

STRATEGIES IN REDUCING POWER LOSSES IN DISTRIBUTION SYSTEMS

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Abstract: Strategies and initiatives in Losses reduction in distribution systems have been triggered because of the growing cost of electricity supply, fuel shortage along with ever-increasing cost to generate more power. Many strategies have been presented to the utilities in shape of both penalties and incentives. The power sector reforms has embarked India on the road to achieve a national turnaround. However the road still remains incomplete because of the challenges in terms of attaining 100% electricity access as a consequence to issues linked to grid connectivity in rural areas and delivering better quality and reliable supply in a cost economical manner. Due to uncertainty of system loads on different distribution feeders, which vary from time to time, the operation and control of distribution systems becomes more complex particularly in the areas where load density is high. On the whole, networks are reconfigured to lessen the real power loss and discharge the network overload. To meet all these challenges, there need to be a special focus provided on the bleeding Indian power distribution sector. Thus, this study aims to suggest recommendations and Strategies for reducing Distribution Loss. Based on the exhaustive research the key strategies implemented for distribution loss reduction by numerous utilities has been represented. This paper has developed a precise and effective strategies for the analysis of the loss reduction problem and for the subsequent development of action plans to solve the overall problem, through a systemic approach.

Index Terms - Losses Reduction, Technical Losses, Non-technical Losses, strategies, power distributions

I. INTRODUCTION

Power distribution networks are erected as interconnected meshed networks. However, they are organized to be radial in operation to ease the over-current protection. The configuration may be transformed with interchanging operations to transfer loads amongst the feeders. Under ordinary conditions, the distribution network operators possibly will anticipate to cut the system power losses and balance the loading amongst feeders and transformers. Conversely, the necessity to improve power quality has grown to be very essential. More precisely, sensitive loads could only be subjected to less voltage drop and shorter interruption while abnormal conditions occur. Even under such conditions, distribution network operators must make sure the quality of power supplied to the industries with the sensitive loads. Consequently, the feeder configuration problem turn out to be more problematic with the differing purposes of satiating both normal and abnormal conditions. The discrete nature of the switch states avoid the use of classical optimization techniques for solving the network reconfiguration problem. Network reconfiguration problem is formulated as a complex combinatorial optimization problem.

To meet necessary level of load demand, DG units are integrated in distribution network to increase voltage profile, offer reliable and continuous power supply and as well attain economic benefits like load levelling, energy efficiency and minimum power loss. Srinivasa Rao et al (2013) have solved network reconfiguration and DG placement together using HSA for the problem of only power loss minimization. Nevertheless, in the proposed work, network reconfiguration and DG installation are dealt concurrently for enhanced voltage stability and power loss minimization. Thus, objective of this paper is reduction of energy losses in distribution in low-voltage distribution network and cost-effectiveness. This study work presented will be very much beneficial to the Indian scenario and for developing countries.

The block diagram of electric power system is as shown in Figure 1.1. The industry doing all these or any of these business processes, Generation, Transmission and Distribution is termed as Electrical utility.

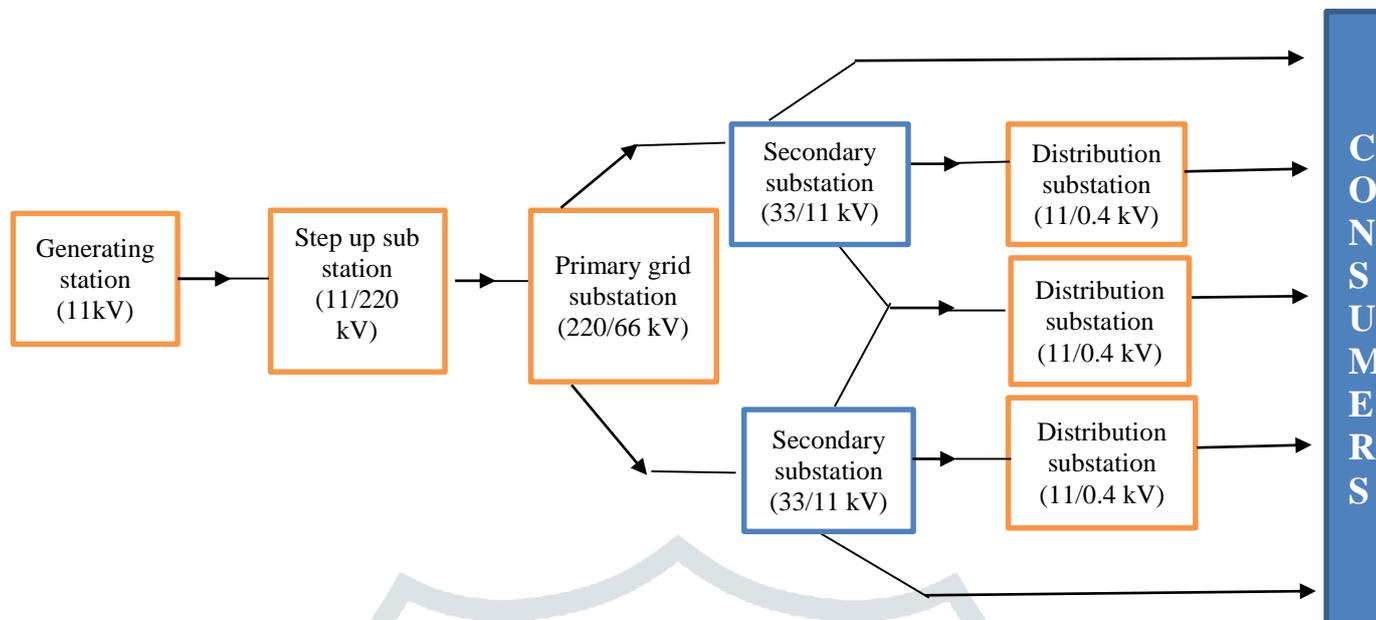


Fig 1.1 block diagram representation of electric power system

II. PROBLEMS IN DISTRIBUTION SYSTEMS

The key issue in distribution systems or quite more suitably the issue challenging the power sector overall is the reduction of transmission and distribution (T & D) losses to minimum levels. The All-India T & D losses were about 15% till 1966-67. Throughout the last few years, electrical utilities across the country have assessed the losses in the range of over 20% to 40% higher than the previous years. T & D losses in advanced countries are around 7-8% only. Considering the Indian conditions like far-off rural areas, load nature and distribution system configuration the permissible (technical) energy losses must be about 10%-15% in different states. While the losses in EHV network are about 4%-5%, bulk of the losses occurs in the T & D system.

Table 1.1 Characteristics of Transmission and Distribution Networks

Characteristic	Transmission	Distribution
Topology	Generally extensively meshed and must be analyzed as a whole	Generally many independent Substations each supplying several Radial feeders. Can be analyzed as multiple independent islands
Network Size	A typical network size ranges from a few hundred busses to one or two thousand.	A typical network size ranges from 10,000 to 1,00,000 electrical nodes depending on feeder length and number of distribution transformers and consumers.
Components	Components line supports and transmission lines and switchyards are almost standardized and less complex	A distribution network typically comprises bus bars, switches, feeders, distribution transformers, loads and therefore appears as a fairly complex network structure
Dynamism and expandability	Once the transmission network is setup for a city it requires rerouting and re-strengthening after a long period	Distribution network is ever expanding and dynamic for further changes on day to day basis depending on consumer needs
Phase unbalance	The degree of unbalance is generally sufficiently small that it can be ignored and only positive sequence terms analyzed	The degree of unbalance may be quite large and each phase must be considered independently.

III. REQUIREMENT OF A DISTRIBUTION SYSTEM

A substantial amount of effort is essential to keep the electric power supply within the supplies to many consumers. Here are some of the requirements of a distribution system:

- Proper voltage
- Availability of power on demand
- Reliability

3.1 Proper Voltage: One significant requirement of a distribution system is the necessity of a proper voltage and it ought to be as little as possible. The voltage changes are usually because of the load variation on the system. Low voltage results in the revenue loss along with the motor burning out and lighting inefficiency. High voltage can result in burning out of lamps permanently and might also result in failure of other appliances. The voltage variations statutory limit is around $\pm 10\%$ of the rated value at the consumer's terminals. Therefore, if the declared voltage is 230 V, then the maximum voltage of the consumer must not exceed 254 V while the minimum voltage of the consumer must not be less than 207 V.

3.2 Availability of Power Demand: Power must be accessible to the consumers to meet their requirements. Since electrical energy can never be stored, the distribution system should be capable of providing consumer's load demands. This demands that operating staff should constantly study load patterns to foretell the major load changes that follow the recognized schedules.

3.3 Reliability: Contemporary industry is practically reliant on electric power for its operation. Office and Homes are well-lit, cooled, heated and also ventilated. This calls for reliable service. Unfortunately, electric power can never be completely reliable. Nevertheless, the reliability can be enhanced to a substantial extent by

- Inter-connected system
- Reliable automatic control system
- Offering additional services.

IV. PERFORMANCE OF DISTRIBUTION SYSTEM

The Distribution system necessitates more attention as it is very challenging to standardize because of its complications. Since it comprises of consumers, power quality turns out to be a supreme consideration in power supply feeding. With a quality power, there is necessity for continual power supply. Demand and Supply has to match for nonstop power supply to the consumers. Therefore for improved performance of the distribution system, the requirements are both reliable and quality power at sensible rate. To evade the power shortage, one significant consideration is lessening the transmission and distribution losses. Transmission and distribution losses (T & D losses) in India have been reliably on the higher side between the ranges of 21–25%. In these losses, 19% is at the distribution level in which 14% is by technical losses. This is because of the insufficient investments for system improvement work.

V. ENERGY LOSS REDUCTION STRATEGY

Enhancement of system and loss reduction can be effectively achieved through energy audit. The energy audit is to be attempted starting with the areas known for excessive losses. The aim of an energy audit is to:

- Measure the overall energy loss in a particular area (sub-station or distribution centre)
- Recognize system elements producing excessive losses
- Categorize losses as per its technical or non-technical factors.
- Propose numerous measures to reduce losses in cost-effective method and working out the effectiveness, payback period, efficiency and longevity of each method.

VI. DECISION PRIORITIES FOR REDUCTION OF TECHNICAL LOSSES

The procedures for decreasing technical losses can be categorized as short term, medium term and long term.

6.1 Short Term Measures

The impact of these measures is larger than medium and long-term measures. But, these measures have to be executed constantly.

6.2 Medium and long term measures

- Implementation of methodical and systematic approach to planning, design, construction, maintenance and operation of distribution system by means of computer aided tools.
- Implementing SCADA which is short form of Supervisory Control and Data Acquisition for all Substations.
- Renovation, transformation and strengthening of 11 kV level Substations, Transformer Centers.
- Adaptation of current distribution network into High Voltage Distribution System (HVDS) that covers lessening of LT lines and re-conducting of over loaded sections.
- By using Geographic Information System (GIS) mapping and collecting pole-wise information and studying the complete distribution system with automated mapping of all electrical components and also the long term distribution system planning considering the projected load development during the next 15-20 years and re-conducting of overloaded lines.
- Implementation of distribution automation techniques for enhancing reliability and power supply security, formation of reliable database.
- In case of metered supplies, metering deficiencies in the form of defective meters have an effect on the precision of energy consumption figures. The amount of defectiveness, very old and defective meters must be recognized and changed wherever needed.
- Introducing Remote Controlled Load Management Scheme (RCLM) that includes grouping and segregation of agricultural consumers and supply regulation as per preannounced schedule in two or three groups with power supply during non-

peaking hours. The welfares of the scheme will be reduction in technical losses owing to reduction in peak demand at 11 kV bus.

- Introduction of time-of-the-day tariff for bulk consumers that charge lower tariff for availing power in off-peak load period and higher tariff in peak load period.

VII. REACTIVE POWER COMPENSATION

Setting up of sufficient reactive compensation in many distribution lines is vital to expand the transmission capability as well as reduce system losses substantially. Since loss is directly proportional to square of the current, there is 2% reduction in current by providing reactive compensation, this ends in about 4% losses reduction. LT motive power consumers cannot safeguard the capacitors working even if they are provided at the time of connections. It is because of lack of requisite knowledge and skills to decide the level of compensation and check the availability of capacitors. Thus while planning the distribution system; such practical problems can be taken care by the power utilities by providing the LT capacitors on distribution transformers. To overcome the seasonal changing load demand characteristics, it will be advisable to deliver minimum level of compensation at LT level to meet the average demand and dynamic capacitor allocation for demand above average demand.

7.1 Improving the Standards

The usage of newest technologies like identification of hot spots by thermo-vision infrared scanning and enhancement in joints turn out to be very vital. Training to upgrade skills and knowledge of the work forces who are engaged in distribution at feeder level and consumer end is very important. Building awareness among the employees about earthing practices, neutral current effects and reactive compensation constantly might drive the distribution network performance to attain the desired results.

7.2 Benefits of Reactive Power Compensation

The application of a reactive power transmitting strategy to increase power system operation has numerous recognized benefits to an electric utility. Few of these benefits are discoursed here (Gonen Turan 1986).

7.3 Cost savings due to reduced system losses

Reduction in total system losses has the benefits of lowering generator fuel cost. Since the real power of generators must supply the system loads and the losses, fuel cost will decrease when system losses decrease.

7.4 Improved Voltage profile

The general voltage profile is improved by flattening and increasing the nominal voltage value. This is important because the voltage profile is a measure of the flow of reactive power in a power system. Voltage can vary considerably from location to location. (Although voltage profile is a valuable indicator of system conditions, it does not by itself show the system reactive reserves which are available in a disturbance).

7.5 Better voltage control

Better voltage control is possible on a system wide basis. A Global voltage control strategy encompassing the entire system is used, compared with the present local voltage control strategy. Investments in communication equipment and metering equipment are necessary to fully achieve this benefit.

7.6 Improved system security

Power system security is improved through better utilization of reactive resources, thus having greater reactive reserves available for system conditions which require sudden reactive demand increases. Although many different conditions can cause a sudden increase in system reactive demand, the substantial increase in loading of already heavily loaded EHV lines, following the tripping of another EHV lines, would generally cause the greatest increase in system reactive demand. This condition can be alleviated by reactive power dispatching.

7.7 Improved interchange transfer capability

Transmission equipment loading decreases due to reduced reactive power flow. Unloading allows higher real power capability which allows increased interchange transfer capability. Interchange transactions are big business for utilities. So, reactive power dispatching is attractive as a mean of facilitating such transactions, especially if they can be performed with no major equipment purchases.

7.8 Improved system operation

The primary responsibility of system operators is supervision of real power generation and active power and reactive power flows in the system, with due regard to the maintenance of correct voltage levels. Operators some time tend to maintain high reactive power reserves, which can result in uneconomical operation. For example, reactive power generating capacity is not fully utilized when operators maintain margins near rotor or stator current limits to avoid overloads caused by system voltage fluctuations. Again, reactive power absorbing capacity may not be fully utilized because of margins maintained for stability reasons or to avoid overloading of the core ends of generator stators. A reactive power dispatching strategy can give operator improved guidelines for reactive power flows, reserve level, and voltage control. The process can be automated and integrated with dispatching procedures presently used at dispatching centers.

VIII. LOSS REDUCTION INITIATIVES

Some of the best initiatives and strategies have been outlined and explained briefly as follows:

8.1 INTERNAL ASPECTS (IMPLEMENTED BY UTILITY)

8.1.1 Governance framework

8.1.1.1 Constitution of loss monitoring, energy audit committee/cells, central vigilance team: Under this initiative, a special cell is formed to take care of loss monitoring as well as energy audit. The whole process of collection of information, processing it

and recommending solution is rationalized by such specialized cells. Committed workforces for loss monitoring and control may possibly will also be recruited into the system.

8.1.1.2 Nomination of feeder managers: Accountability of particular feeders is given to particular personnel with the purpose of better controlling and managing the losses.

8.1.1.3 Theft reporting consumer incentive schemes: Consumers that report occurrences of theft are incentivized through a cash reward as a calculation of amount comprehended.

8.1.1.4 Employee incentive schemes: Incentives for loss reduction are generated by joining employee KPIs to loss reduction in their corresponding regions. A comprehensive staff incentive scheme was prepared by MSEDCL where 10% of the incremental revenue got in a division further than a beginning was paid out to employees of that division. Likewise Performance Based Group Incentive Scheme (PBGIS) was established in Haryana based on reasonable sharing of gains among Distribution Company and the contributing subdivisions arising from reduction of AT&C losses.

8.1.1.5 Employee capacity building with focused programs: Training programs were provided for the employees to learn more about the control measures and loss monitoring. Capacity Building was acknowledged as an indispensable requirement. Training was provided to the workers of the Distribution Utilities in technical, management, consumer and commercial related zones and introduction to the newest improvements in loss reduction, electricity distribution and theft control within India.

8.1.2 Process strengthening

8.1.2.1 Implementation of IT application in Metering, Billing and Collection activities through AMR, HHD, e-mail, SMS based intimation: Fully automated metering, billing and collection systems like AMR or semi-automated systems like hand held devices for meter reading help to minimize meter reading error, billing time and increase collection efficiency leading to less commercial loss. Customer engagement and relationship management through modern communication mediums like email and SMS create enhanced customer service.

8.1.2.2 Implementation of IT application in network management activities such as SCADA, DMS, OMS: IT Packages like Distribution management system (DMS), outage management system (OMS) or SCADA system helps the operation team to be updated with real time network situation and performance. These are essential requirements for distribution utilities to monitor network, plan activities, mobilize workforce in time to reduce network failure or down time. It also helps utilities to build a comprehensive zero information leakage operational system to meet and exceed customer satisfaction and optimize cost and time. IT applications like these helps operation team to identify any loss or leakage in the system through automatic and fast system and helps to reduce losses as a whole.

8.1.2.3 Strengthening of Energy accounting infrastructure like Feeder metering, DT metering & 100% consumer metering: To reduce loss, the first step is to identify loss level. Energy accounting is the fundamental measurement process to identify electricity loss in a distribution system. For implementation of proper energy accounting measurement and recording of energy consumption is required at different level of network. Starting from 100% metering at consumer end to DTs, feeders should be covered to identify any technical and commercial losses across the network. Meter data management system (MDMS) is a central database of meter readings and a layer of meter data analytics on top of this MDMS can be of great help to identify loss of electricity at different level. Most of the states have implemented this initiative barring agriculture consumers which are supplied electricity at a flat rate.

8.1.2.4 Replacement of defective meters and electromechanical meters: There are different generations of electric meters, starting from electro mechanical to modern day smart meters. The purpose of meters has been changed from merely recording only energy consumption to storing other useful information like electric parameters and communicating them back to central remote database. Old electro-mechanical meters are maintenance heavy and not suitable to be a part of automatic metering infrastructure. All defective meters and electro-mechanical meters if replaced by modern digital meters or by smart meters, will help to increase transparency over the meter data and smooth operation for MBC.

8.1.2.5 MIS based periodic reporting of unit wise business parameters: Identification and monitoring of key business parameters are required to gauge the health of the utility. Further, to get a true picture, correct recording of data is utmost important. A robust MIS can help to record correct data and report the business parameters including loss figures on a regular frequency.

8.1.2.6 Soft initiatives of Consumer communication on loss reduction: Proper communication of the plans to the consumers in general is crucial in order to increase public participation and contribution towards the health of a utility. Public outreach programs or communication program through media ads, posters, and videos can help in disseminating information related to penalties in case of theft/meter tampering among the consumers.

8.1.2.7 Connection regularization scheme, interest waiver scheme, VDS: This initiative aims to bring the defaulters into the fold of the utility, be it through surcharge waiver, interest waiver or voluntary disclosure scheme, VDS.

8.1.2.8 Customer feedback programs: Initiatives linked to consumer analysis and feedback indirectly help in loss reduction through faster collection of data/feedback about possible problems in the network. Initiatives like setting up of Interactive Voice Response System IVRS, Toll Free numbers for consumer complaints, mobile alerts through SMS etc. are some of the examples of customer feedback programs. Consumer Analysis Tool, CAT are used to monitor the metering, billing and collection of consumers to identify revenue leakages. TPDDL has developed a home grown Customer Relationship Management, CRM, software SAMBANDH based on business process reengineering and integration of all modules commercial processes, with the provision of auto escalation of parameters and performance assurance.

8.1.2.9 Transformer Management System: It is the next step to feeder management system. Here the local population is encouraged to take ownership of the specific transformers in their locality.

8.1.3 Network strengthening and Technical loss reduction

Bifurcation of feeders: Feeder segregation program can result in following benefits

- Reduction in line losses
- Improved financial condition of discoms
- Improved transparency in subsidy distribution
- Ground water resource management Pre-requisites for feeder segregation project:
- Metering at feeder level would help in effective energy audit thus identifying high loss feeders and LT lines.
- Economical remote metering infrastructure for DTRs or External meters for all customers to facilitate, identify and avoid any type of power pilferage in the system.
- Installation of LT ABC because it can totally eliminate the faults on LT lines and improve reliability
- Avoidance of Theft by direct tapping o Improving HT: LT ratio: Technical loss in electrical system is proportional to the resistance of the network. Electrical resistance is higher for LT lines because of its small diameter and low voltage and high current. One way to avoid this loss is to increase the ratio of HT lines in the network compared to LT lines. It will help in reducing the burden on LT network and eventually the loss.
- DT augmentation in substation: Aging of an electrical equipment causes lower insulation value. Lower insulation increases the chance of electrical leakage and losses. Old sub stations and DTs are augmented in this initiative to avoid this loss.

8.1.4 External Aspects

- Regulatory initiatives o Loss reduction focused clauses in Supply Code or the Grid code: The electricity supply code or grid code of some States mention clauses which incentivize loss reduction or penalize high losses. This incentivizes consumers to move from low voltage to higher voltages and therefore reduce technical losses.
- Loss level based tariff design: Different consumer categories or different areas contribute different proportions to the overall loss level of the utility. Therefore the tariff design for these consumer categories should also depend on their respective loss levels and in turn on the cost of supply of the respective consumer category or respective area of supply. While the tariffs are still being calculated using aggregate loss levels for the entire utility, some states have initiated pilot studies to measure consumer category wise cost of supply for calculation of loss level based tariff design.

IX. CONCLUSION

The loss reduction is a chief priority even an important vital one in some cases for electrical utilities, for the community as one and for the lenders. Attaining an acceptable loss level will provide the confidence of lenders and private investors to boost them to contribute financially in the improvement of the power sector. The management should establish the losses reduction as an investment project that needs to be conducted for many years. A loss reduction project might basically concern all the social and economic aspects in a country. The losses reduction project should include a study of the costs and benefits together with clear implementation stages and Results measurement system. It should also comprise the risk and the uncertainties that might occur. This paper recommends reducing the losses based on strict technical and economical rules that are usually reflected in an action plan, with each action item held by a profitability analysis.

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