Review on loss reduction by improving ratio of HT/LT line in Electrical Distribution System

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Abstract— In this paper review has been taken on technical loss reduction technique that can be implemented by improving ratio of HT to LT lines. In this technique of loss reduction secondary distribution network is minimized as possible as such that the ratio of HT lines to LT lines is higher. As this ratio increases we can see a lot reduction in technical losses in electrical distribution system. The advantage of this review paper is to see the improvement in supply quality and reliability. In these technique first losses in existing distribution network in which L.T. line is higher than H.T. line has been calculated. Then L.T. line network is dismantled. H.T. line network is erected in place of L.T. line network. The high capacity distribution transformers in existing Low tension lines are also replaced by nos. of low capacity distribution transformers. The L.T. conductor is also replaced with fine quality high voltage conductor. Then losses are calculated when this H.T. network is in system. The savings of energy is calculated in terms of units. Then it is converted in terms of rupees. Capex fund required for dismantling of existing Low tension lines and erection of new H.T. line network. Rate of Revenue Return is finally calculated with the help of these figures i.e. Energy saved in terms of rupees and capital expenditure required to implement this project. We also take a review on improvement of line voltage at far end consumer. In Low tension lines we always face a problem of voltage regulation. The voltage at consumer nearby to distribution transformer center is high and it goes on decreasing as we move towards the tail end consumer of L.T. line. The voltage at last consumer is below the standards that must be supplied as per electricity regulation authority. We can see the constant voltage for each and every consumer in this high tension distribution network. In this paper we can also review on reliability of supply. In Low tension lines erection of L.T. lines is such that the distance between Phase to Phase conductors is low as compared to distance maintained at high voltage distribution network. Due to less distance in windy and rainy atmosphere conductors comes in contact with each other and phase to phase fault occurs frequently in Low tension lines. In case of high voltage distribution network the distance is higher due to which chances of conductors touching to each other are less and hence reliability of supply is also maintained. Another advantage of distribution of electricity at high voltage is that less nos. of consumers are affected in case of failure of distribution transformer.

Keywords— High Tension line (HT line), Low Tension Line (LT line), Loss, Phase, Transformers, Energy, Voltage

INTRODUCTION:

Electricity is generated at generating stations then it is supplied to consumers through large and composite networks. This network consists of primary transmission, secondary transmission, primary distribution and finally secondary distribution. This transmission and distribution consist of Power transformers, extra high voltage lines, High voltage lines, distribution transformers and low tension lines. In India the power is generated generally at the voltage of 11kV.This Voltage is stepped up to 440kV. In primary transmission system energy is transmitted at this high Voltage of 440kV from substation near to generating station to EHV substations .At EHV substations this energy is transformed from 440 KV to 132 KV and 220 KV.From this substation secondary transmission starts. Energy is transmitted at the voltage of 132 KV or at 220 KV up to secondary transmission substations. From these 132 KV /220 KV substations primary distribution starts at 33 KV and 11 KV voltages. Energy is transmitted at 33 KV voltages up to distribution substations rated as 33/11 KV substations. From these substations 11 KV feeders runs in villages and cities. Distribution transformers are located in the center area of consumers. From that energy is again transformed from 11 KV to 440 V/220 V which is connected to consumer's premises.

It is the fact that a unit generated at generating stations does not go with the units supplied to consumers. The units supplied at consumer end are always less than that of the units generated. Some percentage of units is lost in Primary and Secondary transmission and distribution network. The difference between energy generated at generating stations and supplied at consumer end is called transmission and distribution loss. Normally transmission and distribution losses in India comes around 22 % to 26 % of the electricity generated. The major amount of losses in a power system is in primary and secondary distribution lines. The transmission and sub transmission lines carry the losses of 30 % of the total system losses from generation point to consumer point. Remaining 70 % of losses occur in primary and secondary distribution system. Again the high percentage of losses comes under secondary distribution i.e. at 440 V and 220 V. In our country the efficiency in distribution system is very poor because of power is supplied at low voltage. The technical losses causes due to energy dissipated in conductors.
The analysis is carried out to determine the losses in the presented low tension distribution system and then reconfiguring this low tension distribution system to high voltage distribution system (HVDS).

Need for this project review:

- The T & D losses in India are in the region of 25 to 32 % and this figure is higher compared to the established International norms. T and D losses is an important sign, depicting the performance of electrical power distribution Utilities. The demand for electrical energy is increasing exponentially at a rate of 5 to 10 % to meet the economic developments. The lack of resources and long lead time needed to build the new generating capacity has resulted in wide gap between demand and supply of electric energy. The. The cost of new energy is also rising hastily due to price rises, exhaustion of fossil fuels and other economic factors.
- The improvement of power system performance to bridge the gap between demand supply and the minimization of cost of energy have assumed higher importance for the power utilities of developing countries.
- The reduction of losses has significant impact on the revenue

  Example; A utility using 30, 000 M U in a year can save 300 M U an additional revenue of Rs 600 millions , if 1% of the T and D losses are reduced. The need for this project in India will be clear by observing following statistics.

Losses scenario in India and World:

- The average percentage of energy losses in Indian Power System was less than 15% in 1965 and has increased 20% TO 25% in 1980 and is continuing at that level
- The percentage T and D losses in the developed countries are up to 15%
- Two Asian countries ; Japan and Korea have achieved remarkable progress in reducing the power losses from 25 to 30%in 1960's to 6% in 1980's

T&D Losses in Various Countries:

Country	T & D Losses (%)
Korea	3.35
Japan	5.06
Germaney	5.53
Canada	6.22
Italy	6.68
France	7.2
Australia	7.38
USA	7.57
China	7.71
UK	8.37
South africa	11.42
Russia	14.88
India	**32.53**

Table 1. T&D Losses in Indian Utilities-2010-11

Table.1 shows the T& D losses in all over the world. In India the state wise literature survey is carried on and the following Table.2 shows the state wise T& D losses in India.

NAME OF THE STATE	T&D Losses (%)
Andhra Pradesh	22.55
Delhi (DVB)	45.40
Gujarath	30.43
Haryana	32.11
Karnataka(KPTCL)	26.08
Kerala	22.48
Madya Pradesh	41.30
Orissa(Gridco)	44.02

Punjab	25.42
Rajasthan (TRANSCO)	44.68
Tamil Nadu	19.28
Uttar Pradesh	34.39
West Bengal	28.54
Maharashtra	32.40
ALL INDIA	**32.53**

Table 2. State wise T & D losses

Norms for technical Losses			
Review of system Losses			
System Components	Exsisting Level	International norms	
		Max Tolerable	Target Level
Transmission	4	4	2
Sub Transmission	4	4.5	2.25
High Voltage Distribution	6	5	3
Low Voltage Distribution	18	2	1
Total	**32**	**15.5**	**8.25**

Table 3. Norms for technical losses

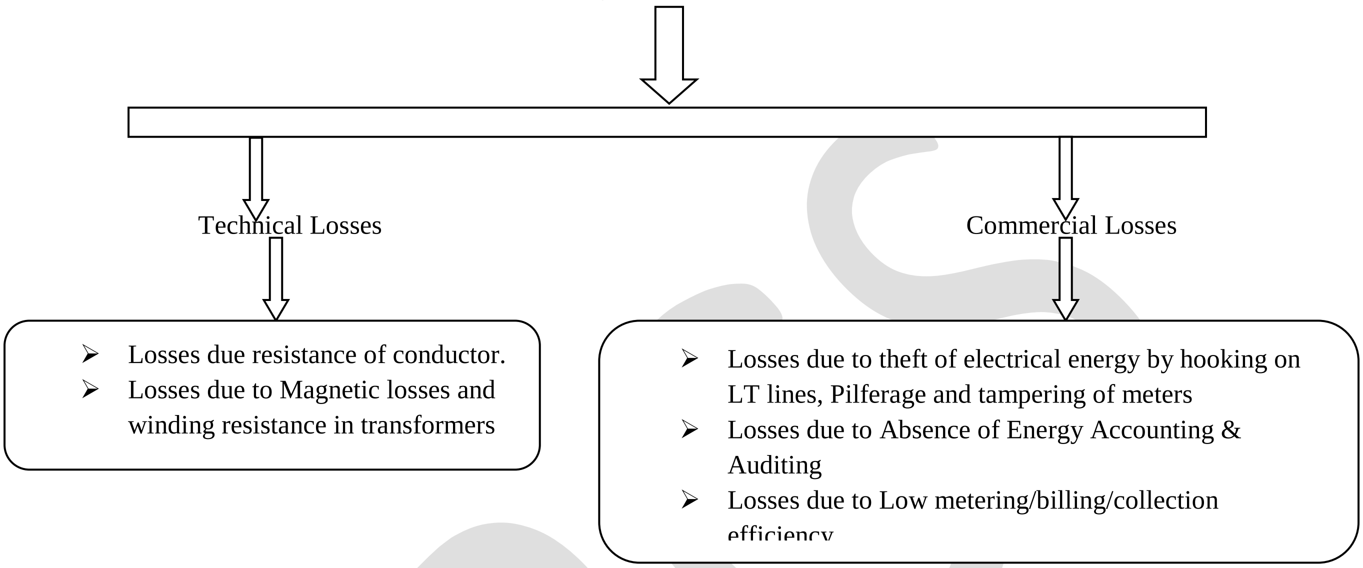
Silent features of Indian Distribution Network (A review):

- In India distribution transformers are mostly 3phase with delta star vector group and the rating are 315 ,200 , 160 and 100 KVA in urban areas and 100,63,25 KVA in rural areas.
- Power losses in the network are high and are of the order 20 to 25% .In agricultural sector voltage at tail end customer may go down to as low as 70%of rated voltage. The voltage regulation may go beyond 6%.
- The power factor of load is poor .The major load due to which power factor is low is fluorescent lamps in urban areas and pump sets in agricultural area.
- Practically 11 KV and 440 V lines in rural areas are extended over long distances to meet demand which is caused from premises established over large geographical area. The distribution lines in semi urban and urban area are largely of radial type. Due to this long distance lines resistance losses in the lines are high. The L V lines are lengthy, the ratio of HV to LV lines are varying from 0.25 to 0.50.Large scale rural electrification has been done through long 11 KV and LT lines.
- The average expansion rate of energy generation during the past decade for the country is around is 7% .
- State electricity boards and other utilities in India are facing power deficiency. The shortfall between power demand and supply is in the range of 2 to 30 % and the average figure for the country is 13.8 %.
- The power deficiency is met by imposing load shedding programmers and restriction of usage of electricity for agricultural consumers. i.e. 8 hours supply within a day which is shifted at night for 3 to 4 days in a week.
- Computer aided mapping and updating network are yet to be introduced .Therefore identification of pockets of higher power losses is a problem.
- Data acquisition system is not available at the distribution substations.
- Many utility are facing with the problems of very high losses due to theft of energy and non paying culture of some part of society.
- The investigations performed on the existing network revealed that the high losses in the distribution network can be effectively reduced by reconfiguration of the network.

Wrong choice of distribution practices:

Distribution system in vogue can be classified as HVDS and LVDS HVDS is based on North American practice, best suited to meet the scattered loads of low load density .LVDS is based on European practice , best suited to meet the concentrated loads of high load density. LVDS which is in vogue in India in metropolitan and large cities at the time of independence was adopted to extend the supply to remote villages and energies Agl. Pump sets without considering the characteristic of the load and the cost of losses. The number of pump sets energized as risen from 6500 in1947 to 10.27 millions in 1994 registering 1580 folds increases, this has resulted in the energy losses from 15% in 1960 to 22-25% by 1980 and remain at the same level Two Asian countries Korea and Japan have reduced their losses from 23 to 30% losses in 1960 to 6% in 1980 by adopting HVDS.

Types of Losses



Causes of higher technical losses:

Losses are inherent to the distribution of electricity and cannot be eliminated. Hence we have to try to keep it at minimum level. To keep it at minimum possible level it is necessary to find out the causes of losses in system. There are two types of technical losses i.e. fixed losses and variable losses. Fixed losses do not change as per change in current. These losses appear in the form of heat and noise. When the transformer is given supply these losses starts to occur. These losses are around 25% to 30% of total technical losses. In primary and secondary transmission corona losses must have to be considered.

- Variable technical losses in system are mainly due to current opposition by resistivity of material like conductor and winding material of transformers. Variable losses differ with the amount of current. These losses are directly proportional to square of the current. The percentage of these losses turn around 75 to80 that of total technical losses. We can reduce these losses by increasing the cross sectional area of lines and cables for a given load. These losses are estimated by Computer Aided Simulations of Distribution Network. Accuracy depends on network operating parameters i.e. Load, Load Factor, System Configuration, Conductor Size, Diversity Factor, Voltage, Frequency, and Length of Line, Transformers and Load Density.Major reasons are described as below:

Spontaneous and disorganized expansion of networks:

- At the time of independence in 1947 electricity was available to 1500 villages out of 579132 total villages. There was a need to enlarge electricity to all villages. The aim of system planners at that time was to extend to power supply to each and every citizen of the country at the minimum capital investment. Due to lack of proper planning this has resulted in spontaneous and disorganized expansion of distribution network resulting in high distribution power losses. The investigations carried out on the present network discovered that the high losses in the distribution network can be effectively reduced by reconfiguration of the network.
- **Low ht/lt ratio:**
  The presented distribution system involves three-phase 11KV feeders from 33/11 KV substation up to distribution transformers of rating 11KV/440V. From these distribution transformers three-phase four wire lines come out. Distribution system with low voltage consists four core cables and long low voltage lines and various loads fed from a bulk power transformer resulting in the

increase in system losses affecting voltage profile. Low voltage distribution is done either by three-phase four-wire, three- phase five-wire, single phase three-wire and single phase two-wire low tension lines. This distribution system involves nearly 2:1 ratio of low and high voltage line lengths. This low ratio of HT to LT causes losses.

- **Improper location of distribution transformer:**
  Distribution transformer should be located at load center. In practical situation once the erection of distribution transformer has been completed it is very costly to shift it as per future load that comes in system. Due to this unequal and unpredictable demand of load it is usually not possible to keep the distribution transformer at load center. Due to this unequal expansion losses increases due to the facorI2*R*L.
- **Non – optimal conductor size:**
  Losses in the feeder are inversely proportional to the conductor size. The bigger the size, the lower the resistance and the lower is the losses. While doing expansion of the electricity to new areas , the conductor size is usually selected on the based on the thermal loading limit to curtail the capital investment ,ignoring the cost of losses .With rapid load growth, the conductor size have become inadequate ,causing in high power losses. Investigations on numerous distribution feeder discovered that about 5% of the feeder segments from sources end are responsible approximately for 70 to 80% of the losses in the feeder and loss reduction in the order of 30 to 40% can be achieved by reconductoring of the first few segments of feeders.
- **Inadequate reactive power compensation:**
  The power factors at which the system is operated is an vital pointer of power loss level as the losses are inversely proportional to square of power factor.In urban areas, the lighting load (comprising fluorescent tube lights) is liable for the poor PF .The fluorescent lights have low power factor of 0.5, while in rural areas, the inductive load comprises of the agricultural pump sets with PF of the order 0.7 to 0.75.The investigations made on several distribution feeders indicated that the loss reduction to the extent of 20 to 30% can be achieved by optimal shunt compensation. For a given load if power factor is low the current drawn is high and the losses proportional to the square of the current will be more. Thus the line losses owing to the poor power factor can be reduced by improving the power factor.
- **Inadequate augmentation of transmission and distribution system:**
  Normal load increase of the Indian Utilities is around 8%.This rapid load growth, in turn, calls for the setting up of a large number of substations to meet growing demand. The erection of a new substation requires substantial investment; say Rs. 2.0 to 25 crore s on an average. The incapability of utilities to execute for long range planning and setting up of new distribution substations at most favorable locations has resulted in high power losses.
- **Lengthy distribution lines:**
  The distribution lines in rural areas are largely radial laid. These lines extend over long distances. It results in high resistance losses in the lines.
- **Bad workmanship:**
  Joints are source of power loss. Therefore the number of joints should be kept minimum. Firm connections must have been done by using proper techniques. In LT distribution system joints are used at line terminations, cut-point locations, DTC locations, at drop out fuses, in distribution boxes where cutouts and bus bars are present, in substations and at transformer bushings. These joints should be periodically inspected. Sparking and heating at joints should be eliminated if it has been observed. Replacement of deterioted wires and lines should be done timely to avoid losses of power.
- **Unbalanced load at distribution transformer:**
  The losses in distribution system increases when the load at distribution system is unbalanced. Unequal load distribution among three phases in L.T. system causing high neutral currents, leaking and loss of power.
- **Poor quality of equipments :**
  The losses are due resistance of conductor used for lines and losses in transformers. In transformers two types of losses occurs
  1. ***Fixed losses:*** These are the magnetic losses which consist of hysteresis losses and eddy current losses. These can be kept at minimum by using high quality silicon steel stampings.

2. ***Variable Losses:*** These are dependent on load and mainly due to winding resistance of transformer. Thus it can be kept at minimum level using high quality copper for winding.

Commercial reasons for high distribution losses:

Commercial losses are near about 18% to 20% .Theses are related to theft of energy, meter reading, faulty meters and error in billing of customer and unmetered supply to customers. 99.95% of these losses occur on LT network.

- **Theft:**
  Theft of power has been done by connecting hooks of wires on L.T. distribution system. This power delivered to customers is not measured by energy meter. This direct and illegal hooking is possible only in L.T. distribution system. If we convert L.T. system in H.T. system people cannot connect illegal hooks on HT lines. Theft of energy is also done by tempering of energy meters by various ways.

Loss reduction techniques:

- **Improving HT/LT ratio:**
  We can improve the HT/LT ratio by converting LT distribution network into HT distribution network.Conveting LT lines to higher voltage consist high initial cost but after some specified time period this system is beneficial.In agricultural sector if we go for HVDS system it connects cluster of 2 to 3 AGR customers employed a small distribution transformer of capacity 6.6 KVA, 15KVA and 25 KVA through 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. Installation of additional distribution transformers of low capacity at each consumer's premises instead of cluster formation will decrease the losses. We can reduce the losses by installation of single phase transformers to feed residential and commercial customers in rural areas and providing of small distribution transformers with a distribution box attached with its body, having provision for installation of meters.
- **Adopting Arial Bunch Conductor:**
  In HVDS it is not possible to erect high tension lines for each and every consumer. Where LT network cannot be eliminated Arial bunch conductor can be employed to avoid illegal hooking of people. In Agriculture sector more than one customer is connected at a single low capacity transformer. For these customers Arial bunch conductor can be employed to avoid theft of energy.
- **Network reconfiguration:**
  By using higher the cross section area of the conductor the losses will be lower .Reducing the length of LT lines or by relocation of transformer centers at load centers we can go for low distribution losses. Substitution of distribution transformers having higher fixed losses with those having lower no load losses such as amorphous core transformers of shunt capacitors for improvement of power factor.
- **Provision of HT Supply for bulk consumers:**
  Utility must erect distribution system that can provide supply to large commercial and industrial consumers from feeders.
- **By utilizing feeders as per capacity:**
  The higher the load on power lines higher the losses. Distribution losses will increase if the load on distribution feeders crosses its limit.
- **Vigilance activity:**
  By conducting vigilance activity such as mass theft detection drive commercial losses can be reduced. In case of LVDS system vigilance activity should have to carry for both type of theft i.e. hooking on LT network and for tempering of meters but in case of HVDS hooking is near about zero so Vigilance can concentrate on consumers doing theft of energy by tempering of meters.
- **Public Awareness:**
  Utilities can aware public by campaigning regarding save of electrical energy. For this purpose utility can employ energy conservation programmes.
- **Implementation of energy audit schemes:**
  It should be mandatory for all utilities to carry out Energy Audits. Further time bound action for initiating studies for practical evaluation of the total losses into technical and non-technical losses has also to be drawn by the utilities to recognize high loss areas to initiate remedial measure to reduce the losses.

Why LVDS should be replaced by HVDS:

The drawbacks of low voltage distribution are as follows:

- Poor tail end voltage: The percentage voltage regulation in LT distribution system goes beyond 6 % in case of heavy loaded transformers and in case of lengthy distribution lines due to which customers connected at far end of the line always faces low voltage problems in LVDS.

- Motor burn outs almost twice in each cropping period because of working of motors at low voltage which causes winding heating and burning.
- High rate of DTC failure: The rate of DTC failure is higher in LVDS system as compared to HVDS system.
- More resistive loss is present because of low voltage profile.
- Ease of theft of energy: People can easily do theft of electrical energy in agricultural and slim area in LT distribution system by simply connecting hooks of the wires on LT lines whereas it is almost impossible to connect hooks on HT network lines.
- Inappropriate load management results in overloading of conductors and transformers.
- Monitoring of unauthorized hooking or tapping the bare conductors is of LT lines is more difficult.
- No. of consumers that affects due to DTC failure are less in case of HVDS.

High voltage distribution system (HVDS):

To improve quality of supply and reduce losses HVDS is suggested.11 KV lines are extended to as nearer to the loads as possible and erect small size single phase transformers 5, 10 or 15 KVA and release supply with zero or minimum LT line and the unavoidable short LT lengths to be enclosed by insulated wires like ABC (Aerial Bunched Cables). The major advantages of using ABC in HVDS are that the faults on LT lines are totally eliminated, thus improving reliability and also theft by direct tapping is avoided. HVDS project is to reconfigure the existing Low voltage (LT) network as High Voltage Distribution System, wherein the 11kV line is taken as near to the loads as achievable and the LT power supply is fed from small capacity transformer and minimum length of LT line. Existing network consists of large capacity transformers at one point and the connections to each consumer are provided through heavy distance LT lines. This long length of LT lines is causing low voltage condition to the majority of the consumers and high technical losses. In the HVDS plan, LT distribution network is converted into 11 kV mains feeders and thereby installing the small capacity distribution transformer as near as to the load. By converting these LT lines to HVDS, the current flowing through the lines shall reduce by 28 times and will carry down the technical losses in the LT line hugely. The prevailing low voltage in the LT line is also affecting the efficiency of the electric equipments and breakdown is also very high. Also there is a tendency of unauthorized connections to hook to the LT lines which results in over loading of the transformers and failure of the transformers. The scheme consists of converting the existing 3 phase 4 wires lines to 11 kV systems using the existing supports and providing intermediate poles wherever necessary and individual transformers are provided to both agricultural loads and loads other than agriculture. HVDS is most successful method in dropping the technical losses and improving the quality of supply in power distribution system. As the authorized consumers do not allow unauthorized tapping by another as their transformer gets overloaded or may get damaged, resulting in outage of power supply for longer durations. Based on the feedback received from Andhra Pradesh and Gujarat where HVDS schemes have been operational in urban and rural application it is noticed that the investment on conversion from LVDS system to HVDS is recovered by way of loss reduction within a period of 5 to 7 years. There are three types of High Voltage Distribution System namely, Single phase and single neutral , two phase two wire and three phase small rating transformer with three phase HV system.

Analysis of existing LT system and proposed HVDS system and annual saving and payback period:

- Line loss in KW = [{(Cum load in KVA/ (1.732 × voltage in KV × DF)} ^2 × Length in Km × Resistance constant/1000
- Line loss in Units = [{(cum load in KVA/ (1.732 × voltage in KV × DF)} ^2 × Length in Km × Resistance constant × LLF × 8760] /1000
- Where Voltage = 11 KV for HT line
  = 0.4 kV for LT line
  Diversity factor (DF) = 1.5 for HT line = 1.1 for LT line
  Load Factor (LF) = Annual Energy consumption / (Peak × 24 × 0.9 × 365 ×1000)
  = 0.18 for HT line = 0.36 for LT line
- Line Loss Factor (LLF) = (0.2 × LF) + [0.8 × (LF^2)]
  = 0.36 for HT line = 0.18 for LT line
- Reduction in losses = Losses in existing low voltage system - Losses in HVDS
- Annual Savings = Price of a unit × reduction in losses in terms of unit
- Payback Period = (Capital Outlay ÷ Annual Savings)

Examples of *HVDS:*

Different case case studies has been done to find out the superiority of HVDS over LVDS.The results for different case studies are as per below.

1. High voltage distribution system in ANDHRA PRADESH:
   As per ref. paper the study has been carried out for HVDS system at Patnum Substation. It has been found that percentage loss in existing LT system was 16.82%.By converting this LT system into HVDS the loss has been carried out up to 5.30%.The net reduction of losses is 11.52%.Simmillarly the study shows that the voltage profile is improved from340 V to 440 V for the tail end consumer.
2. The case study has also been done for BEHLLA feeder in Punjab state having 100 KVA distribution transformer feeding nine consumers as per paper presentation in IOSR Journal of Electrical and Electronics Engineering (IOSRJEEE) ISSN: 2278-1676 Volume 1, Issue 5 (July-Aug. 2012), PP 39-45. The study clears the facts that Net Losses has been reduced. The details are as follows:

Net Losses for LT Distribution = 19810.404 Units.

Net Losses in HVDS = 4624.55 Units.

Net Reduction in Losses = (Total LT losses-Total HT losses)

= (19810.404-4624.55) = 15185.84 Units.

Power Purchase Price = Rs.5

Annual Savings Annual Savings = 5(Reduction in Losses)

= 5(15185.84) = Rs.75929.24

Capital Outlay = (Total Transformer Cost + Miscellaneous Cost)

= Rs. (2, 15,000+10,000) = Rs.2, 25,000

Payback Period Payback period is the length of time required by the cumulative net cash inflows to cover-up the fixed capital investments.

Payback Period = (Capital Outlay / Annual Savings)

= (225000/75929.24) = 3 Years.

CONCLUSION*:*

It is shown that the substantial amount of generated power is being wasted as losses. Therefore, loss minimization in power system has assumed greater significance.HVDS scheme has led to the formulation of new strategy of energy conservation and minimization of transmission and distribution losses by reducing the power theft. The adoption of HVDS has been indicated as the necessary factor in efficient energy distribution and developing the proper utilization of electricity and efficient distribution of energy in agricultural sector thereby, tackles the problems faced by the farmers. Effective implementation of HVDS scheme has reduced the failure of transformers, burning of agricultural pump sets and curtailment of demand through retrofitting of energy-efficient pumps. This in turn, reduced the wastage of energy and optimization of power intake, thereby promoting the environmental concerns and because of reduced consumption, the farmer gets benefited by the reduction in his monthly expenditure on electricity. It is concluded that the use of distribution transformer of small rating for two or three consumers has reduced the outages, transformer and power losses due to low current and pilferage to a great extent. Also, the accountability of the farmer has increased resulting in moral ownership of the transformer dedicated to single pump. However, initial expenditure on dismantling the existing system is high but it can be compensated in short span of time thus, increasing the annual energy saving. The restructuring of existing LVDS as HVDS in agricultural field presents one of the best technically feasible and financially viable method for providing reliable and quality supply to consumers. Adoption of this innovative measure has been stated to have improved the commercial and technical performance in the particular state. The implementation of this HVDS project opens the avenues for the work in many other related areas. The same work can be extended to commercial, large residential and unbalanced distribution system.

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