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Optimization of Electrical 3 phase power distribution loss to rural areas in Uttrakhand State

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ABSTRACT

This paper presents the technique of reducing distribution system losses of Kotuli village in Almora district of Uttrakhand state. The field survey was done to know about the condition of feeder and distribution system. The village distribution feeder generally supplies load to household lighting and agricultural loads. Strict observations were done and Recommendation for overall loss reduction techniques that leads to further improvement of overall efficiency of the system. After observation in the village it was found there is uneven distribution system was set up and due to this there distribution line losses were found to be very high and just by changing the distribution transformer position nearer to load center and replace the same with energy efficient transformer there was huge distribution line loss reduction and even the payback for the same is less than 4 years. In doing so the power theft chances will also reduce, as the high voltage line will directly be supplied nearer to load center this is known as the High voltage distribution system(HVDS). As the distribution line losses will reduce the demand for power from the utility will also get reduced thereby reducing the loading on 10MVA ,33/11KV distribution transformer that can share the power to other village loads. In the proposed system there will be two single-phase transformers in place with 3 phase transformer that can also avoid overloading on 1 particular transformer as in future the load will going to increase as the population will increase and due to the new upcoming technology, most of the process will be done by electrical energy.

Key Words: *Energy savings, Electricity consumption, Line losses, Payback.*

1. INTRODUCTION

Kotuli is a village in Hawalbag Block in Almora District of Uttarakhand State, India. It is located 13 KM towards North from District headquarters Almora, 6 KM from Hawalbag and 192 KM from the State capital of Dehradun . Kotuli's local Language is Hindi. Kotuli Village Total population is 120 and number of houses are 25. Female Population is 49.17%. Village literacy rate is 65.4% and the Female Literacy rate is 31.8%. There is no railway station near to Kotuli for more than 10 km. However, Kathgodam Railway Station is major railway station 51 KM near to Kotuli . Almora, Nainital, Haldwani, Ramnagar are the nearby cities to Kotuli.

Table 1.1: Particulars of the Village

Village Name	Kotuli
Nearest City/Town	Hawalbag
Tehsil	Hawalbag
District	Almora
State	Uttarakhand
Gram Panchayat	Kotuli
Climate	Warm and Temperate
Average Annual Temperature	6.6 ^{0}C to 38.1^{0}C
Annual Precipitation Fall	1367 mm
Location Code	052964
Available Area Measured	124.39 hectares
Latitude	29°39’54.75’’ N
Longitude	79◦35’26.6’’ E
Elevation	4396 feet
Total Population	120
Name of Pradhan	Smt. Hema Bisht
Nearest Village	Maini

In a power system every element offers resistance to flow of current. Energy consumed by all these loads termed as technical loss. The resistance of all these elements will leads to overall system voltage drop.
The main problem with distribution systems are Voltage drop, Distribution line losses and Reliability of power supply. Total transmission and distribution losses are about 40-50%. The major part of the loss is taking place only in distribution sector which accounts for 80-90% of total T&D losses. To reduce losses and increase system efficiency a policy has been made[1]. The initiatives of this policy for distribution system aiming at upgradation of system, AT&C loss reduction, electricity theft control and supply to rural areas [2]. The voltage variation maximum limits at customer end as per Indian Electricity rules are +6 to –9% at high voltage and ±6% at low voltage.[3]

2. OBSERVATIONS

A detailed electrical audit has been conducted of 23 houses in the village Kotuli and a systematic distribution of loads (such as fans, LEDs etc.) of each house has been enlisted.

The houses were distributed unevenly with 5 houses at the base of the hill, near the road at an altitude of 4080 feet while the remaining 18 houses were located at the top of the hill at an altitude of 4500 feet.

The daily load consumption of the 18 houses at the top of the house is 7.213 Kilowatt while the daily load consumption of the 5 houses at the bottom of the hill is 6.706 Kilowatt.

A single 3-phase 11KV/ 433 V distribution transformer of 25 KVA is located at an altitude of 4088 feet from which two phases provide supply to the five houses at the bottom of the hill and the other single phase is taken to the top of the hill to provide supply to the remaining 18 houses at the top of the hill.

The 433V conductor on the secondary side is an Aluminum Conductor Steel Reinforced rabbit and the 11KV feeder is Aluminium conductor steel Reinforced racoon of the following specifications:[4]

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Table 2.1 Aluminum Conductor Steel Reinforced rabbit 433 V side

Aluminum Conductor steel Reinforced rabbit conductor 433V side	
Overall diameter	10.05 mm
Total area	61.7 mm^2
Total weight	214 kg/km
Calculated breaking load	18.4 kN
Maximum resistance at 20°C	0.5426 ohm/km

Table 2.2 Aluminium Conductor Steel Reinforced Racoon 11 KV side

Aluminum Conductor Steel Reinforced Racoon 11 KV side	
Overall diameter	12.3mm
Total area	92.4 mm^2
Total weight	320 kg/km
Calculated breaking load	27.2 kN
Maximum resistance at 20°C	0.3623ohm/km

a) The length of the single distribution conductor from the secondary of the transformer to the top of the village is 625m.
b) The 11KV conductor on the primary side of the proposed transformer will also be an Aluminum Conductor Steel Reinforced recoon conductor of the above same specifications.

3. METHODOLOGY

The distribution loss (in terms of kilowatt) has been calculated of the single conductor which is going from the secondary side of the 11KV/433V existing transformer to the top of the hill.

The losses for the other two phases going downhill has not been calculated as the significant energy loss is for the single phase conductor going on top of the hill.

The annual energy loss for the 433 V-conductor has been calculated in terms of cost.

The losses for the 6.5KV feeder on the primary of the single phase transformer are calculated for the proposed location on top the hill.

The annual energy loss for the 6.5KV feeder conductor has been calculated in terms of cost

The total cost of the two single phase transformers including all the other investment costs (such as salvage costs, labor charges, installation costs, etc.) has been calculated.

The difference in the cost savings from before and after the proposed installation has been calculated.

Payback period for the present proposed installation has been calculated.

4. CALCULATIONS:

Existing 3- phase, 25KVA 11KV/433VTransformer Distribution Side Calculations:

I. Existing transformer rating: 25KVA, 11KV/ 433V, 3-phase
II. Kilowatt consumption at the top of the hill (of 18 houses) = 7.213KW (measured)

III. Secondary current along 433V side, having power factor of 0.94 of load 2 of 23 houses having single phase supply.

$I = (7.213/240\times0.94)*1000$------------(1)

$I = 31.97$ A ----------(2)

Since the power factor at load side is 0.94

IV. Resistance of ACSR rabbit conductor per kilometer at 20 degree Celsius = 0.5426 Ω/km

V. Resistance at 35 degree Celsius

$R = \{(273+35/273+20)\times 0.5426\}$ Ω/km--------(3)

$R = 0.5703$ Ω/km ----------(4)

VI. Resistance for the entire length of 625 meters, $R = (0.625\times0.5703)$ Ω---------(5)

$R = 0.3564$ Ω ----------(6)

VII. Total Distribution Loss, TDL= 2 I^2R (Since, only 1phase is going uphill to the village),

$TDL=2\,(31.97)^2\times 0.3564$ watts ------------(7)

TDL= 728.53 watts -----------(8)

TDL= 0.7285 KW -----------(9)

VIII. Annual losses = (0.7285×8760) KWH -------------(10)

= 6381.66 KWH -----------(11)

It is clearly showing from above equations that 6381.66KWH is the line loss from existing transformer to load end , since if we remove this transformer and replaced it with energy efficient single phase transformer with placing it near load center then massive energy will save and since high voltage line will go to load center then chance of electricity theft will also get reduced.

IX. Cost per KWH of energy = 3.5 INR ----------(12)

X. Annual Losses in terms of cost = (6381.66×3.5) INR -----------(13)

= 22335.81 INR -----------(14)

XI. Kilowatt consumption at bottom of the hill (of 5 houses) = 6.706 KW(Measured) ---(15)

XII. For a power factor of 0.87 (since few of the loads of the 5 houses comprised of inductive loads(Washing machine, printers, fridge, etc.), the apparent power required = (6.706/0.87) KVA

= 7.708 KVA ---(16)

XIII. Thus, two single phase transformers of 10 KVA each are proposed, both at the bottom and top of the hill that can step down from 6.5 KV from a 11 KV feeder to 240V.

Since no three phase load is there in the village so its better to placed two single phase transformers at both load end that is one at the uphill and other at downhill that leads to very less or negligible line losses.

Proposed 1-phase, 10 KVA, 6.5 KV/240V Transformer Primary Calculations:

I. Proposed transformer rating: 10 KVA, 6.5KV/240V, 1-phase

II. Primary current along 6.5KV side,

$I = 10/6.5$ A -------(17)

$I = 1.53$ A --------(18)

III. Resistance of ACSR Racoon conductor per kilometer at 20 degree Celsius

= 0.3623 Ω/km -------(19)

IV. Resistance at 35 degree Celsius,

$R = \{(273+35/273+20)\times 0.3623\}$ Ω/km --------(20)

$R = 0.3808$ Ω/km ---------(21)

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V. Resistance for the entire length of 625 meters, R = (0.625×0.3808) Ω -------(22)

R= 0.238 Ω ----------(23)

VI. Total transmission loss,

$TTL = 2I^2R$,

$TTL = 2(1.53^2 \times 0.238)$ watts -------(24)

TTL = 1.11watts --------(25)

VII. Annual losses = $(1.11\times10^{-3}\times 8760)$ KWH --------(26)

= 9.7236 KWH -------(27)

For single phase transformer that is placed at the uphill to fulfill uphill load having primary side current is very less so overall line losses as compared to 11 KV line is very less and chances of electricity theft is negligible.

As electricity theft is the biggest issue in distribution system now a days that is not metered and that leads to overload on the transformer and increase the maximum demand of power system , as the maximum demand will increase the current requirement will increase and for that the size of the conductor will also increase that increases the size of transmission towers and the foundation for these towers must be strong that leads to increase in the overall cost of power system network.

VIII. Cost per KWH of energy = 3.5 INR --------(28)

IX. Annual Losses in terms of cost = (9.7236× 3.5) INR -------(29)

= 34.03 INR -------(30)

5. RESULTS

5.1 Savings Calculations

I. Daily Loss reduction (in KW) from equation (9) & (25)

= (0.7285 - 0.00111) KW ----------(31)

= 0.7273 KW ---------(32)

II. Annual Loss reduction (in KWH) from equation (11) & (27)

= (6381.66-9.7236) KWH ----------(33)

= 6371.93 KWH --------(34)

III. Annual Loss reduction (in INR) from equation (14) & (30)

= (22335.81- 34.03) INR -------(35)

= 22301.78 INR -------(36)

It is clearly mention from above equation there is a saving of 6371.93 KWH , since this will reduce the loading on 10MVA 33/11KV distribution transformer and this saved energy can be supplied to other nearby villages that are connected to this distribution transformer.

a. Existing Transformer losses calculation

a. For uphill

I. No load losses=100W (From R&D plate of transformer) --------(37)

II. Full load loss = 680W (From R&D plate of transformer) ---------(38)

III. Load = 7.213KW ----------(39)

IV. Total loss= $100 + (7.213/25 * 0.94)^2 * 680$ ---------(40)

=164W --------(41)

b. For downhill

I. Load=6.706KW --------(42)

II. No load loss=0KW(Already considered during up hill) (43)

III. Full Load losses = 680W(From R&D plate of transformer) --------(44)

IV. Total loss= $0 + (6.706/25 * 0.94)^2 * 680$ ---------(45)

= 55.37W --------(46)

Total Existing 3 phase 25 KVA 11/0.433KV transformer losses

I. = 164+55.37 (from equation (41) & (46)

= 219.37W --------(47)

=0.2193KW-------(48)

II. Annual losses =0.2193*8760 (Operating hours in a year are 24*365=8760) --(49)

=1921.068KWH ---------(50)

In comparison to 3phase 25 KVA 11/.433KV the losses of single phase 10KVA 6.5/.240KV are very less that are accounting for overall loss reduction of distribution system network.

b. Proposed 2 numbers single phase 10 KVA 6.5/.240KV transformer losses

a. First transformer that is situated uphill

I. No load losses=45W (From manufacturer) ---------(51)

II. Full load losses=300W (From manufacturer) --------(52)

III. Load=7.213KW---------(53)

IV. Total losses= $45 + (7.213/10 * 0.94)^2 * 300$ ------(54)

=221.64W --------(55)

b. Second transformer that is situated downhill

I. No load loss=45W (From manufacturer) ------(56)

II. Full Load Loss=300W (From manufacturer) ------(57)

III. Load=6.706KW ------(58)

IV. Total loss= $45 + (6.706/10 * 0.94)^2 * 300$-------(59)

=197.68W --------(60)

Since the total load of the village is very less so it is sufficient to provide two single phase transformer each having capacity of 10 KVA to fulfill the total load requirement taking in account the future scenario of load demand according to load consumption pattern.

Total losses of proposed two numbers single phase transformers

= 221.64+197.68 (from equation (55) & (60) ----------(61)

=419.32W -------(62)

Total losses annually

= 419.32*8760/1000 8760 (Operating hours in a year are 24*365=8760) ---(65)

=3673.24KWH------- (66)

Total savings

= 6371.93+(1921.068-3673.24) (From equation (34), (50). (66))

=4619.758KWH -------(67)

=527.3W ----------(68)

Cost per KWH=INR 3.5/KWH --------(69)

Total cost of savings in INR

= 3.5*4619.758 ---------(70)

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=16169.1531 INR -------(71)

6. INVESTMENT

a) Transformer and Installation Costs = 38,000 INR(copper winding) including GST costs **(Company: AccurateTransformers Ltd (Haridwar)**

b) Total cost of two transformers = 76,000 INR

c) Salvage value of existing transformer=15000INR

d) Total investment=76000-15000

=61000INR --------(72)

As the investment of two single phase 10 KVA 6.5/.240KV is not very much since the salvage value of existing 3 phase 25KVA 11/.433 KV is also considered to the net investment is not that much and due to this the payback period get reduced.

7. PAYBACK

Payback = (Total investment/Total savings)

= 61000/16169.153 (from equation (71) & (72))

=3.77Year

It is clearly calculated from the data that the payback period after replacing the existing 3 phase 25KVA 11/.433KV transformer with 2 nos single phase 10KVA 6.5/.240 KV transformer and also after changing the position is less than 4 years and that is quite attractive for the utility in saving tremendous amount of energy that leads to reduce the loading on substation distribution transformer.

Table5.1 Summary of loss reduction

Total loss reduction and payback after proposal	
Existing	
Line losses before proposed	728.53W
Annually line losses	6381.66KWH
Total cost in INR for line losses(INR3.5/KWH)	22335.81
Transformer Losses annually	1921.068KWH
Total cost in INR for transformer Losses(INR3.5/KWH)	6723.738
Proposed	
Line losses before proposed	1.11W
Annually line losses	9.7236KWH
Total cost in INR for line losses(INR3.5/KWH)	34.03
Transformer Losses annually(Both the transformers)	3673.24KWH
Total cost in INR for transformer Losses(INR3.5/KWH)	12856.34
Total savings in KWH	4619.758KWH
Total savings in INR	16169.153
Total investment including salvage value of existing transformer in INR	61000
Payback(Years)	3.772615671

8. CONCLUSION

The total active power reduction of 527.3 W for the entire village. The total power reduction of reduction of 4619.758 KWH annually for the entire village. The cost reduction of 16169.153 INR annually for the entire village. It will take 3.77years for the investor to get its investment back. There are opportunities to use the annual savings for other sustainable community development purposes like setting up of a community biogas plant or installing renewable energy driven street lights in the village roads. There is much control on theft of electricity as high voltage distribution system is set up.

9. REFERENCES

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