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Loss Analysis of Conversion from Low Voltage Distribution System to High Voltage Distribution System

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Abstract

This paper presents the analysis of losses for conversion from low voltage distribution system to high voltage distribution system based on simulation of typical power distribution network in agriculture feeder. Conversion from LVDS to HVDS involves removal of existing distribution transformer (100kVA/63kVA) and installation of distribution transformer (25kVA) near to the consumer load and conversion of the existing low voltage (0.433 kV) line into high voltage (11kV) line.

Keywords: High Voltage Distribution System (HVDS), Irrigation Pump (IP), Low Voltage Distribution System (LVDS)

1. Introduction

The T & D losses in Indian power sector was 34% in 2001-02 and has reduced to 21.4% in the year 2016-17 .The terminology of T & D losses has been modified as Aggregate of Technical and Commercial (AT & C) losses to address the losses in power distribution separately. The power distribution is the primary need for a sustainable and progressive economy of a country. Hence the losses in the power distribution of 30% to 20% will carry its impact on the power sector and the economy. In India since 2002 various reform activities have been proposed and implemented as a drive to reduce the losses specifically in the power distribution. Though statistically at national level the losses have been reported as 34% in 2001-02 there were many state utilities reported 60% to 40% which were very high losses and the primary reason were observed in power distribution as compared to transmission and sub transmission. To segregate the transmission and distribution in the power sector unbundling of the state utilities into transmission and distribution companies were made. Further to the unbundling the accountability of loss reduction in distribution companies were focused. Accordingly, the state distribution companies have thrived to reduce the losses from overall 34% in 2001-02 to 21.4% in 2016-17. In the process several projects and schemes have been addressed for system strengthening and to reduce the losses in the power distribution companies. The reduction in technical losses and commercial losses in the secondary distribution had become the focus for the utilities. The technical losses arise due to lack of optimization of the network at planning stage. This has led to the higher losses (I^2R losses) in the 11 kV network, LT network and distribution transformer. To address the higher losses the state distribution companies have adopted High Voltage Distribution System (HVDS) in the secondary power distribution network. In this paper simulation and analysis of the 11 kV network and LT Network has been studied for a typical 11 kV agricultural feeder for conversion from Low Voltage Distribution System (LVDS) to High Voltage Distribution System (HVDS).

2. High Voltage Distribution System

The secondary distribution network in the agricultural feeder is comprises of the 11 kV feeder , the 100 kVA or the 63 kVA distribution transformer and subsequent LT network connecting to the agricultural pump set and domestic consumers. The 11 kV line lengths in an agricultural feeder shall be approximately in the range of

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5 km to 30 km. The corresponding LT network would be in the range of 15 km to 20 km. The LT to HT ratio is in the range of 3 to 5 approximately.

In general, the loads are scattered in the agricultural feeder. Thus there has been a constraint of planning the transformer location and line lengths in the secondary distribution network which has led to longer LT line lengths and lack of optimized loading of distribution transformer leading to high losses.

In order to reduce the losses in secondary network, the location of transformer, its loading and the conversion of the longer LT line to HT line, the HVDS scheme was designed and adopted by utilities.

In HVDS scheme the existing 100 kVA or 63 kVA transformer is removed and the 25 kVA transformers installed near to the agricultural load (IP Set) aiming at resolving the location and loading of the distribution transformer and reducing the longer LT line length. This process could reduce the losses in the secondary distribution network.

These losses can be classified and analyzed primarily into line losses and transformer losses in the process of conversion from LVDS to HVDS.

3. Technical Losses in Power Distribution

3.1 Technical Losses

It is found that technical losses are having the significant contribution to the total losses for a power distribution companies. The technical losses may not be optimal in a system due to overloading or under loading of power components. If it is under loaded the investment cost will be higher and if it is overloaded the losses will be higher. Hence the system has to be planned for optimal loading. Optimal loading is in general not achieved as the prioritized focus is on operation and maintenance as compared to the planning of the network. Load forecasting and simulation tools with proper data and information of the network are some of essentials in arriving at the optimal loading. Technical losses in power distribution network are mainly classified as Line losses & Transformer losses.

3.1.1 Line Losses

Line losses in any distribution system occur due to heat dissipation resulting from the current flowing through the conductor. Losses occur in the conductor is due to the inherent property of the conductor. The major losses occur in conductor depends on the network configuration, characteristic of load and ampere kilometer loading on the feeder. Line losses could be further classified as HT line losses and LT line losses in a distribution network.

Table 1. Details of overhead conductor

Conductor Name	Current Capacity (A)	Total Area (mm2)	Total Weight (kg/km)	Rated Strength (kN)	Resistance at 20 Deg.
Dog	360	118.6	394	32.7	0.2733
Rabbit	240	61.7	214	18.4	0.5426
Weasel	170	36.9	128	11.4	0.9077

The details of overhead conductor used by power distribution companies in general are as below:

3.1.2 Transformer Losses

Transformer losses are classified as No load losses & load losses. No load losses of a transformer is a type of fixed load, it slightly varies with the applied voltage at transformer terminals. Load losses of a transformer are variable losses and it varies according to the load on the transformer.

The details of the transformer parameters used in the power distribution are as below:

Table 2. Details of transformer parameters

Transformer Capacity (kVA)	Resistance (ohm)		% Impedance	No Load Loss (kW)	Full Load Loss (kW)	Full Load at 50% loading (kW)
	HT	LT				
25	134	50	4.4	76	405	101
63	40.6	15.8	4.7	118	820	204
100	22.8	9.1	4.5	167	1159	289

4. Loss Analysis of Conversion From LVDS to HVDS

Simulation of conversion of LVDS to HVDS has been carried out by using Simpow software on typical distribution network for 11 kV agricultural feeders comprising of 100 kVA or 63 kVA in LVDS and 25 kVA in HVDS. Thus three case simulations carried out to analyze the losses Viz., 1. Simulation on 100 kVA distribution transformer associated LT network 2. Simulation on 63 kVA distribution transformer associated LT network and 3. 11 kV feeder comprising of 10 number of 100 kVA and 10 number of 63 kVA for agricultural loads. For all the simulation the following has been considered:

1. Resistance of Rabbit Conductor for HT Line as in Table 1.
2. Resistance of Weasel Conductor for LT Line as in Table 1.
3. 10 HP load for IP set.
4. Typical Transformer losses as in Table 2.

4.1 Conversionfrom LVDS to HVDS (100 kVA Distribution Transformer)

For simulation study, conversion of one 100kVA transformer from LVDS network to HVDS has been considered by providing four numbers of 25kVA transformers to meet the same load of 8 IP sets of 10 HP each. The process of conversion from LVDS to HVDS involves the removal of 100 kVA transformer and providing 25 kVA transformers near to the consumer (IP Set) and by converting the existing LT network to HT network up to the 25 kVA transformer location. The LT to HT conversion involves only the change in cross arm, insulators and associated accessories with the existing poles and conductors.

Network diagrams of LVDS and HVDS network for a 100kVA transformer conversion to 25 kVA are shown in Figure 1 and Figure 2 respectively. The network comprises of weasel conductor and its resistance is as in Table 1.The line lengths of the typical network are as in Table 3 and 4 for LVDS and HVDS respectively.-The simulation results of the load flow for LVDS and HVDS are as in Table 5.The comparison of the results for LVDS and HVDS reflects a technical loss reduction of 24.272 kW.

Table 3. Line lengths of LVDS network

Line		Line length (km)
N0	NP1	0.100
NS1	N1	0.200
N1	IP1	0.200
N1	IP2	0.200
N1	N2	0.300
N2	IP3	0.200
N2	IP4	0.200
N2	N3	0.300
N3	IP5	0.200
N3	IP6	0.200
N3	N4	0.300
N4	IP7	0.200
N4	IP8	0.200

Table 4. Line lengths of HVDS network

Line		Line length (km)
N0	NP1	0.350
NS1	IP1	0.050
NS1	IP2	0.050
NP1	NP2	0.450
NS2	IP3	0.050
NS2	IP4	0.050
NP2	NP3	0.450
NS3	IP5	0.050
NS3	IP6	0.050
NP3	NP4	0.450
NS4	IP7	0.050
NS4	IP8	0.050

Table 5. Summary of load flow results for simulation of LVDS to HVDS (100kva transformer)

Parameter	Unit	LVDS	HVDS
Input Current	A	4.84	3.63
Source	kW	85.155	60.882
Load	kW	59.680	59.680
Line Losses	kW	24.028	0.1813
Transformer No Load Losses	kW	0.167	0.304
Transformer Load Losses	kW	1.2798	0.7178
Total Losses	kW	25.475	1.202
Loss Savings (Conversion of LVDS to HVDS)	kW	24.273	

4.2 Result Analysis

The active power available based on rated capacity of the 100kVA transformer for a power factor of 0.85 shall be 85 kW. The simulation result reflects a source kW as 85.155 kW, which comprises of the 59.68 kW of active power delivered to the 10 numbers of IP Sets and 25.475kW of losses.

I.e. 29.9 % is the loss percentage and 70.1 % is the useful active power to the IP Sets in an LVDS with reference to 85.155 kW of source and 1.97% is the loss percentage and 98% is the useful active power to the IP Sets in an HVDS with reference to 60.88 kW of source. 24.273 kW of losses are saved due to conversion from LVDS to HVDS.

Ultimately the analysis reflects that 24.273 kW is the power savings based on LVDS to HVDS conversion on a 100 kVA transformer which could be delivered as active power to additional consumers.

It is also observed that the transformer losses are not increasing due to four number of 25 kVA considered in the conversion. The load loss for 25 kVA has been considered for 70 % of loading which amounts to a total load loss of 717.80 Watts for four 25 kVA transformers. The Load loss in LVDS is 1279 Watts.

Comparatively the load loss is not increasing due to conversion from LVDS to HVDS for the same load in the network.

The no load losses is increased by 136 Watts for the same load.

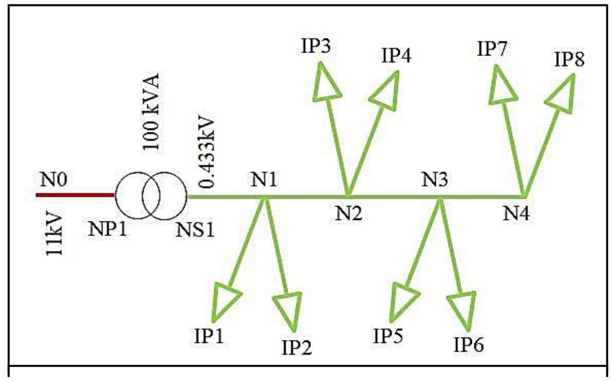

Figure 1. Low voltage distribution system network.

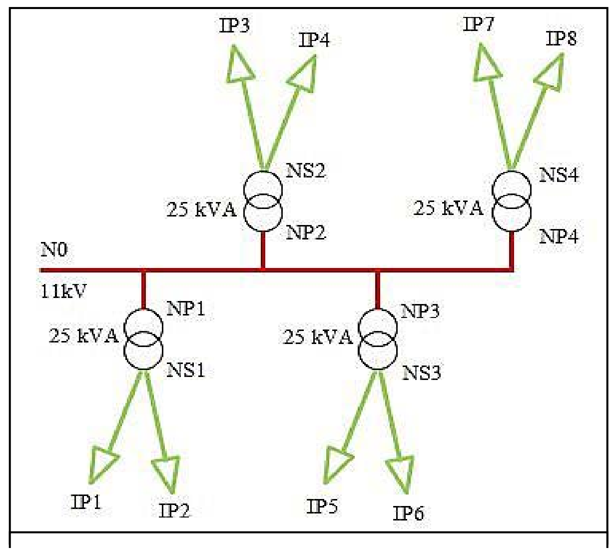

Figure 2. High voltage distribution system network.

4.2.1 Conversion from LVDS to HVDS (63 kVA Distribution Transformer)

For simulation study, conversion of one 63kVA transformer from LVDS network to HVDS has been considered by providing three numbers of 25kVA transformers to meet the same load of 5 IP sets of 10 HP each. The process of conversion from LVDS to HVDS involves the removal of 63 kVA transformer and providing 25 kVA transformers near to the consumer (IP Set) and by converting the existing LT network to HT network up to the 25 kVA transformer location. The LT to HT conversion involves only the change in cross arm, insulators and associated accessories with the existing poles and conductors.

Network diagrams of LVDS and HVDS network for a 63kVA transformer conversion to 25 kVA are shown in Figure 3 and Figure 4 respectively.

The network comprises of weasel conductor and its resistance is as in Table 1. The line lengths of the typical network are as in Table 6 and 7 for LVDS and HVDS respectively.

The simulation results of the load flow for LVDS and HVDS are as in Table 8. The comparison of the results for LVDS and HVDS reflects a technical loss reduction of 5.857 kW.

Table 6. Line lengths of LVDS network

Line		Line length (km)
N0	NP1	0.100
NS1	N1	0.200
N1	IP1	0.200
N1	IP2	0.200
N1	N2	0.300
N2	IP3	0.200
N2	IP4	0.200
N2	IP5	0.300

Table 7. Line Lengths Of HVDs Network

Line		Line length (km)
N0	NP1	0.350
NS1	IP1	0.050
NS1	IP2	0.050
NP1	NP2	0.450
NS2	IP3	0.050
NS2	IP4	0.050
NP2	NP3	0.450
NS3	IP5	0.050

4.2.2 Result Analysis

The active power available based on rated capacity of the 63 kVA transformer for a power factor of 0.85 shall be 53.5 kW. The simulation result reflects a source kW as 43.89 kW, which comprises of the 37.30 kW of active power delivered to the 5 IP Sets and 6.59 kW of losses i.e. 15 % is the loss percentage and 85 % is the useful active power to the IP Sets in an LVDS with reference to 43.89 kW of Source and1.93 % is the loss percentage and 98.06 % is the useful active power to the IP Sets in an HVDS with reference to 38.036 kW of source. 5.857 kW of losses are saved due to conversion of LVDS to HVDS.

Table 8. Summary of load flow results for Simulation of Lvds tO HVDS (63kVA TRANSFORMER)

Parameter	Unit	LVDS	HVDS
Input Current	A	2.55	2.26
Source	kW	43.893	38.036
Load	kW	37.30	37.30
Line Losses	kW	5.90	0.105
Transformer No Load Losses	kW	0.118	0.228
Transformer Load Losses	kW	0.566	0.402
Total Losses	kW	6.593	0.736
Loss Savings (Conversion of LVDS to HVDS)	kW	5.857	

Ultimately the analysis reflects that only 5.857 kW is the Power savings based on LVDS to HVDS conversion on a 63 kVA transformer which could be delivered as active power to additional consumers.

With respect to transformer losses during LVDS to HVDS conversion from 63kVA transformer to 3 numbers of 25kVA transformer after HVDS, the transformer losses (Refer Table 8) is not increasing due to HVDS conversion. Based on 7.46 kW loading for one IP Set the loading for 5 IP Sets shall be 59% for 3 numbers of 25kVA transformers (Refer 38.036 kW in Table 8) for a capacity of 63.75 kW for 63kVA transformer.

The total losses for 3 numbers of 25kVA are 402 Watts (Refer Table 8) and the total losses for one 63kVA transformer in LVDS are 566 Watts (Refer Table 8).

Comparatively the load loss is not increasing due to conversion from LVDS to HVDS for the same load in the network.

But the no load losses is increased by 110 Watts (Refer Table 8) for the same load.

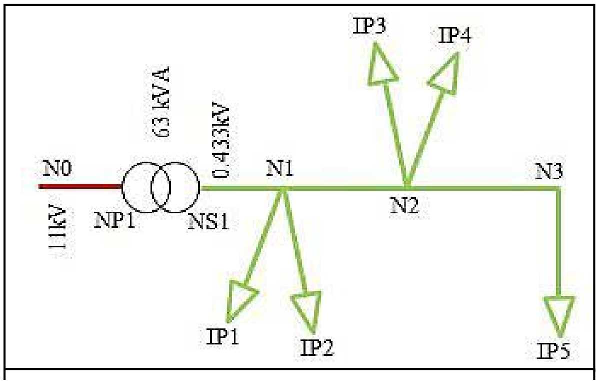

Figure 3. Low voltage distribution system network.

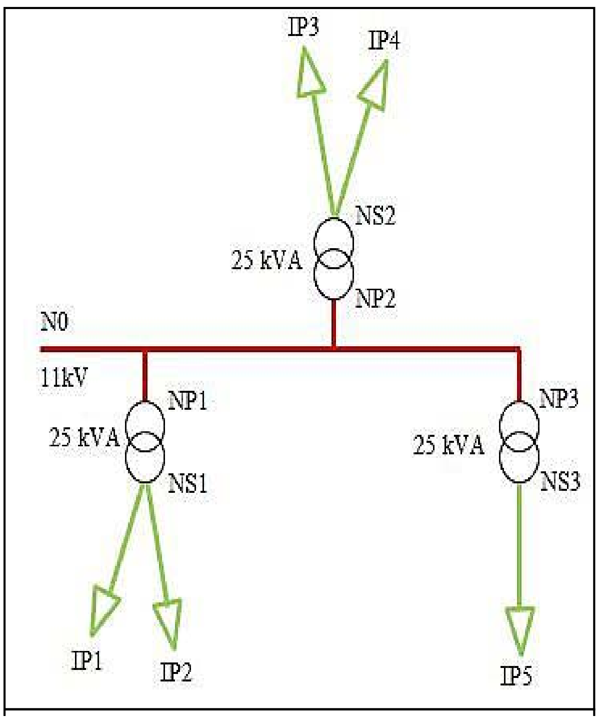

Figure 4. High voltage distribution system network.

4.3 Loss Estimation of Typical 11kV Network (Conversion from LVDS to HVDS)

In order to Analyze the loss savings due to LVDS to HVDS in an 11 kV Feeder, a typical 11 kV network comprising of 10 numbers of 100 kVA transformer and 10number of 63 kVA transformer has been simulated for LVDS and HVDS.

In 11 kV LVDS network a total 130 numbers of IP sets (80 numbers of IP sets due to 100kVA transformer and 50 numbers of IP sets due to 63kVA transformers) have been considered for simulation. The line lengths for each 100 kVA and 63 kVA transformer conversion have been considered as brought out in 100 kVA and 63 kVA transformer conversion, Section 1 and 2 respectively.

Similarly, in 11kV HVDS network also a total 130 numbers of IP sets (80 numbers

of IP sets due to conversion from LVDS to HVDS for 100kVA transformer and 50 numbers of IP sets due to conversion from LVDS to HVDS for 63kVA transformers) have been considered for simulation. Pictorial view of 11 kV feeder is shown in Figure 5.

Table 9. Summary of load flow results for simulation of LVDS to HVDS conversion (11kv feeder)

Parameter	Unit	LVDS	HVDS
Input Current	A	75.30	59.30
Source	kW	1315.21	996.37
Load	kW	969.80	969.80
HT line losses	kW	12.158	7.30
LT line losses	kW	311.29	2.61
Transformer No Load losses	kW	2.86	5.32
Transformer Load losses	kW	19.10	11.34
Total Losses	kW	345.41	26.57

4.3.1 Result Analysis

Based on the loss analysis of 100kVA transformer conversion, it is observed that current on 11kV side has been decreased from 4.84 A to 3.63 A, and for 63kVAtransformer conversion there is a decrease in current from 2.55 A to 2.26 A on 11kV side. Accordingly the input current at the 11 kV feeder end is reduced from75.30 A to 59.30 A and the HT line losses on the feeder have reduced from 12.158 kW to 7.30 kW. Similarly LT line losses have reduced from 311.29 kW to 2.61 kW.

Thus giving rise to a total line loss reduction (HT line losses + LT line losses) of 313.54 kW for a feeder load of 1315.21 kW of LVDS (i.e. 23.2 %).

The transformer No load losses have increased from 2.86 kW to 5.32 kW as there are 70 number of 25 kVA transformers after HVDS as compared to 10 number of 100 kVA transformer and 10 number of 63 kVA transformers in LVDS.

However the transformer load losses have reduced from 19.10 kW to 11.34 kW (Refer Table 9).

The overall loss benefit or savings due to LVDS to HVDS conversion cumulative of Line losses and transformer losses is 318.84 kW for the typical 11 kV feeder network analyzed in this paper for a feeder load of 1315.21 kW in LVDS which is 24.2%.

5. Conclusion

The losses of individual 100 kVA transformer and 63 kVA transformer has been analyzed for a typical LT network comprising of loading 10 HP IP sets within the transformer capacity as an initial stage of analysis for both LVDS and HVDS.

Subsequently a typical 11 kV feeder comprising of 10 numbers of 100 kVA transformer and 10 numbers of 63 kVA transformer has been simulated for both LVDS and HVDS for the same loading condition. The same LT network of individual 100 kVA transformer and 63 kVA transformers have been considered for the 10 numbers of 100 kVA transformer and 10 numbers of 63 kVA transformer for simulation and loss analysis of the typical 11 kV network.

Based on the simulation and Analysis of the 11 kV network for conversion from LVDS to HVDS it is observed that the overall loss reduction is 318.84 kW for a feeder load of 1315.21 kW which is 24% loss reduction.

Though the conversion from LVDS to HVDS is involving more (70 number) number of 25 kVA the overall transformer losses are reduced by 5.3 kW for the 130 number of 10 HP IP Sets considered in the typical 11 kV network. However it is observed that the No load losses are increased by 2.46 kW and Load losses are decreased by 7.76 kW.

Based on the analysis of losses for LVDS to HVDS for a typical 11 kV network for the same loading condition the loss reduction of 24 % can be envisaged for conversion from LVDS to HVDS. The feeder current has reduced from 75.30 A to 59.30 A for the same number of IP sets.

The 100 kVA Transformer conversions are observed to provide more contribution and loss reduction as compared to 63 kVA Transformer conversion. Thus for an 11 kV feeder network the conversion shall be preferred for 100 kVA transformer based on the loading conditions and 63 kVA will not be suitable for a considerable loss reduction.

The conversion from LVDS to HVDS shall also reduce the power theft, as the hooking of power from LT in LVDS could not be made on HT line after HVDS conversion.

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