should be located at the load center to keep voltage drop within permissible limits.

**(4) Low Power Factor of Primary and secondary distribution system:**

* In most LT distribution circuits normally the Power Factor ranges from 0.65 to 0.75. A low Power Factor contributes towards high distribution losses.
* For a given load, if the Power Factor is low, the current drawn in high  And  the losses proportional to square of the current will be more. Thus, line losses owing to the poor PF can be reduced by improving the Power Factor. This can be done by application of shunt capacitors.
* Shunt capacitors can be connected either in secondary side (11 KV side) of the 33/11 KV power transformers or at various point of Distribution Line.
* The optimum rating of capacitor banks for a distribution system is 2/3rd of the average KVAR requirement of that distribution system.
* The vantage point is at 2/3rd the length of the main distributor from the transformer.
* A more appropriate manner of improving this PF of the distribution system and thereby reduce the line losses is to connect capacitors across the terminals of the consumers having inductive loads.
* By connecting the capacitors across individual loads, the line loss is reduced from 4 to 9% depending upon the extent of PF improvement.

**(5) Bad Workmanship:**

* Bad Workmanship contributes significantly role towards increasing distribution losses.
* Joints are a source of power loss. Therefore the number of joints should be kept to a minimum. Proper jointing techniques should be used to ensure firm connections.
* Connections to the transformer bushing-stem, drop out fuse, isolator, and LT switch etc. should be periodically inspected and proper pressure maintained to avoid sparking and heating of contacts.
* Replacement of deteriorated wires and services should also be made timely to avoid any cause of leaking and loss of power.

**(6) Feeder Phase Current and Load Balancing:**

* One of the easiest loss savings of the distribution system is balancing current along three-phase circuits.
* Feeder phase balancing also tends to balance voltage drop among phases giving three-phase customers less voltage unbalance. Amperage magnitude at the substation doesn’t guarantee load is balanced throughout the feeder length. Feeder phase unbalance may vary during the day and with different seasons. Feeders are usually considered “balanced” when phase current magnitudes are within 10.Similarly, balancing load among distribution feeders will also lower losses assuming similar conductor resistance. This may require installing additional switches between feeders to allow for appropriate load transfer.
* Bifurcation of feeders according to Voltage regulation and Load.

**(7)  Load Factor Effect on Losses:**

* Power consumption of Customer varies throughout the day and over seasons. Residential customers generally draw their highest power demand in the evening hours. Same commercial customer load generally peak in the early afternoon. Because current level (hence, load) is the primary driver in distribution power losses, keeping power consumption more level throughout the day will lower peak power loss and overall energy losses. Load variation is Called load factor and It varies from 0 to 1.
* Load Factor=Average load in a specified time period / peak load during that time period.
* For example, for 30 days month (720 hours) peak Load of the feeder is 10 MW. If the feeder supplied a total energy of 5,000 MWH, the load factor for that month is (5,000 MWh)/ (10MW x 720) =0.69.
* Lower power and energy losses are reduced by raising the load factor, which, evens out feeder demand variation throughout the feeder.
* The load factor has been increase by offering customers “time-of-use” rates. Companies use pricing power to influence consumers to shift electric-intensive activities during off-peak times (such as, electric water and space heating, air conditioning, irrigating, and pool filter pumping).
* With financial incentives, some electric customers are also allowing utilities to interrupt large electric loads remotely through radio frequency or power line carrier during periods of peak use. Utilities can try to design in higher load factors by running the same feeders through residential and commercial areas

**(8)  Transformer Sizing and Selection:**

* Distribution transformers use copper conductor windings to induce a magnetic field into a grain-oriented silicon steel core. Therefore, transformers have both load losses and no-load core losses.
* Transformer copper losses vary with load based on the resistive power loss equation (P loss = I2R).
* For some utilities, economic transformer loading means loading distribution transformers to capacity-or slightly above capacity for a short time-in an effort to minimize capital costs and still maintain long transformer life.
* However, since peak generation is usually the most expensive, total cost of ownership (TCO) studies should take into account the cost of peak transformer losses. Increasing distribution transformer capacity during peak by one size will often result in lower total peak power dissipation-more so if it is over Loaded.
* Transformer no-load excitation loss(iron loss) occurs from a changing magnetic field in the transformer core whenever it is energized. Core loss varies slightly with voltage but is essentially considered constant. Fixed iron loss depends on transformer core design and steel lamination molecular structure. Improved manufacturing of steel cores and introducing amorphous metals (such as metallic glass) have reduced core losses.

**(9)  Balancing 3 phase loads**

* Balancing 3-phase loads periodically throughout a network can reduce losses significantly. It can be done relatively easily on overhead networks and consequently offers considerable scope for Cost effective loss reduction, given suitable incentives.

**(10)   Switching off transformers**

* One method of reducing fixed losses is to switch off transformers in periods of low demand. If two transformers of a certain size are required at a substation during peak periods, only one might be required during times of low demand so that the other transformer might be switched off in order to reduce fixed losses.
* This will produce some offsetting increase in variable losses and might affect security and quality of supply as well as the operational condition of the transformer itself. However, these trade-offs will not be explored and optimized unless the cost of losses are taken into account.

**(11)    Other Reasons for Technical Losses:**

* Unequal load distribution among three phases in L.T system causing high neutral currents.
* leaking and loss of power
* Over loading of lines.
* Abnormal operating conditions at which  power and distribution transformers are operated
* Low voltages at consumer terminals causing higher drawl of currents by inductive loads.
* Poor quality of equipment used in agricultural pumping in rural areas, cooler air-conditioners and industrial loads in urban areas.

**(2) Non-Technical (Commercial Losses):**

* Non-technical losses are at **16.6%,** and related to meter reading, defective meter and error in meter reading, billing of customer energy consumption, lack of administration, financial constraints, and estimating unmetered supply of energy as well as energy thefts.

**Main Reasons for Non-Technical Losses:**

**(1)  Power Theft :**

* Theft of power is energy delivered to customers that is not measured by the energy meter for the customer. Customer tempers the meter by mechanical jerks, placement of powerful magnets or disturbing the disc rotation with foreign matters, stopping the meters by remote control.

**(2)  Metering Inaccuracies:**

* Losses due to metering inaccuracies are defined as the difference between the amount of energy actually delivered through the meters and the amount registered by the meters.
* All energy meters have some level of error which requires that standards be established. Measurement Canada, formerly Industry Canada, is responsible for regulating energy meter accuracy.
* Statutory requirements5 are for meters to be within an accuracy range of +2.5% and – 3.5%. Old technology meters normally started life with negligible errors, but as their mechanisms aged they slowed down resulting
* in under-recording. Modern electronic meters do not under-record with age in this way.
* Consequently, with the introduction of electronic meters, there should have been a progressive reduction in meter errors. Increasing the rate of replacement of mechanical meters should accelerate this process

**(3)  Un metered Losses for very small Load:**

* Unmetered losses are situations where the energy usage is estimated instead of measured with an energy meter. This happens when the loads are very small and energy meter installation is economically impractical. Examples of this are street lights and cable television amplifiers.

**(4)  Un metered supply:**

* Unmetered supply to agricultural pumps is one of the major reasons for commercial losses. In most states, the agricultural tariff is based on the unit horsepower (H.P.) of the motors. Such power loads get sanctioned at the low load declarations.
* Once the connections are released, the consumers increasing their connected loads, without obtaining necessary sanction, for increased loading, from the utility.
* Further estimation of the energy consumed in unmetered supply has a great bearing on the estimation of T&D losses on account of inherent errors in estimation.
* Most of the utilities deliberately overestimate the unmetered agricultural consumption to get higher subsidy from the State Govt. and also project. reduction in losses. In other words higher the estimates of the unmetered consumption, lesser the T&D loss figure and vice versa.
* Moreover the correct estimation of unmetered consumption by the agricultural sector greatly depends upon the cropping pattern, ground water level, seasonal variation, hours of operation etc.

**(5)  Error in Meter Reading:**

* Proper Calibrated Meter should be used to measure Electrical Energy. Defective Energy Meter should be replaced immediately.
* The reason for defective meter are  Burning of meters, Burn out Terminal Box of Meter due to heavy load, improper C.T.ratio and reducing the recording, Improper testing and calibration of meters.

**(6)  Billing Problems:**

* Faulty and untimely serving Bill should be main part of non-Technical Losses.
* Normal Complain regarding Billing are Not Receipt of Bill, Late Receipt of Bill, Receiving wrong Bill , Wrong Meter Reading, Wrong Tariff, wrong Calculations.

**How to reduce Technical Losses:**

**(1)  Converting LV Line to HV Line:**

* Many Distribution pockets of Low Voltage (430V) in Town are surrounded by higher voltage feeders. At this lower voltage, more conductor current flows for the same power delivered, resulting in higher I2R losses.
* Converting old LV (430V) feeders to higher voltage the Investment Cost is high and often not economically justifiable but If parts of the LV (430V) Primary feeders are in relatively good condition, installing multiple step-down power transformers at the periphery of the 430 volt area will reduce copper losses by injecting load current at more points (i.e., reducing overall conductor current and the distance traveled by the current to serve the load).

**(2)  Large Commercial / Industrial Consumer get direct Line from Feeder:**

* Design the distribution network system in such a way that if it is Possible than large consumer gets direct Power Line from feeder.

**(3)  Adopting High Voltage Distribution Service (HVDS) for Agricultural Customer:**

* In High Voltage direct service (HVDS) ,11KV line direct given to cluster of 2 to 3 Agricultural Customer for Agricultural Pump set and employed small distribution Transformer (15KVA) for given  these 2 to 3 customer through smallest ( almost negligible) LT  distribution Lines.
* In HVDS there is less distribution losses due to minimum length of Distribution Line, High quality of Power Supply with no Voltage drop, Less Burn out of motor due to less voltage fluctuation and Good quality of Power, to avoid overloading of Transformer.

**(4)  Adopting Arial Bundle Conductor (ABC):**

* Where LT Line are not totally avoidable use Arial Bundle Conductor to minimize faults in Lines, to avoid direct theft from Line (Tampering of Line).

**(5)  Reduce Number of Transformer:**

* Reduce the number of transformation steps.
* Transformers are responsible for almost half of network losses.
* High efficiency distribution transformers can make a large impact on reduction of Distribution Losses

**(6)  Utilize Feeder on its Average Capacity:**

* By overloading of Distribution Feeder Distribution Losses will be increase.
* The higher the load on a power line, the higher its variable losses. It has been suggested that the optimal average utilization rate of distribution network cables should be as low as 30% if the cost of losses is taken into account.

**(7)** **Replacements of Old Conductor/Cables:**

* By using the higher the cross-section area of Conductor / cables the losses will be lower but the same time cost will be high so by forecasting the future Load an optimum balance between investment cost and network losses should be maintained.

**(8)  Feeder Renovation / Improvement Program:**

* Re conductoring of Transmission and Distribution Line according to Load.
* Identification of the weakest areas in the distribution system and strengthening /improving them.
* Reducing the length of LT lines by relocation of distribution sub stations or installations of additional new distribution transformers.
* Installation of lower capacity distribution transformers at each consumer premises instead of cluster formation and substitution of distribution transformers with those having lower no load losses such as amorphous core transformers.
* Installation of shunt capacitors for improvement of power factor.
* Installation of single-phase transformers to feed domestic and nondomestic load in rural areas.
* Providing of small 25kVA distribution transformers with a distribution box attached to its body, having provision for installation of meters, MCCB and capacitor.
* Lying of direct insulated service line to each agriculture consumer from distribution transformers
* Due to Feeder Renovation Program T&D loss may be reduced from 60-70 % to 15-20 %.

**(9)  Industrial / Urban Focus Program:**

* Separations of Rural Feeders from Industrial Feeders.
* Instantly release of New Industrial or HT connections.
* Identify and Replacement of slow and sluggish meters by Electronics type meters.
* In Industrial and agricultural Consumer adopt One Consumer, one Transformer scheme with meter should be Introduced.
* Change of old Service Line by armored cable.
* Due to Feeder Renovation Program T&D loss may be reduced from 60-70 % to 15-20 %.

**(10)    Strictly Follow Preventive Maintenance Program:**

* Required to adopt Preventive Maintenance Program of Line to reduce Losses due to   Faulty / Leakage Line Parts.
* Required to tights of Joints, Wire to reduce leakage current.

**How to reduce Non-Technical Losses:**

**(1)  Making mapping / Data of Distribution Line:**

* Mapping of complete primary and secondary distribution system with all parameters such as conductor size, line lengths etc.
* Compilation of data regarding existing loads, operating conditions, forecast of expected loads etc.
* Preparation of long-term plans for phased strengthening and improvement of the distribution systems along with transmission system.

**(2)  Implementation of energy audits schemes:**

* It should be obligatory for all big industries and utilities to carry out Energy Audits of their system.
* Further time bound action for initiating studies for realistic assessment of the total T&D Losses into technical and non-technical losses has also to be drawn by utilities for identifying high loss areas to initiate remedial measures to reduce the same.
* The realistic assessment of T&D Loss of a utility greatly depends on the chosen sample size which in turn has a bearing on the level of confidence desired and the tolerance limit of variation in results.
* In view of this it is very essential to fix a limit of the sample size for realistic quick estimates of losses.

**(3)  Mitigating power theft by Power theft checking Drives:**

* Theft of electric power is a major problem faced by all electric utilities. It is necessary to make strict rule by State Government regarding Power theft. Indian Electricity Act has been amended to make theft of energy and its abatement as a cognizable offense with deterrent punishment of up to 3 years imprisonment.
* The impact of theft is not limited to loss of revenue, it also affects power quality resulting in low voltage and voltage dips.
* Required to install proper seal management at Meter terminal Box, at CT/PT terminal to prevent power theft. Identify Power theft area and required to expedite power theft checking drives.
* Installation of medium voltage distribution (MVD) networks in theft-prone areas, with direct connection of each consumer to the low voltage terminal of the supply transformer.
* All existing un metered services should be immediately stopped.

**(4)**  **Replacement of Faulty/Sluggish Energy Meter:**

* It is necessary to replacement of Faulty or sluggish Meter by Distribution Agency to reduce un metered Electrical energy.
* Required to test Meter periodically for testing of accuracy of meter. Replacement of old erroneous electromechanical meters with accurate Electro static Meter (Micro presser base) for accurate measurement of energy consumption.
* Use of Meter boxes and seals them properly to ensure that the meters are properly sealed and cannot be tampered.

**(5)  Bill Collection facility:**

* Increase Bill’s Payment Cells, Increasing drop Box facility in all Area for Payment Collection.
* E-Payment facility gives more relief to Customer for bill Payment and Supply agency will get Payment regularly and speedily from Customer.
* Effectively disconnect the connection of defaulter Customer who does not pay the Bill rather than give them chance to pay the bill.

**(6)  Reduce Debit areas of Sub Division:**

* Recovery of old debts in selected cases through legal, communication and judicial actions.
* Ensuring police action when required to disconnect connection of defaulter Consumer.

**(7)  Watchdog effect on users.**

* Users must aware that the distribution Agency can monitor consumption at its convenience. This allows the company fast detection of any abnormal consumption due to tampering or by-passing of a meter and enables the company to take corrective action.
* The result is consumer discipline. This has been shown to be extremely effective with all categories of large and medium consumers having a history of stealing electricity. They stop stealing once they become aware that the utility has the means to detect and record it.
* These measures can significantly increase the revenues of utilities with high non-technical losses.

**(8)  Loss Reduction Programmed:**

* The increased hours of supply to Agriculture and Rural domestic consumers have resulted in higher loss levels.

**Power Distribution System**

Power Distribution Systems Distribution networks have typical characteristics. The aim of this chapter is to give an idea about global distribution networks design and establish the distinction between country and urban distribution networks. In a conclusion, the state of the art in load flow and state estimation calculations related to distribution networks is described. The problem of power consumption estimation is then introduced.

**2.1-Global Design of Distribution Networks**

The electric utility system is usually divided into three subsystems which are generation, transmission, and distribution. A fourth division, which sometimes is made, is subtransmission. However, the latter can really be considered as a subset of transmission since the voltage levels and protection practices are quite similar. The distribution system is commonly broken down into three components: distribution substation, distribution primary and secondary. At the substation level, the voltage is reduced and the power is distributed in smaller amounts to the customers. Consequently, one substation will supply many customers with power. Thus, the number of transmission lines in the distribution systems is many times that of the transmission systems. Furthermore, most customers are connected to only one of the three phases in the distribution system. Therefore, the power flow on each of the lines is different and the system is typically ‘unbalanced’. This characteristic needs to be accounted for in load flow studies related to distribution networks.

**2.1.1-Distribution Substations**

The distribution system is fed through distribution substations. These substations have an almost infinite number of designs based on consideration such as load density, high side and low side voltage, land availability, reliability requirements, load growth, voltage drop, cost and losses, etc.. 6 For a typical substation, the voltage of the high side bus can be anywhere from 34.5 kV all the way up to 345 kV. The average high side voltage level is approximately 115 to 138 kV. Two or more feeders are normally connected to the low voltage bus through a feeder breaker.

**2.1.2-Distribution Feeders**

On a primary distribution feeder, various equipment can be distinguished such as fuses, distribution transformers, reclosers, switches. Much of these equipment, such as reclosers, are used only at the distribution level. Other equipment such as capacitors, transformers, and arresters are also used at the transmission levels but with considerably different rules of application. Most distribution feeders are three-phase and four-wire. The fourth wire is the neutral wire which is connected to the pole, usually below the phase wires, and grounded periodically. A three-phase feeder main can be fairly short, on the order of a mile or two, or it can be as long as 30 miles. Actually, the length of feeders is closely linked with load density at location. For instance, for an area where the customer load density is strong, primary network will end very close of consumers and secondary feeders will be short. For a weak load density area, primary and secondary feeders will be longer. Distance separating substation from customers will be covered both by primary and secondary feeders in order to provide the best quality supply. These differences explain why a distinction is made between country distribution networks, where customers are spread, and urban distribution networks, where large urban agglomerations must be taken into consideration.

**2.1.3-Secondaries**

The purpose of the distribution transformer is to reduce the primary voltage to a level where it can be used by the customer. Single-phase transformers range in size from 10 kVA to about 300 kVA with units in the 25 and 37.5 kVA size being the most popular for residential areas. The secondary voltage level in the United States for residential service is 120/240 Volts. Lower wattage devices, such as lights, are connected line-to-neutral across both sides of the 7 transformer secondary. Higher wattage devices, such as ovens, clothes dryers, etc., are usually connected across the 240 volt circuit since this has the effect of reducing voltage drop and losses.

