International Journal of Electrical and Electronics Research ISSN 2348-6988 (online)
Vol. 2, Issue 3, pp: (11-20), Month: July - September 2014, Available at: www.researchpublish.com

Improvement in Voltage Profile and Loss Minimization Using High Voltage Distribution System

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Abstract: **this paper presents the comparison of existing low voltage distribution system with proposed high voltage distribution system in terms of losses. The study is based on a real low voltage agricultural feeder in Punjab state. The investigation is carried out to determine the losses in the existing low voltage (LT) distribution system and then converting this low voltage distribution system to proposed high voltage distribution system (HVDS) by replacing the one large transformer of 100 KVA with various transformers of small rating and then determining the reduction in losses in terms of units and annual savings in terms of rupees due to proposed method. To check the feasibility of the proposed work, the annual saving and payback period of the proposed method is also determined.**

Keywords: **Annual Savings; Feeder; High Voltage Distribution System; Payback Period.**

1. INTRODUCTION

In recent decades, different schemes have been proposed to reduce the losses in the distribution system and hence, to increase the efficiency of electric devices and power distribution networks. In distribution systems, the voltage at buses reduces when moved away from the substation, also the losses are high. The reason for high losses is the use of low voltage for distribution as in the low voltage system; the current is high and thus more losses. Thus by using high voltage for distribution we can reduce the losses as current in HVDS (high voltage distribution system) is low. Since the losses prevailing in the existing power distribution system can be classified as: a) Technical losses b) Non-Technical losses. Technical losses on distribution systems are primarily due to heat dissipation resulting from current passing through conductors and from magnetic losses in transformers. Technical losses occur during transmission and distribution and involve substation, transformer, and line related losses. These include resistive losses of the primary feeders, the distribution transformer losses (resistive loses in windings and the core losses), resistive losses in secondary network, resistive losses in service line and losses in KWh meter. These losses are inherent to the distribution of electricity and cannot be eliminated but can be reduced. Non-Technical losses include tampering with the meter to create false consumption information used in billings, to making unauthorized connections to the power grid. Non-payment, as the name implies, refers to cases where customers refuse or are unable to pay for their electricity consumption. It is estimated that electricity theft costs in India is in crores in a year. Electricity theft is part of a phenomenon known as “Non-Technical Losses” (NTL) in electrical power systems. And thus it is necessary to focus on both sides’ i.e. on technical losses as well as on nontechnical losses and it can be achieved by using proposed HVDS method for distribution. The main advantage of using high voltage for distribution is to reduce the theft of energy and decrease in unauthorized connection as the LT lines are virtually eliminated and even short LT lines required will be with insulated cables. This makes direct tapping very difficult and thus increases the authorized connection which will improve revenue. Also the current in the proposed method is low due to high voltage and thus low power losses. It also helps in avoiding unnecessary iron losses in overrated distribution transformer which otherwise occur in the existing system and hence reduces technical losses.

DISTRIBUTION SYSTEM:

The primary and secondary power distribution network, which generally concerns the consumer in India, is the distribution network of 11kV lines or feeders downstream of the 33kV substation. Each 11kV feeder which emanates from the 33kV substation branches further into several subsidiary 11kV feeders to carry power close to the load points (localities, industrial areas, villages, etc). At these load points, a transformer further reduces the voltage from 11kV to 415V to provide the last-mile connection through 415V line also called as Low Tension (LT) line to individual customers, either at 240V as single-phase supply or at 415V as three- phase supply. A feeder could be either an overhead line or an underground cable. In urban areas, owing to the density of customers, the length of an 11kV feeder is generally up to 3 kms. On the other hand, in rural areas, the feeder length is much larger even up to 20 kms. A 415V line should normally be restricted to about 0.5-1.0 km. In existing distribution systems, the voltage at buses reduces when moved away from the substation, also the losses are high. The reason for high losses is the use of low voltage for distribution as the current is high in the low voltage system and thus more losses. Thus by using high voltage for distribution we can reduce the losses as current in high voltage distribution system (HVDS) is low. In the existing system pilferage is very easy because of lengthy bare LT conductor, and thus many unauthorized connections are tapped from the bare LT conductor.

LOSSES IN THE DISTRIBUTION SYSTEM:

The losses prevailing in the existing power distribution system can be classified as: a) Technical losses b) Non-Technical losses. Technical losses on distribution system are primarily due to heat dissipation resulting from current passing through conductors and magnetic losses in transformers. Technical losses occur during transmission and distribution involves substation, transformer, and line related losses. These include resistive losses of the primary feeders, the distribution transformer losses (resistive loses in windings and the core losses), resistive losses in secondary network, resistive losses in service line and losses in KWh meter. These losses are inherent to the distribution of electricity and cannot be eliminated but can be reduced. Non-Technical losses include tampering with the meter to create false consumption information used in billings, making unauthorized connections to the power grid. Non-payment, as the name implies, refers to cases where customers refuse or are unable to pay for their electricity consumption. It is estimated that electricity theft costs in India is in crores in a year. Non-Technical losses (NTL) include electricity theft. Electricity theft is defined as a conscience attempt by a person to reduce or eliminate the amount of money he will owe the utility for electric energy. It can be done by tampering with the meter to create false meter reading i.e. create false consumption information used in billings, meters not read, non performing and under performing meters, making unauthorized connections and direct tapping. Non-payment, as the name implies, refers to cases where customers refuse or are unable to pay for their electricity consumption. It is estimated that electricity theft costs in our country is in crores in a year. Both the technical and non-technical losses are together termed as T&D (transmission and distribution) losses. In India, average T&D losses are estimated as 23% of the electricity generated. But in actual practice these losses are as high as 50% in some states of India. In addition to above two types of losses, there is also a loss in revenue due to non realization of revenue billed and the aggregate of all these losses is termed as AT&C (aggregate technical and commercial) losses. For this issue, Electricity Board is trying to draw attention to the need for reforms in electricity transmission and distribution sector, create mass awareness about transmission losses due to theft and misuse of electric energy. Also effective checks and balances in power distribution at various levels are imperative and to strictly implement timely revenue collection. And thus it is necessary to focus on both side i.e. on technical losses as well as on non-technical losses and it can be achieved by using proposed HVDS method for distribution. The main advantage of using high voltage for distribution is to reduce the theft of energy and decrease in unauthorized connection as the LT lines are virtually eliminated and even short LT lines required will be with insulated cables i.e. ABC. This makes direct tapping very difficult and thus increases the authorized connection which will improve revenue. Also the current in the proposed method is low due to high voltage and thus low power losses. It also helps in avoiding unnecessary iron losses in overrated distribution transformer which otherwise occur in the existing system and hence reduces technical losses.

REASONS OF HIGHER LOSSES:

To understand the method to reduce the losses, it is necessary to look for various reasons for higher losses in the existing system. The main reasons are:

- Lengthy distribution lines

- Inadequate size of conductors
- Over-rated distribution transformers and hence their under utilization
- Low voltage (less than declared voltage) appearing at transformers and consumers terminals
- Distribution transformer not located at load center on the secondary distribution system
- Low power factor
- Poor HT/LT ratio
- Poor quality of equipment
- Too many stages of transformations
- Transformer Losses
- Bad workmanship
- Direct tapping by the non-customers
- Pilferage by the existing customers
- Defective metering, billing and collection functions

LOSS REDUCTION BY HIGH VOLTAGE DISTRIBUTION SYSTEM:

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 possible and the LT power supply is fed by providing appropriate capacity transformer and minimum length of LT line with an objective to provide better quality power supply, reduction of losses and better consumer service. In the existing system, large capacity transformers are provided at one point and the connections to each load is extended through long 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 project, long length LT mains are converted into 11 kV mains and thereby installing the appropriate capacity distribution transformer as near as to the end and the supply is provided to the consumer at suitable voltage level. By converting these lines to HVDS, the current flowing through the lines shall reduce by 28 times and will bring down the technical losses in the LT line drastically. This can be explained by one single illustration that for a 100 KVA load the amperage at 11kV is 5 amperes where as it is 140 amperes at LT voltage of 415 Volts. The prevailing low voltage in the LT line is also affecting the efficiency of the electric gadgets 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. The length of the LT lines is restricted to less than 300 meters. HVDS is most effective method in reducing the technical losses and improving the quality of supply in power distribution system. In this system high voltage lines are extended to as nearer to the loads as possible and erect small size transformers. This system aims at LT less system or less LT and the unavoidable short LT lengths to be covered 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. 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 Greater Noida where HVDS schemes have been operational in urban and rural applications. It is noticed that the investment on conversion from conventional system to HVDS is recovered by way of loss reduction within a period of 3 to 5 years in most cases. 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.

2. METHODOLOGY

In this section, problem for calculation of losses in power lines and distribution transformer for both existing LT system and proposed HVDS system are discussed. To understand it clearly, losses in both the cases and their comparison is shown in tabular form. To determine power losses in the LT line, we require value of resistances for conductor, here rabbit conductor of 50 mm^2 is used, voltage on LT side is 400V and 11kV for HVDS. The length of line is taken from MPSEB (Madhya Pradesh state electricity board) data along with the single line diagram. For losses in the transformer the appropriate value is chosen from the table.

TABLE 1: Transformer Losses

S. No.	KVA Rating	No Load Losses or Iron Losses (W)	Load Losses or Cu Losses (W)
1.	5	40	150
2.	10	40	225
3.	15	60	275
4.	25	110	720
5.	63	200	1300
6.	100	290	1850

3. COMPARISION OF EXISTING LT SYSTEM AND PROPOSED HVDS SYSTEM

HVDS represents North American practice whereby the HV line is extended up to the load point; in the instant case, supply is tapped off from 3-phase HV mains in proximity of an agricultural pump and provided via a distribution transformer of 10 kVA capacity to serve a 5-7 HP load, thus restricting the LT line to the length of the service cable. A typical schematic diagram of 'before and after' scenario is shown in Fig.

The HVDS has been constructed by refurbishing and retrofitting LT lines using the same poles and conductors and erecting new insulators and hardware supports. Once conversion of LT to HT lines is completed, the transformer is installed either on a single or double pole structure, depending on angularity of the lines.

The distribution systems shall be at high voltage and the L.T. system shall be the least or eliminated as far as possible. HVDS or high voltage distribution systems by converting existing LVDS is in progress in many Discoms reducing the technical losses appreciably. This can be explained by one single illustration that for a 100 KVA load the amperage at 11KV is 5 Amps where as it is 140 Amperes at L.T. voltage of 415 Volts.

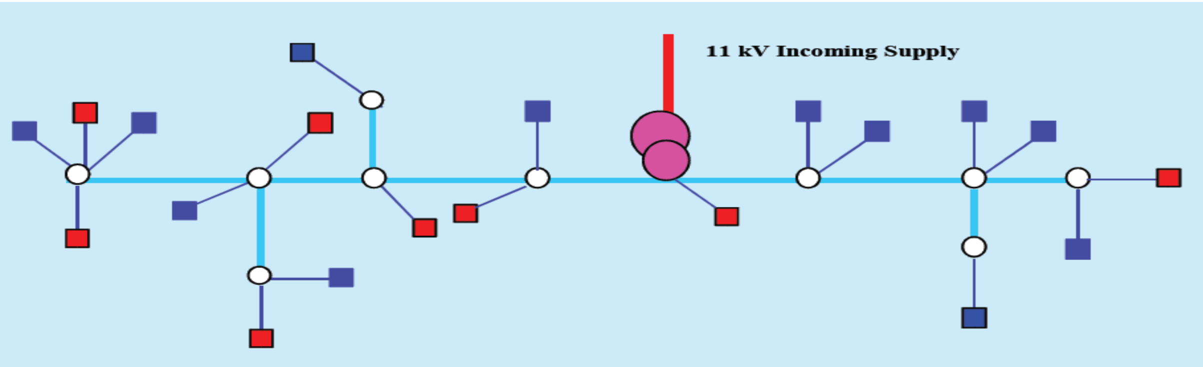

Fig.1 LT Distribution

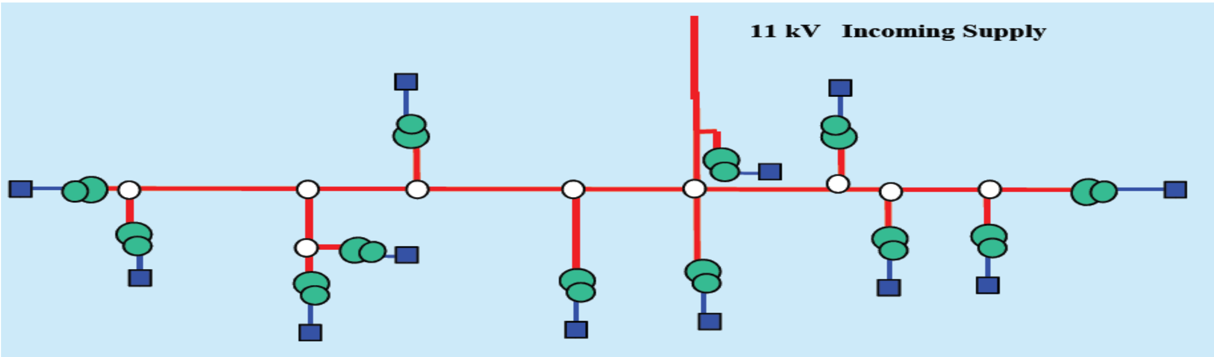

Fig.2 HT Distribution

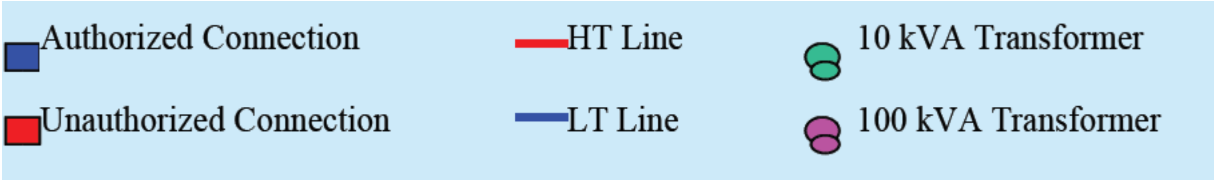

Fig. 3 High Voltage Distribution System

TABLE 2: Detail of Line Length and Transformer in Existing System and Proposed System

S. No.	Parameters	Existing LT System	Proposed HVDS System
1.	Length of HT	0	1.32 km
2.	Length of LT	1.32 km	0
3.	Number of transformer	100 KVA - 1 no.	6.5 KVA- 4 no. 10 KVA- 5 no. 16KVA- 2 no.

TABLE 3: Details of Losses in Existing LT System

S. No.	Consumer	Power Losses in watts	Transformer		Transformer losses	
			Rating of Transformer	Number of Transformer	Copper Losses in watts	Iron Losses in watts
1.	Consumer 1	170.29	100kva	1	1850	290
2.	Consumer 2	90.072				
3.	Consumer 3	67.554				
4.	Consumer 4	372.95				
5.	Consumer 5	951.38				
6.	Consumer 6	5.63				
7.	Consumer 7	137.92				
8.	Consumer 8	70.36				
9.	Consumer 9	189.26				
10.	Consumer 10	104.145				
11.	Consumer 11	11.26				

TABLE 4: Details of Losses in Proposed HVDS System For Upper 11 Consumers Respectively

Power Losses in watts	Transformer		Transformer losses	
	Rating of Transformer in KVA	Number of Transformer	Copper Losses in watts	Iron Losses in watts
0.225	10	1	225	40
0.1188	10	1	225	40
0.0892	10	1	225	40
0.492	10	1	225	40
1.255	10	1	225	40
0.00743	6.3	1	150	40
0.182	6.3	1	150	40
0.0928	16	1	275	60
0.2498	6.3	1	150	40
0.137	16	1	275	60
0.0148	6.3	1	150	40

TABLE 5: Existing vs. Restructured System

Voltage Source	LVDS O/P	HVDS O/P
V21	408.47V	411.99V
V22	409.72V	412.54V
V23	407.17V	412.54V
V24	406.50V	412.54V
V31	407.3V	412.64V
V32	405.35V	413.216V
V33	404.35V	413.116V
V34	404.26V	413.110V
V35	405.35V	413.216V
V36	404.00V	413.216V
V37	404.00V	413.21V
V38	404.00V	413.816V
V41	408.90V	412.87V
V42	407.64V	413.49V
V43	407.24V	413.20V
V44	407.24V	413.10V
V51	408.26V	413.816V
V52	406.34V	413.83V
V53	406.12V	413.21V
V54	406.01V	414.26V
V55	407.57V	414.16V

4. CALCULATION OF POWER LOSSES, LOSS REDUCTION, ANNUAL SAVING AND PAYBACK PERIOD

Power losses in the line is calculated for each branch and then total power loss is calculated b y taking the summation of each branch as given by (1) and (2).

$P_i = 3 \times I^2 \times R \times L$ … (1)

$P = \sum P_i$ …(2)

Total loss, $P_T = P_L + P_O + P$ … (3)

Total Loss per annum, $P_a = (P_T \times 8 \times 365) \div (1000$… (4)

Reduction in losses = Losses in existing low voltage system - Losses in HVDS ... (5)
Annual Savings = Price of a unit × reduction in losses in terms of unit … (6)

Payback Period = (Capital Outlay ÷ Annual Savings) ... (7)
In this scheme, total capital outlay is estimated as = 195.865 lakhs

Annual savings = Annual loss reduction in units × Unit price
= 34.53 × 2.50
= 86.325 lakhs

Payback period = Total capital outlay / Annual savings
= 195.865 lakhs / 86.325 lakhs
= 2.27 years

Where,
P_i = power losses of the branch ‘i’ P = Total power losses in line
P_L = Transformer load losses
P_O =Transformer no load losses

P_a = Total Loss per annum
n = total number of branches;
Number of hours = 8
Number of days in a year = 365
Price of a unit is taken as Rs 5

The data obtained from MPSEB include single line diagram of existing LT system is shown in Fig. and that of proposed HVDS system is shown in Fig. Also number of consumer, load sanction, line length, rating and number of transformer installed for both LT system and HVDS system are shown in tables. The various power losses and transformer losses prevailing in existing LT system is shown in table and that for the proposed HVDS system is given in table . Also the comparison of losses in LT system and Proposed HVDS system is given in table.

TABLE 6: Comparison of Existing LT System and Proposed HVDS System

S. No.	Parameter	Existing System	HVDS System
1.	Total power losses	2170.82watts	2.863 watts
2.	Total power losses per annum	6338.79units	8.35996 units
3.	Total iron losses per annum	2540.4 units	1401.6 units
4.	Total copper losses per annum	3637.67 units	6643 units
5.	Total transformer losses per annum	6178.07 units	8044.6 units
6.	Total losses per annum	12123.55 units	8052.95 units

5. RESULT AND DISCUSSION

In the table, it is summarized that by adopting proposed HVDS method, the T&D losses can be reduced by 33% and there is always feasibility for load extension, since for each consumer, a separate transformer of required rating is installed. Thus no need to install overrated transformer to serve future load demand and hence unnecessary iron losses of high rating transformer can be avoided. Also because of large LT line and small or no LT line, tapping is not possible which reduces pilferage or unauthorized connection. It will also bring commercial viability in the power sector and hence attract companies to invest in the power sector which ultimately provide a solution of one of the major problem of underutilized energyy potential

TABLE 7: Summary of Proposed HVDS Method

Total load sanction in KVA	82.054 KVA
Rating of installed transformer in existing system	100 KVA
Is transformer overloaded or underloaded	Under load
Net iron losses in existing LT system	2540.4 units
Net iron losses in proposed HVDS system	1401.6 units
Net reduction in losses per annum	3453000units
Percentage reduction in losses per annum	33.57%
Annual saving	Rs 8632500
Capital outlay of the proposed system	Rs 19586500
Payback period	2.27 years

An incidental benefit is that the distribution transformers have been relieved of overloading, resulting in a lower overall failure rate, which reduced from 14.7 % in 2010-11 to 7% in 2013-14, as indicated in Fig.

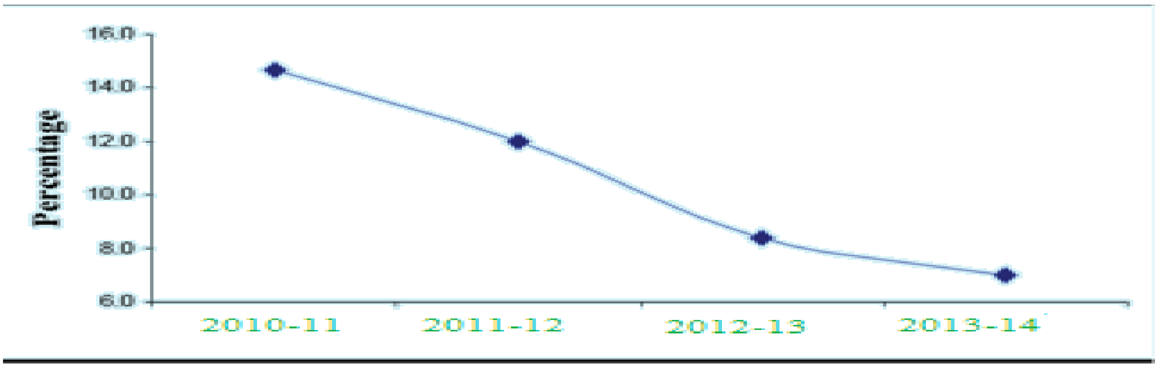

Fig. 4 Transformer Failure

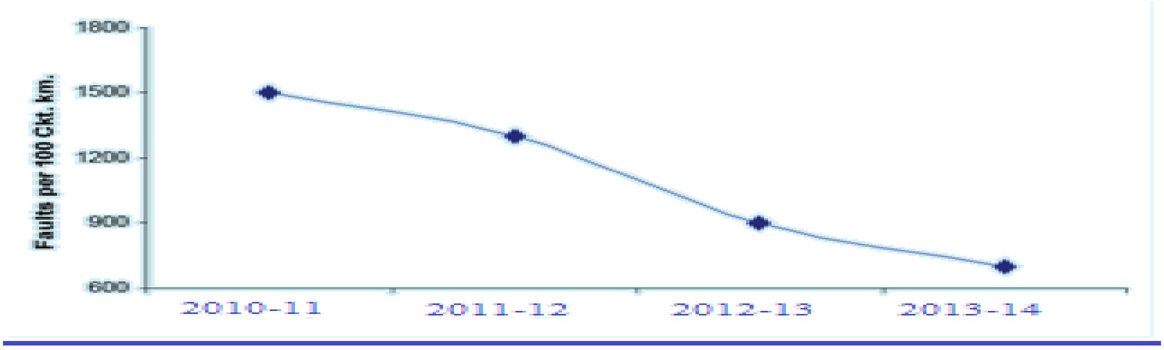

Fig. 5 LT Line Faults

The LT line faults per 100 circuit kilometer of agricultural network have also recorded a downward trend, having been reduced from 1500 in 2010-11 to 700 in 2013-14.

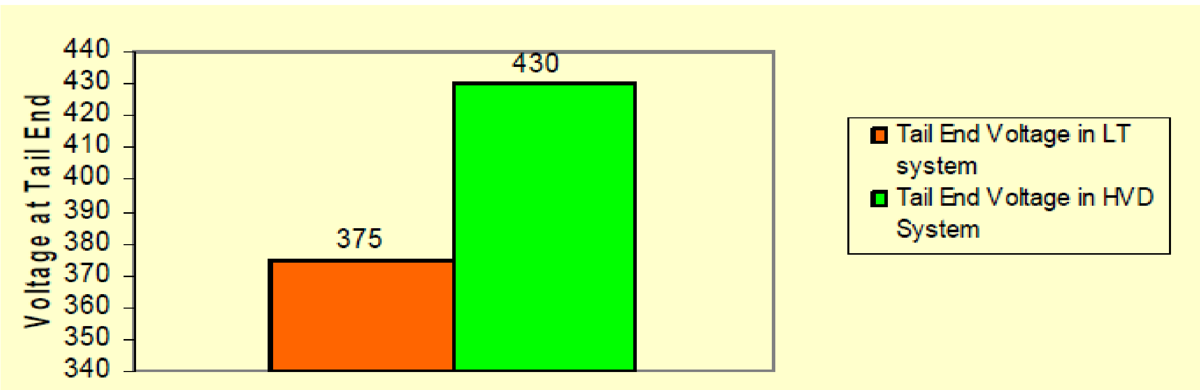

Fig. 6 Voltages At Tail End

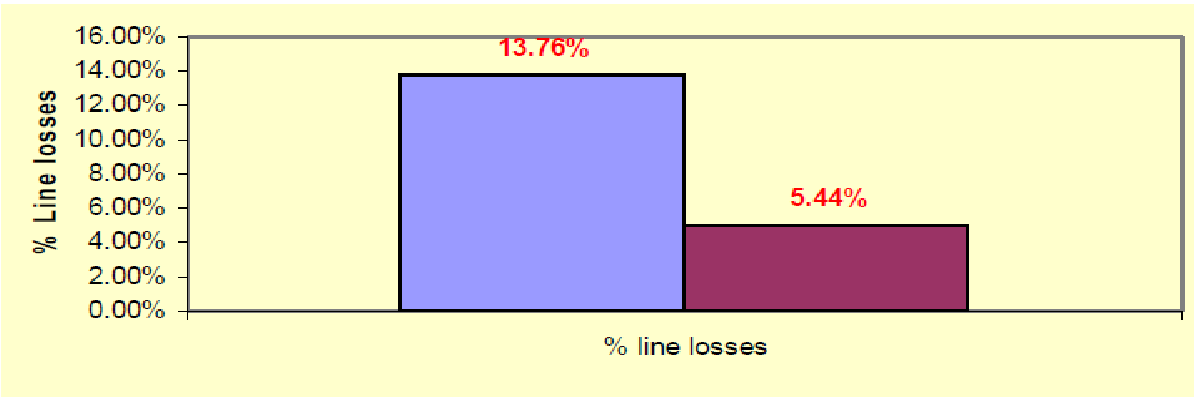

Fig. 7 Percentage Line Losses

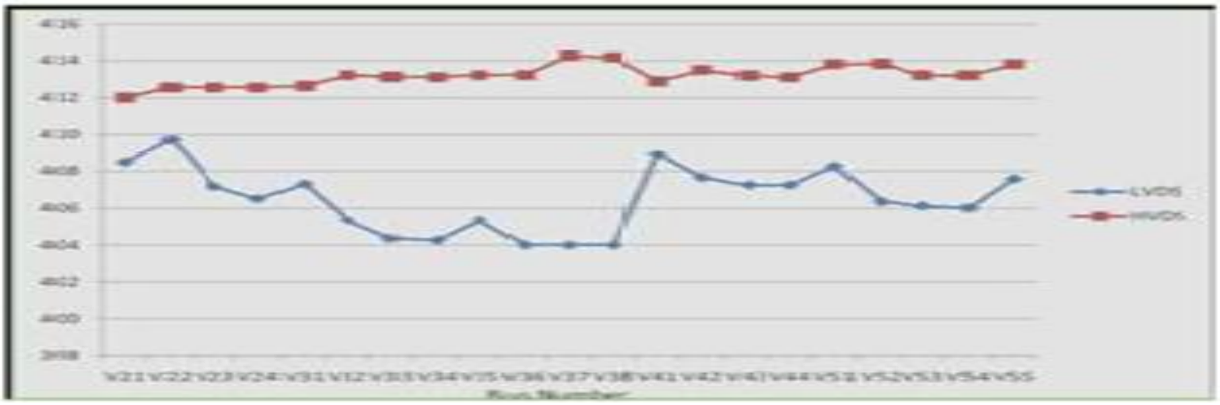

Fig. 8 Payback Period by Power Consumption

Overall we are getting 3% voltage improvement in the Proposed System

P=√3 VI Cosǿ

V (Voltage) increase and because of that I (Current) decrease in I Cos ǿ and the I^2R Losses will Decrease.

So we can assume that, because of the Effect of

1) Reduced I^2R Losses (1% Voltage improvement)
2) Due to I^2R Losses the Longitivity will increase (1% Voltage improvement)
3) Cost Consumption (1% Voltage improvement)

Approximately 3% Voltage improvement per day.

If we get 3% Improvement per day then within 30 days, we will get 1 day power consumption free. If we get 3% Improvement per day then within 12 Months, we will get 12 days power consumption free If we get 3% Improvement per day then within 30 years, we will get 360 days that is nearly 1 year power consumption free.
The Tail End Voltage in Existing System is 407.57V and in the Proposed System the Tail End Voltage is 414.16V.

6. CONCLUSION

In this paper, the following conclusions are drawn:

- The conversion of LT distribution system in to HVDS system results in increase in energy saving and reduction in losses.
- The adoption of HVDS makes the system more reliable and thus reduces the number of outages.
- The chances of unauthorized connections and theft of energy are reduced.
- It will improve the power quality.
- It will bring the commercial viability in the power sector.

REFERENCES

[1] Abaide, A.R., Canha, L.N., Barin, A. and Cassel, G. (2010), "*Assessment of the smart grids applied in reducing the cost of distribution system losses*", 7th International Conference on the European Energy Market (EEM), Madrid, Spain, pp.1-6.

[2] Arefi, A., Hagifam, M.R., Yavaalab.A, Olaaei. J. and Keshtkar, H. (2011), "*Loss reduction planning in electric distribution networks of IRAN until 2025*", 16th conference on Electric Power Distribution Network (EPDC), Bandar Abbas, Iran, pp.1-6.

[3] Attia, H.A. (2008), "*Optimal voltage profile control and losses minimization of rad ial d istribution feeders*", 12th International Conference on Power System (MEPCON) Middle-East, Aswan, Egypt, pp. 453-458.

[4] Bansal, I., Gill, S.H. and Gupta, A. (2012), "*Minimisation of losses by implementing High Voltage Distribution System in Agricultural sector*", IOSR Journal of Electrical and Electronics Engineering, vol.1, No. 5, pp. 39-45.

[5] Depuru, S.S.S.R., Lingfeng, W. and Devabhaktuni, V. (2010), "*A conceptual design using harmonics to reduce pilfering of electricity"*, Power and Energy Society General Meeting, IEEE, Detroit, United States, pp.1-7.

[6] Gomes, V.F., Carneiro, S., Pereira, R.L.J. , Vinagre, P.M., Garcia, N.A.P., Oliveir, J.E. and Araujo, R.L. (2005), "*A New Distribution System Reconfiguration Approach Using Optimal Power Flow Technique and Sensitivity Analysis for Loss Reduction*", Panel Session Entitled Advanced Models for Distribution System Analysis, IEEE PES General Meeting San Francisco, CA, USA, vol.1, pp.897-901.

[7] Gupta, A., Gill, S.H. and Bansal, I., (2012), "*Effectiveness of High Voltage in Distribution System: High Voltage Distribution System*", IOSR Journal of Electrical and Electronics Engineering, vol. 1, No.5, pp. 34-38.

[8] Hussain, I. and Roy, A.K. (2012) , "*A new heuristic approach for optimal reconfiguration of distribution systems for improvement of power delivery efficiency through loss reduction*", International Conference on Advances in Engineering, Science and Management (ICAESM) , Nagapattinam , Tamil Nadu, pp.571-576

[9] Mustafa, S.S., Yasen, H.M. and Abdullah, H.H. (2011), "*Evaluation of Electric Energy Losses in Kirkuk Distribution Electric System Area*", Iraq J. Electrical and Electronic Engineering, vol.7, No.2, pp. 144-150.

[10] Nipprt, T., Steinke, K. and Schrörs, M.(2007), "*Loss Reduction in High Voltage Urban Distribution Systems",*19th International conference on Electricity Distribution, session 3, Vienna, Austria, Paper No. 719, pp. 1-4.

[11] Ramesh, L., Madhusudhanaraju, M., Chowdhury, S.P., Chowdhury, S. (2011), "*Voltage profile improvement through high voltage d istribution system*", International Conference on Sustainable Energy and Intelligent Systems (SEISCON), Chennai, India, pp.468-473.

[12] Ramesh, L., Ravindiran,S., Chowdhury, P.S., Chowdhury,S., Song,H.Y. and Goswami,K.P. (2007), "*Distribution System Loss Minimization and Planning using Cymdist*", 42nd International Universities Power Engineering Conference (UPEC), University of Brighten, Brighten, UK, pp. 316-321.

[13] Sampath Kumar, S.A., Vasudaven, V., Antony, J., Raju, Madhu Sudhana and Ramesh, L. (2011), *"Minimization of power losses in distribution system through HVDS concepts,*" International Conference on Sustainable Energy and Intelligent Systems, Chennai, India, pp.86-90.

[14] "*Environmental and Social Review (ESR) on high voltage distribution project for agriculture consumers in the state of Punjab*", Punjab State Electricity Board (PSEB), Patiala.

[15] "*Distribution Reform, Upgrades and Management (DRUM)*", 2002, New activity Design Report by USAID, India.

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