Power Distribution Through HT Lines by Using Small Rating DTR's in Agricultural Area: A Case Study

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Abstract

This study is based on a real distribution feeder in Madhya Pradesh (M.P.) state. The paper presents comparative analysis between the LT- distribution system and proposed HT- distribution system in terms of technical and non-technical losses. The main reason for high I^2R losses (i. e. technical losses) is the use of low voltage in existing LT- distribution system. On the other hand, non-technical losses mainly include electricity theft which is done by direct hooking of unauthorized loads in LT lines. In this paper, existing LT- distribution system is converted into proposed HT- distribution system to reduce technical and non-technical losses. Under this proposed HT- distribution system, HT (11KV) lines are extended nearer to the loads as possible and release supply to 4 or 5 consumers with unavoidable least (or almost nil) LT lines; preferably with insulated overhead cables. Hence, power is distributed mainly through HT lines. In this paper, transformers of low capacity are introduced for implementing the proposed HT- distribution system. The superiority of proposed HT- distribution system is validated by determining the reduction in losses, annual savings and payback period.

Keywords: Proposed HT- Distribution System, Small Rating Distribution Transformers, Reduction in Losses, Annual Savings, Payback Period.

1. Introduction

Losses reduction is an important issue in existing distribution system, involving operational, economical and quality of service aspects. In agricultural area of India, shortage of electricity, power cuts, theft of electricity are common and it has adversely effected the country's economic growth. Today's modern world, energy demand is increasing day by day and to meet this ever increasing demand power companies are making every effort to increase the energy availability but the efforts made by the power companies to bridge
the gap between energy demand and energy availability are all in vain. Moreover, power companies are in loss
because of technical and non-technical losses. It is estimated that electricity theft cost in our country is in crores in a year. For this issue, electricity board is trying to create mass awareness about distribution losses and
misuse of electrical energy. Thus, it is necessary to focus on both side i.e. on technical losses as well as on non-technical losses in existing distribution system and
it can be achieved by using proposed HT- distribution system for power distribution. Electricity theft and unauthorized load connections are reduced by using high voltage for power distribution; as in the proposed HT- distribution system, LT lines are virtually eliminated and unavoidable short LT lines are replaced with insulated overhead cables. This makes direct tapping very difficult and increases the authorized connections. Thus, the proposed HT- distribution system helps to improve revenue and it also reduces I^2R losses of existing distribution system [1].

2. Losses in electrical distribution system

The delivery of power from sources to the consumer points is always accompanied with power losses. Such non-negligible amount of losses has a direct impact on the overall efficiency and financial issues of the existing distribution system. Therefore, method for losses reduction is essential for achieving the financial goals of distribution companies. To make it easier to investigate losses in electrical distribution system, it is helpful to divide different types of losses into two categories as: A) Technical losses and B) Non-Technical losses. To find errors in the existing distribution system and also to be able to reduce losses it is important to know how much of the losses that are technical and how much that are non-technical [2,3].

2.1. Technical losses

Technical losses occur especially in overhead distribution lines and transformers. The technical losses primarily take place due to the following factors:-

2.1.1. I^2R losses in overhead distribution lines: Electrical energy losses in overhead distribution lines are wasted in the form of I^2R losses. These I^2R losses are current depending losses and mainly caused by the use of low voltage in distribution. As in the existing distribution system; the current is high due to low voltage and thus occurs more I^2R losses [4].

2.1.2. Transformer losses: Transformer losses can be classified into two components, namely, no-load and load losses. No-load losses occur from the energy required to retain the continuously varying magnetic flux in the core and its invariant with load on the transformer. Load losses are a function of the winding current. It mainly arise from resistance losses in the conducting material of the windings and it varies with load [4].

2.2. Non-technical losses

The other category, the non-technical losses mainly include electricity theft in existing distribution system. Electricity theft is done by direct hooking of loads in LT lines. Non-technical losses are also known as "Commercial losses". Mostly, non-technical losses are associated with LT lines. In some regions, the electrical energy is illegally taking from the nearest LT line. Electricity theft by direct hooking and making unauthorized connections are the most common and visible form of non-technical losses. Hence, these unauthorized load connections are the main sources of the non-technical losses [3,4,5].

3. Existing LT- distribution system

In the existing LT- distribution system, high capacity distribution transformer is provided at one point and the connections to each load is extended through long LT lines. In agricultural area, predominantly loads are pump sets which is used for irrigation purpose. The existing LT- distribution system consists 3 phase, high capacity distribution transformer and on each DTR of 100 KVA or 200 KVA, 20 to 30 such pump sets are connected. The loads in agricultural areas are widely dispersed and LT (low tension) lines run for long distances to feed a small load. In some rural areas, length of LT lines are much larger even up to 20 kms. Hence, long LT (low tension) lines and many number of load connections with high capacity distribution transformer resulting in the increase in distribution losses, affecting voltage profile and performance of the distribution system [6].

4. Disadvantages experienced with existing LT- distribution system

- Lengthy LT lines and poor tail end voltage at the consumer point.
- High I^2R losses.
- Unsatisfactory voltage profile due to high voltage drop.
- Poor quality of power supply.
- Electricity theft by direct hooking of unauthorized load connections in LT lines.
- Unreliable supply due to overloading of LT lines.
- Overloading and failure of distribution transformer due to direct hooking of unauthorized load connections in LT lines and also frequent LT faults. Thereby, its maintenance and repair requires high expenditure.
- In the event of transformer failure entire unit is to be replaced and it consumes more time and due to inordinate delay in replacement of failed distribution transformers, there is a great damage loss in standing crops.
- Many number of consumers affect in case of any failure in high capacity distribution transformer.
- Fluctuations in voltage because of many number of consumers connected under high capacity DTR, frequent fuse blow-outs and motor burns out due to low voltage, consequently expenditure on repairs.
- Nobody owns the transformer in existing LT- distribution system, since everybody thinks that others will take care of the transformer.

To overcome all these problems, implementation of proposed HT- distribution system is considered as the best move to enhance the performance of existing LT- distribution system.

5. Proposed HT- distribution system

In this paper, HT- distribution system is adopted to reduce the technical and non-technical losses appreciably. At higher voltage, lower current is needed to transfer the same amount of power. Thus proposed HT- distribution system helps in reducing I^2R losses. This proposed system employs small rating distribution transformers of various capacity (16 KVA, 25 KVA). Under this proposed HT- distribution system, HT (11 KV) lines are extended nearer to the loads as possible and release supply to 4 or 5 consumers with unavoidable least (or almost nil) LT (low tension) lines, preferably insulated overhead cables. Hence, power is distributed mainly through HT lines by using small rating distribution transformers [9].

6. Advantages of proposed HT- distribution system

- I^2R losses can be minimized to the lowest level.
- Voltage drop is negligible.
- High quality of power supply and excellent voltage profile earns total consumer satisfaction.
- Electricity theft by direct hooking of unauthorized load connection is avoided.
- Prevention of unauthorized loads and consequently no over loading in transformer. Thus, negligible transformer failures and minimal number of outages.
- In the event of transformer failure or any fault, only 4 or 5 consumers will be affected.
- The authorized consumers assume ownership and take responsibility of the distribution transformer; as only 4 or 5 pump sets are connected on each DTR in agricultural area.
- No frequent fuse blow outs, less fluctuations and also less burnouts of motors.
- Faults on LT lines are totally eliminated, thus improving reliability.
- No additional generation capacity needed for new loads, as in the reduction in power losses and consequently power can be supplied to new loads without any further investment on the infrastructure, thereby saving in power purchase cost [10].

7. Case study

A real case study is presented in this paper. This study is showing the advantages of the proposed HT- distribution over existing LT- distribution system in the agricultural area of Hinotiya Village. The data along with single line diagram has been taken from Madhya Pradesh Poorv Kshetra Vidyut Vitaran Company Limited (MPPKVVCL) [11]. In this study, technical and non-technical losses for both existing LT- distribution system and proposed HT- distribution system are discussed. To understand it clearly, losses in both cases and their comparison is shown in tabular form. This study work also includes determination of reduction in losses, annual savings and payback period.

7.1. Methodology

The study work includes two stage methodology. In the first stage; power losses (I^2R losses) and transformer losses for both existing LT- distribution system and proposed HT- distribution system are determined in the agricultural area of Hinotiya Village. In the second stage; reduction in losses, annual savings and payback period are calculated.

7.2. Mathematical formula for calculation of power losses and current

The Power losses in a line is based on the measured current of the load and can be calculated as:

$$\text{Power losses} = I^2 \times R \times L$$

Where, I : Current in Amperes, R : Resistance of line conductor in Ohms per Kilometer, L : Length of line in Kilometers.

For 3 phase, Power losses = $3(I^2 \times R \times L)$ ……… (1)

Here, current can be determined by using the formula as given below:

$$I = \frac{P}{\sqrt{3} \times V \times COS\emptyset}$$

Where, P: Capacity of load in distribution line, V: Voltage in distribution system, COSØ: Power factor.

In this paper, the current is computed from the load and power loss for each consumer is evaluated by putting the value of corresponding current, line length and fixed value of resistance in equation 1: $[3(I^2 \times R \times L)]$ for both existing LT- distribution system and proposed HT- distribution system.

8. Calculation of losses in existing LT- distribution system

The single line diagram of LT- distribution system in Hinotiya Village is shown in fig. 1. In this fig, a 200 KVA distribution transformer is feeding the consumer's pump sets in the part of agricultural area of Hinotiya Village, (Madhya Pradesh).

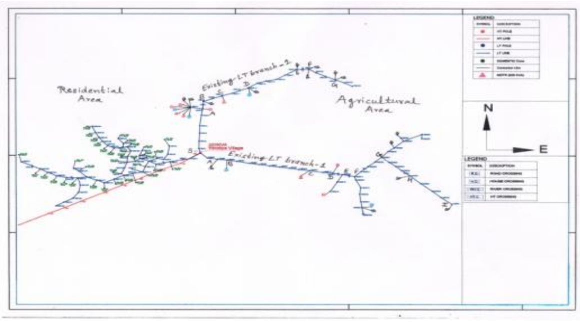

Figure 1: Existing LT- distribution system

8.1. Power losses (I^2R losses) of existing LT- distribution system in agricultural area

To determine power losses (I^2R losses) in the existing LT line, the value of resistance of the conductor is required. Here, Weasel conductor of 30 sq. mm is used and the resistance for this particular conductor is 0.928 Ohm/Km. The power factor is assumed to be 0.8 and voltage of the existing LT- distribution system is 433 volts. In fig. 1, one main long distribution trunk line is taken for calculation of I^2R losses in both LT branch-1 & LT branch-2 of the existing LT- distribution system. The length between one pole to another pole is 0.06 km. (say). Details of the consumers, loads, LT poles, length of existing LT line, current and I^2R losses for the both existing LT branch-1 and LT branch-2 are given in Table I and Table II respectively. For the calculation of I^2R losses; existing LT branch-1 and LT branch-2 can be simplified as shown in fig. 2 and fig. 3 respectively.

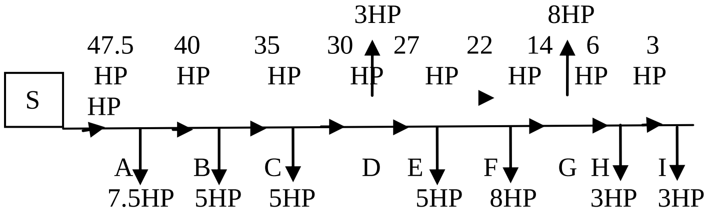

Figure 2: Loads in LT branch-1 of existing LT-distribution system

Table I. Parameters and Power losses of existing LT branch-1

S. N.	Name of Con-sumer Point	No. of Poles	Length of LT Line (KM.)	Total Load in LT Line (HP)	Current (Amp.)	Power Losses (I^2R losses) (Watts)
1	A	2	0.12	47.5	59.060	1165.298
2	B	1	0.06	40	49.734	413.168
3	C	8	0.48	35	43.517	2530.628
4	D	2	0.12	30	37.301	464.827
5	E	1	0.06	27	33.570	188.244
6	F	1	0.06	22	27.354	124.986
7	G	4	0.24	14	17.407	202.454
8	H	4	0.24	6	7.460	37.184
9	I	4	0.24	3	3.730	9.296
						Total 5136.085

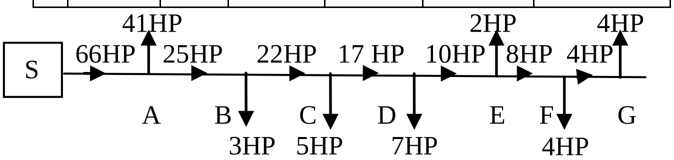

Figure 3: Loads in LT branch-2 of existing LT-distribution system

Table II. Parameters and Power losses of existing LT branch-2

S. N.	Name of Con-sumer Point	No. of Poles	Length of LT Line (KM.)	Total Load in LT Line (HP)	Current (Amp.)	Power Losses (I^2R losses) (Watts)
1	A	**7**	0.42	66	82.062	7874.132
2	B	1	0.06	25	31.084	161.396
3	C	2	0.12	22	27.354	249.972
4	D	3	0.18	17	21.137	223.886
5	E	5	0.30	10	12.433	129.104
6	F	1	0.06	8	9.946	16.524
7	G	3	0.18	4	4.973	12.393
						Total 8667.407

Total LT- power losses (I^2R losses) are evaluated by summing up the individual power loss of each load at the consumer point in LT branch-1 and LT branch-2 of the existing LT- distribution system. (refer figure 1)

From Table I and Table II,
Total power losses (I^2R losses) of the existing LT-distribution system= [sum of power losses (I^2R losses) in existing LT branch-1 + sum of power losses (I^2R losses) in existing LT branch-2]
= [5136.085 Watts + 8667.407 Watts]
= 13,803.492 Watts

8.2. Transformer losses in existing LT-distribution system

In fig. 1, a high capacity distribution transformer of 200 KVA is used to supply the power to the consumer's pump sets. Hence, the losses in distribution transformer also contribute to the total losses of existing LT distribution system. The transformer losses include no-load losses and full-load losses. For distribution transformer of 200 KVA, the fixed value of no-load losses and full-load losses are 550 Watts and 2800 Watts respectively.
Total Transformer Losses = (550 + 2800) = 3350 Watts.

8.3. Power theft losses in existing LT-distribution system

Power theft includes unauthorized connections of loads. Theft losses contribute to the 12% of total load. Hence, the sum of the all loads in existing LT branch-1 and LT branch-2 are 35,435 Watts and 49,236 Watts respectively.

Total Load (Watts) = (35,435 + 49,236)
= 84,671 Watts
Thus, Total Power Theft Losses
= 12% of Total Load (Watts)
= 12 % of 84,671 Watts
= 10,160.52 Watts

9. Calculation of losses in proposed HT-distribution system

The single line diagram of proposed HT- distribution system with small rating distribution transformers is shown in fig. 4. In this diagram, HT- distribution has done only in the part of agricultural area of Hinotiya Village in which proposed HT lines are extended nearer to the consumer's pump sets as possible and power is distributed mainly through proposed HT (11 KV) lines.

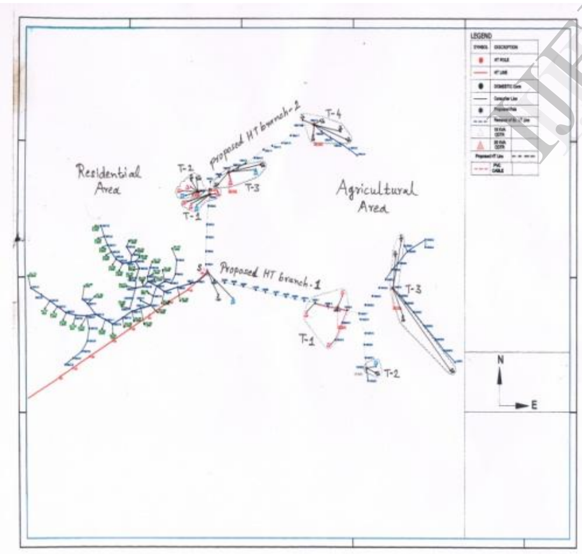

Figure 4: Proposed HT- distribution system

9.1. Power losses (I^2R losses) of proposed HT- distribution system in agricultural area

In the proposed HT- distribution system, voltage is 11000 Volts, as LT line is converted into 11 KV - HT line. The conductor of existing LT- distribution system is not replaced and the same existing conductor (i.e. weasel conductor) is used in proposed HT-distribution system. The resistance of the weasel conductor is 0.928 Ohm/Km and power factor is assumed to be 0.8. In fig. 4, one main long distribution trunk line is taken for calculation of I^2R losses in both HT branch-1 and HT branch-2 of the proposed HT- distribution system. Here, length between one pole to another pole is 0.06 km (say). Details of the consumers, loads, poles, length of proposed HT line, current and I^2R losses for the both proposed HT branch-1 and HT branch-2 are given in Table III and Table IV respectively. For the calculation of I^2R losses; proposed HT branch-1 and HT branch-2 can be simplified as shown in fig. 5 and fig. 6 respectively.

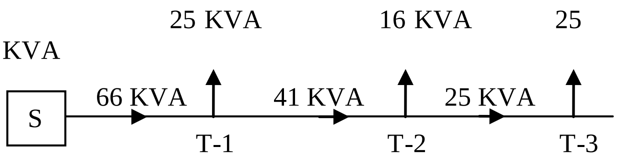

Figure 5: Loads in HT branch-1 of proposed HT-distribution system

Table III. Parameters and Power losses of proposed HT branch-1

S. N.	Trans-former Name	No. of Cons. Avail -ing Load	No. of Poles	Length of HT Line (KM.)	Total Load in HT Line (KVA)	Current (Amp.)	Power Losses (I^2R losses) (Watts)
1	T-1	3	13	0.78	66	4.330	40.713
2	T-2	2	2	0.12	41	2.689	2.415
3	T-3	4	5	0.30	25	1.640	2.246
							Total 45.374

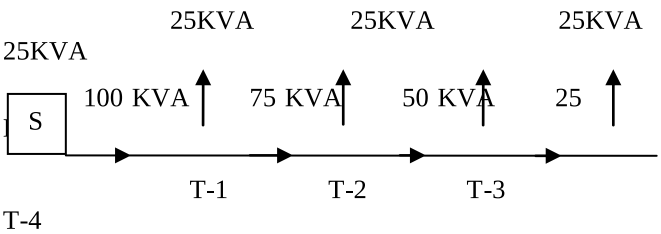

Figure 6: Loads in HT branch-2 of proposed HT-distribution system

Table IV. Parameters and Power losses of proposed HT branch-2

S. N.	Trans-former Name	No. of Cons. Avail-ing Load	No. of Poles	Length of HT Line (KM.)	Total Load in HT Line (KVA)	Current (Amp.)	Power Losses (I^2R losses) (Watts)
1	T-1	4	6	0.36	100	6.560	43.129
2	T-2	5	1	0.06	75	4.920	4.043
3	T-3	4	3	0.18	50	3.280	5.391
4	T-4	5	9	0.54	25	1.640	4.043
							Total 56.606

Total HT- power losses (I^2R losses) are evaluated by summing up the individual power loss of each load in the both HT branch-1 and HT branch-2 of the proposed HT- distribution system. (refer figure 4)

From Table III and Table IV,
Total power losses (I^2R losses) of the proposed HT-distribution system
= [sum of power losses (I^2R losses) in proposed HT branch-1 + sum of power losses (I^2R losses) in proposed HT branch-2]
= [45.374 Watts + 56.606 Watts]
= 101.98 Watts

9.2. Transformer losses in proposed HT-distribution system

Selection of appropriate small rating distribution transformers for this proposed HT- distribution system and the fixed value of no load and full load transformer losses are given in Table V.

Table V.

S. N.	Transformer Rating (KVA)	No-Load Losses (Watts)	Full-Load Losses (Watts)
1.	16	60	275
2.	25	110	720

Total no-load losses for the proposed HT-distribution system
= (Number of DTR's) × (No-load losses)

Total full-load losses for the proposed HT-distribution system
= (Number of DTR's) × (Full-load losses)

Hence, the number of various small rating DTR's (distribution transformers) and the value of no-load losses and full-load losses for the proposed HT-distribution system is given in Table VI.

Table VI. Transformer losses in proposed HT-distribution system

S. N.	Capacity of Required Small Rating Distribution Transformers	No. of DTR's	Total No-Load Losses in Proposed HT-Distribution System (Watts)	Total Full- Load Losses in Proposed HT-Distribution System (Watts)
1.	16	1	60	275
2.	25	6	660	4320
			Total- 720 Watts	**Total- 4595 Watts**

From Table VI,
Total Transformer losses in the proposed HT-distribution system
= [sum of total no load losses + sum of total full load losses]
= [720 Watts + 4595 Watts]
= 5315 Watts

10. Results

The results are obtained including comparison of existing LT -distribution system and proposed HT-distribution system, reduction in losses, annual savings and payback period.

10.1. Comparison of existing LT-distribution system and proposed HT-distribution system

The comparison of existing LT- distribution system and proposed HT- distribution system is given in Table VII.

Table VII.

S. N.	Parameters	Existing LT-Distribution System	Proposed HT-Distribution System
1.	Total Power Losses (I^2R Losses) (Watts)	13,803.492	101.98
2.	Total Transformer Losses (Watts)	3350	5315
3.	Total Power Theft Losses (Watts)	10,160.52	--
		Total-27,314.012 Watts	**Total-5416.98 Watts**

10.2. Reduction in losses

Reduction in losses (Watts)
= [Total losses in existing LT- distribution system
 - Total losses in proposed HT- distribution system]
= [27,314.012 Watts - 5416.98 Watts]
Reduction in losses = 21,897.032 Watts

Since, the total time period of the power supply in agricultural area is 8 hours of 24 hours in 250 days per annum. Therefore,

Reduction in losses per annum in terms of units
= (21,897.032×8×250) ÷ 1000
= 43,794.064 Units

10.3. Annual savings

Annual Savings = Price of a unit × Reduction in losses per annum in terms of units
= Rs. 5 × 43,794.064 Units
= Rs. 2, 18, 970.32

10.4. Capital outlay and Payback period

It is estimated that total cost of the all required materials for this proposed HT- distribution system is Rs. 6, 80, 073.7603 [11].

Payback Period = (Total Capital Outlay / Annual Savings)
= (6, 80, 073.7603 / 2, 18, 970.32)
= 3.105 Years.

11. Conclusion

Finally, it is concluded that the proposed HT-distribution system is the best technique for reducing the I^2R losses and electricity theft losses. It also reduces failure of DTR's, outages and burning of agricultural pump sets etc. By the use of a small rating distribution transformer for three or four consumers, unauthorized load connections has reduced in the proposed HT- distribution system and thus, authorized consumers feel ownership and not allow others to meddle in the LT lines. Hence, HT-distribution system is technically superior to LT-distribution as it also provides better quality of power supply and excellent voltage profile to the consumer's pump sets in agricultural areas. However, initial expenditure of proposed HT- distribution system is high but it can be compensated in short span of time by the way of losses reduction and annual savings.

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