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Techno-Economic Analysis for Electrical Energy Saving in Distribution Sector through Capacitor Placement and LT Less Distribution System

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ABSTRACT: The electrical power system has three parts generation, transmission and distribution. The distribution system provides link between the transmission system which work on high voltage and the consumers. So, the resistive losses in the distribution sector are high because of low voltage and high current. The distribution companies having enticement to reduce the losses because of the cost difference is there between the real loss and standard losses. If the losses are more than the standard ones, then the distribution companies are economically penalized or if opposite happens then they get profit [1]. So the reducing the losses in the distribution sector is well research topic. In this paper also for saving electrical energy two methods are proposed which are capacitor placement and introducing high voltage distribution scheme. To check the feasibility of proposed work a test area is taken in Rajasthan state, India and the annual saving and payback period of the proposed method are also determined.

KEYWORDS: Distribution Sector, Losses, Electrical energy saving, capacitor placement, LT less system, Loss reduction, Economic analysis, Payback period.

I.INTRODUCTION

The transmission and distribution system provide the essential link between the power generation sources and the ultimate consumption. Hence for the optimize utilization of the generated power efficiently transmission and distribution system are necessary. Since the transmission system expansion is carried out in a planed way based on the detail study of technical aspects, so the losses in the transmission system are less. However the distribution sector is growing in an unplanned manner and the main objective of the utilities is to meet the growing demand of the consumers as soon as possible. Because of this approach the distribution system is become the most inefficient component of the power system [2]. Hence the losses are more so extra investment is needed to fulfil the demand. Since the reducing loss is more economical than increase the generation [3] because saving of one unit of energy is equal to the generation of two unit of energy so the requirement to enhance the efficiency of distribution system to achieve benefits and provide acceptable power quality to the consumer make the climate for the loss minimization. In the literature various methods for the loss minimization in distribution sector are available such as capacitor placement, Network Reconfiguration, Conductor Grading, Load Balancing, DG allocation, High Voltage Distribution System etc. Among these the basic method is capacitor placement.

II. LOSSES IN THE POWER SYSTEM

The losses occurs in the power system can be classified into two types as technical losses and non-technical losses. The technical losses mainly occur due to heat dissipation in the conductor due to current passing, from the magnetic losses in transformers, winding resistive losses and service line. Technical losses can be further classified as fixed losses and variable losses [4]. Fixed losses doesn’t vary with the changes in load current and are mainly caused by the energizing the transformer core, due to leakage current and loss in dielectric material inside the transformer. Variable losses

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depend upon the changes in load current and are proportional to the square of current, hence called I²R losses. Fixed losses are much smaller in magnitude when compared to the variable losses, which form the majority of the technical losses. These losses are inherent and can't be eliminated but can be minimized. The non-technical losses are mainly occurs due to power theft by hooking the lines, unauthorized connections and less efficient billing system. By taking some precautions these losses can be eliminated. In addition to these two losses there is also a revenue loss due to non realization of billed energy and the aggregate of all these losses is known as Aggregated Technical and Commercial losses i.e. AT&C losses.
These losses can be defined as the difference between the energy input to the feeder and the electrical energy sold on the feeder, accounted in the form of billing.

$$\text{AT\&}C\ Losses = Energy\ Input - Energy\ Sold$$

$$\%\ \text{AT\&}C\ Losses = \frac{(\text{Energy Input} - \text{Energy Sold})}{\text{Energy Input}} \times 100$$

To understand the method for minimizing the losses it is necessary to know the various reasons due to which losses are occur in existing system. The reason are

- Lengthy distribution lines
- Inadequate size of the conductor
- Use of overrated distribution transformers
- Distribution transformer located far from the load center
- Low power factor
- Poor HT/LT line ratio
- Direct tapping by non-consumers
- Pilferage of energy by existing consumers
- Defective metering, billing and collection.

III. CAPACITOR PLACEMENT

In the power distribution system network most of the loads are inductive in nature and this leads to poor the power factor of the system. In order to optimal utilization of generated power it is necessary to maintain the power factor close to unity. Power factor of the system can be improved by using capacitive loads in the circuit. The capacitor provides the leading current which can cancel the lagging current demanded by the inductive load, so that the overall power factor of the system get improves hence decrease the losses [5]. The power factor is defined as the ratio of useful power i.e. active power (kW) to the total power or the apparent power (kVA). When the inductive loading cancelled by the capacitive loading then the total power supplied will be utilized. This makes the total capacity of the generator available to serve as the active power [6]. Hence the capacitor connected anywhere in the circuit it will provide relief from the reactive loading but the full advantages in the loss reduction and voltage improvement will not be gain. So the proper placement of the capacitor is necessary in the system to get almost full relief from the reactive loading. The total power loss in the system can be defined as

$$Total\ Power\ Loss = I^2R$$

Since the current (I) is having two components active component (I_a) and the reactive component (I_r) so the total power loss can also be expressed in the form of active component and reactive component.

$$Total\ Power\ Loss = I_a^2R + I_r^2R$$

Since the active power loss component for a given configuration can't be minimize for a radial network with the single source because all the needful active power is supplied by one source only at the root end but the reactive power loss can be minimized by supplying reactive power need locally by using capacitor [7]. The advantages of using capacitor in the network are

- Loss minimization
- Power flow control
- Improvement in stability
- Power factor correction

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- Voltage profile management.

In the late 50's the capacitor were used to place at substation where the feeder was connected. Later placing capacitor along with feeder was found favourable due to availability of pole mounted equipments and closeness to the load but in this, problem of overcompensation is occur generally [8]. So the placement of the capacitor is a optimization problem [9]. In this first find the location for the capacitor placement by determining load curve since the load on the power system is keep on varying with the time and the value of load is also depends on the point of measurement[10], in sequential manner so as to avoid overcompensation at any location and maximize the energy saving and minimizing the capital investment[11,12].
A study has been performed to analyse the effectiveness of conductor grading in minimising distribution losses and for this purpose, a test area has been considered which is the 11 kV Deetyakhedi feeder in the distribution network of Jhalawar circle under Jaipur Vidhyut Vitran Nigam Ltd. in the Rajasthan state, India. The single line diagram of the feeder is shown in fig. 1.

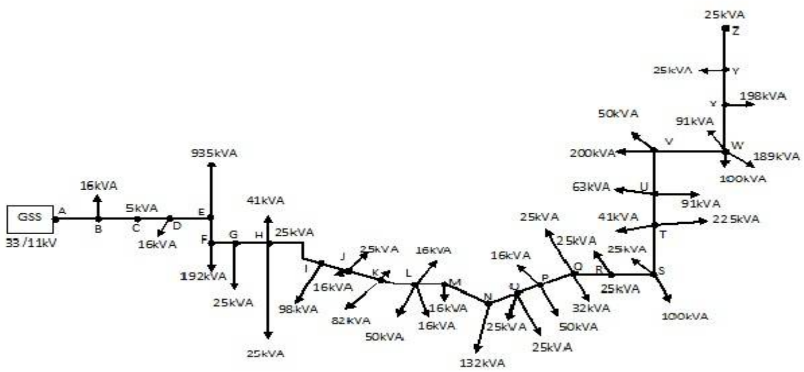

Fig. 1: Single Line Diagram of 11 kV Deetyakhedi Feeder

The Table 1 shows all the details which are required for the analysis purpose about the 11kV Deetyakhedi Feeder starting from the substation up to the consumers.

Table 1: Details of Deetyakhedi feeder

Type of feeder	Rural
Length of feeder	10.5km
Conductor type used in feeder	Weasel
Electrical energy input	670591kWh/month
Electrical energy sold	402354kWh/month
Loss unit	268237kWh/month
Percentage of total losses	40 %
Percentage of technical losses	17 %
Percentage of non-technical losses	23 %
Percentage of transformer losses	4%
Percentage of line losses	13%
Percentage voltage regulation	16.7 %

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In the fig 2 the graph between the electrical energy supplied to the feeder and the electrical energy sold through the billing from the month April to January is shown. This is used for identifying the average losses in the feeder.

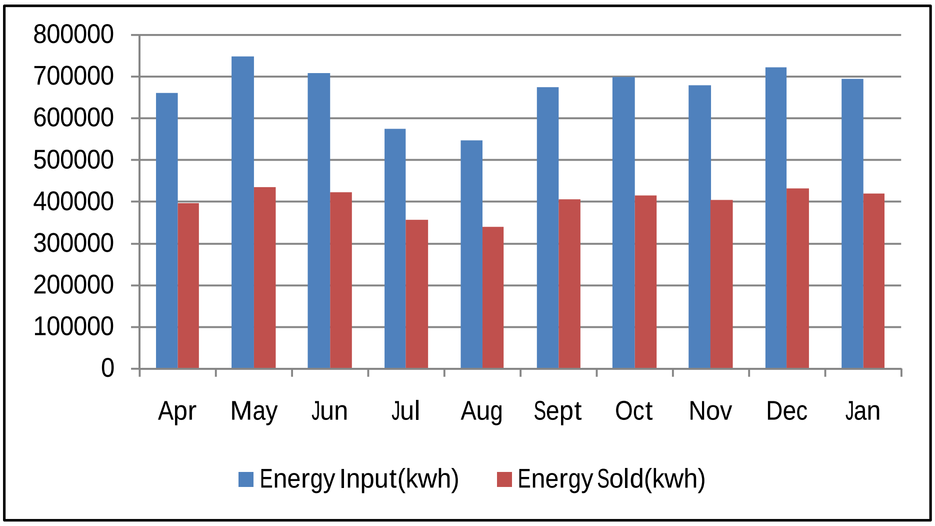

Fig. 2: Graph showing Monthly Energy Input and Energy Sold of 11 kV Deetyakhedi Feeder

After the analysis of the Deetyakhedi Feeder it is observed that the reactive power demand at point E is highest so reactive power compensation is required at this point.
Reactive power Demand at point E = 374 kVAr
As the capacitor bank of such rating are not available in the market so take the approximate values as 400 kVAr.
Losses before Capacitor Placement = 80048 kWh/ month
Losses after Capacitor Placement = 71457 kWh/month
Reduction in Losses due to capacitor placement = 2.5 %
Saving in unit due to reduced losses after Capacitor Placement in per month = 8591 kWh/month

The outcome of the economic analysis performed on the feeder in the case of capacitor placement is as follows.
Total investment on capacitor placement of 400 kVAr = 249734 Rs.
Unit cost of energy sold = 4.07 Rs. per unit (as per JVVNL rates)
Total saving = 34965 Rs. per month
Payback period = 7.14 months

IV. LT LESS DISTRIBUTION SYSTEM

In the existing low voltage distribution system a transformer with large capacity is provided at one point and all the connections are provided through that by using LT lines. Due to this length of the low tension line become more which causes low voltage at buses as going away from the substation and more technical as well as the non-technical losses [13]. So the distribution transformer with loads scattered in nature and unauthorized connections are the main cause of high AT&C losses [14]. Some other drawbacks of low Voltage Distribution System are

- High rating of distribution transformer is required to supply the power
- Voltage profile at load end get reduces
- More resistive losses due to high current
- More chances of theft by unauthorised connections
- Overloading of transformer and conductor due to improper load balancing
- Unauthorized hooking of LT line is difficult to monitor

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To overcome all these disadvantages and to improve the efficiency of the system the best option is replacing existing LT line into 11kV line. This 11kV line is taken near to the load as much as possible and from there LT power is supply through a small rating transformer with minimum length of LT line preferably insulated overhead cables system to improve the power quality and provide better consumer services. By converting LT line into 11 kV line the current flowing through the lines get decreases by 28 times [15] so bring down the technical losses drastically. The length of the LT line in this scheme is restricted to be less than 300m.
Advantages of LT less System are as follows

- Excellent voltage profile
- Negligible transformer failure due to decrease in overloading
- Reduction in losses since 11kV line is taken
- Unauthorized tapping from 11kV line is not possible as LT lines are short and insulated
- In the event of failure of transformer less number of consumers gets affected.
- Since losses get reduce so same power can be supplied to additional loads without any extra investment on the infrastructure or the generation.

The LT less System can be of two types either 1-Ø or 3-Ø LT less system [16]. In 1-Ø LT less system single phase 11kV line is erected near to the consumer as much as possible and step down to lower voltage by single phase transformer. The single phase system is mostly used for the domestic areas. From there the load can be connected through aerial bunched conductor cable to avoid the theft. Similarly in three phases LT less system the 3-Ø distribution transformer are used to feed the three phase or the single phase loads.
For LT less system proposal following ratings of transformer are to be considered for the agricultural consumers

- Up to 7.5 HP – Three phase 10kVA transformer
- 7.5HP to 10HP - Three phase 16kVA transformer
- 10HP to 20HP - Three phase 25kVA transformer

For the analysis of this technique a small village Borda, of the same test area 11kV Deetyakhedi Feeder has been considered. In this village one transformer of 100kVA is used to supply the load requirements of all the consumers. Since the length of LT line is more in this village so the losses especially non technical are very high. For implementing LT less scheme replace this existing 100kVA transformer with the four 5kVA single phase transformer, two 10kVA single phase transformer and three 10kVA three phase transformer according to the consumer. For this conversion some changes will required in the existing low voltage system such as replace the low tension line into high tension line, LT cross arm to 11kv cross arm, LT insulator to 11kV insulator and hardware, the service line bare conductor by the AB cable[17]. Substation structure is to be commissioned to place the transformers according to the load. Each transformer is earthen at three places for provide safety.
The single line diagram of the existing Borda Village in the Deetyakhedi feeder is shown in the fig 3.which is used for the analysis purpose.

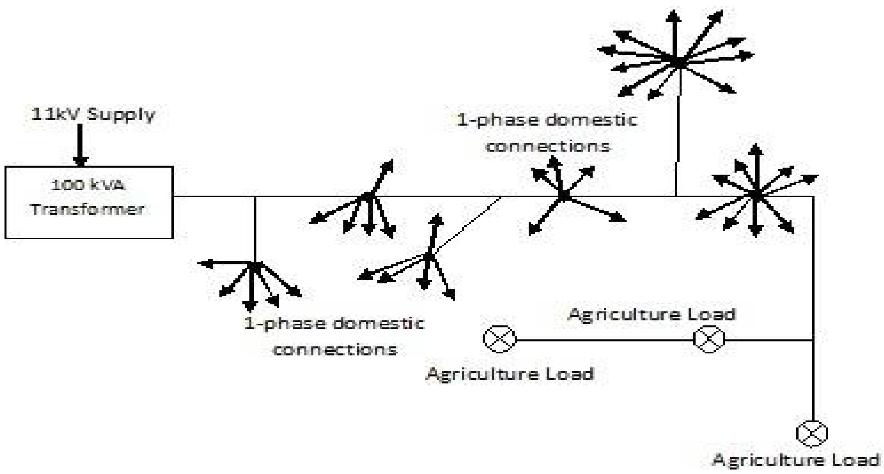

Fig. 3: Single Line Diagram of 11kV Deetyakhedi Feeder before implementing LT Less System Scheme

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Fig 4 shows the Borda village of Deetyakhedi Feeder after the implementation of LT less distribution system scheme where the single 100 kVA transformer is replaced by the number of small rating transformers.

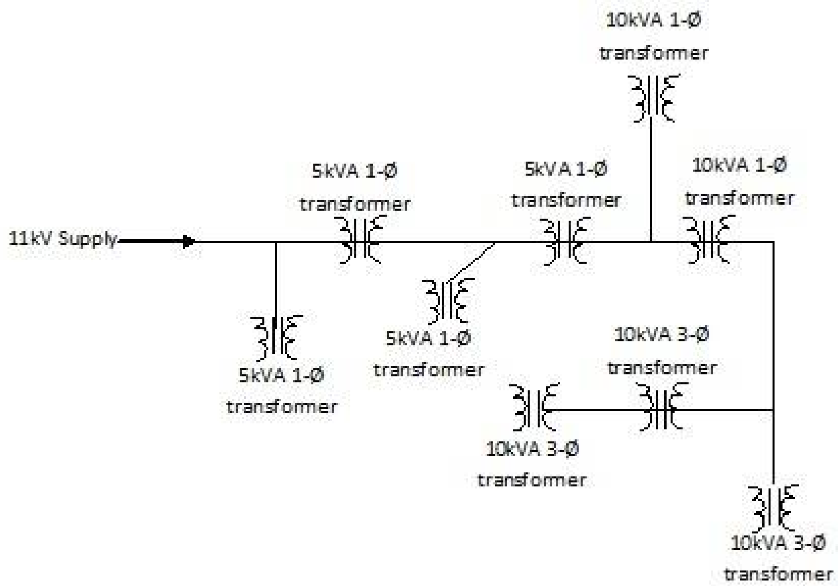

Fig. 4: Single Line Diagram of 11kV Deetyakhedi Feeder after implementing LT Less System Scheme

- Total losses before implementing LT less scheme= 10320kWh/ month
- Total losses after implementing LT less scheme= 4321kWh/month
- % reduction in losses = 58 %

The outcome of the cost benefit analyse is performed in the case of LT Less Scheme is as follows.
Total investment on LT Less Scheme (transformer+ line material) = 445050 Rs.
Cost of retrieved material at 50% of new material = 78481 Rs.
Labour cost at 15 % of material cost = 78530 Rs.
Net investment = 445099 Rs.
Total saving = 24412 Rs. Per month
Payback period = 18.23 months

V. RESULTS

The results for both the techniques i.e. capacitor bank placement and LT less distribution system scheme are discussed here in this section.

a) Capacitor Placement Technique:
The loss percentage in the existing case and after the placement of capacitor is showing in the fig. 5. From the graph it is clear that by placing the capacitor at the point E which is having highest reactive power demand then the percentage reduction in the loss will be approximately 2.5%.

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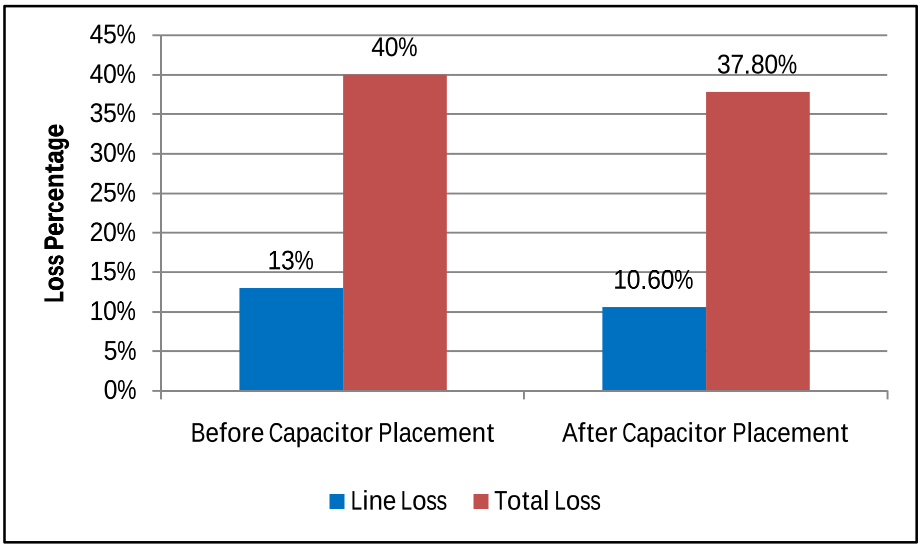

Fig. 5: Percentage of losses before and after capacitor placement

Since the investment cost will be recovered in only 7.14 months, capacitor placement is a viable option for this feeder both from economical and energy saving point of view and by this method some load get reduce and extra 641 kW release which can further be fulfil the demand of some consumers.

b) LT Less Distribution System Scheme:

The graph showing the loss percentage in the existing case and after the implementation of LT less system in fig. 6, from the graph it can be concluded that by using LT less distribution system scheme the reduction in both types of losses i.e. technical losses and the non-technical losses is at good extent which is 58% considering some assumptions.

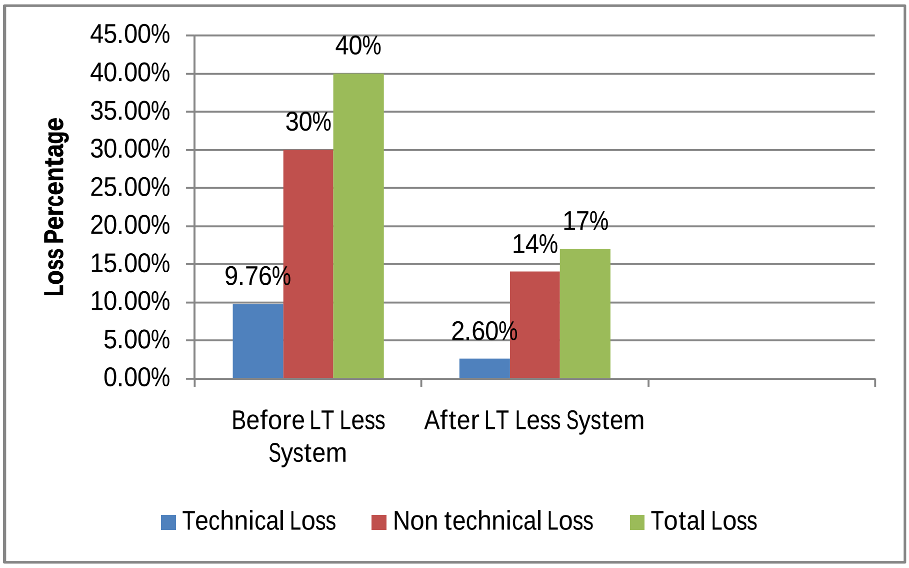

Fig 6: Percentage of losses before and after implementing LT Less Scheme

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The payback period is only around 18.23 months which make the LT less system scheme suitable technique for loss minimization in the distribution system.

VI. CONCLUSION

The distribution system is the final and most crucial link in the chain of electricity supply and unfortunately the weakest one. The distribution system has great significance as this segment has a direct impact on the commercial viability and ultimately to the consumer. In this paper the two techniques i.e. capacitor placement and LT Less System scheme to reduce losses are considered so that the efficiency of the system get improve. For implementing these technique the 11kV Deetyakhedi Feeder is Considered from the Rajasthan, India. Both the techniques were separately employed and the results were examined and the cost benefit analysis was also performed to check the feasibilities of the techniques. From the result it has been concluded that both methods are effective in reducing the losses by good extent. Since the payback period of both methods found to be favourable so both the methods are economically viable options to reduce the losses. Some assumptions are considered while analysing the techniques. Although both the techniques are satisfactory but the LT Less System Scheme would be more suitable for the test area, since it will reduce both technical as well as non-technical losses.

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REFERENCES

[1] Kalambe, Shilpa, and Ganga Agnihotri. "Loss minimization techniques used in distribution network: bibliographical survey." renewable and sustainable energy reviews 29, 2014: 184-200.
[2] Ghosh, Soham. "Loss Reduction and Efficiency Improvement: A Critical Appraisal of Power Distribution Sector in India." International Journal of Modern Engineering Research (IJMER) vol.2 Issue 5, 2012.
[3] Dabre, G. B., A. A. Dutta, and A. N. Kadu. "Performance evaluation of distribution network and reduction in technical & non-technical losses by using energy efficient equipment and cost benefit analysis in the power sector." Power, Automation and Communication (INPAC), 2014 International Conference on. IEEE, 2014.
[4] Bhatti, Shahzad Sarwar, et al. "Electric Power Transmission and Distribution Losses Overview and Minimization in Pakistan." International Journal of Scientific & Engineering Research, vol. 6, Issue 4, April-2015
[5] Su, Ching-Tzong, and Chu-Sheng Lee. "Feeder reconfiguration and capacitor setting for loss reduction of distribution systems." Electric power systems research vol.58, Issue 2, pp.97-102, 2001
[6] Chopade, Pravin, and Marwan Bikdash. "Minimizing cost and power loss by optimal placement of capacitor using ETAP." System Theory (SSST), 2011 IEEE 43rd Southeastern Symposium on. IEEE, 2011.
[7] Vibhute, B. V., H. P. Inamdar, and S. A. Deokar. "Maximum loss reduction by optimal placement of capacitors on a distribution system." Power India Conference, 2006 IEEE. IEEE, 2006.
[8] Bortignon, G. A., and M. E. El-Hawary. "A review of capacitor placement techniques for loss reduction in primary feeders on distribution systems."Electrical and Computer Engineering, 1995. Canadian Conference on. Vol. 2. IEEE, 1995.
[9] Vahid, Marvasti, et al. "Combination of optimal conductor selection and capacitor placement in radial distribution systems for maximum loss reduction." Industrial Technology, 2009. ICIT 2009. IEEE International Conference on. IEEE, 2009.
[10] Salehinia, A. R., et al. "Energy loss reduction in distribution systems using GA-based optimal allocation of fixed and switched capacitors." Energy Conference and Exhibition (EnergyCon), 2010 IEEE International. IEEE, 2010.
[11] Abul'Wafa, Ahmed R. "Optimal capacitor allocation in radial distribution systems for loss reduction: A two stage method." Electric Power Systems Research 95, pp.168-174, 2013.
[12] Swarnkar, Anil, Nikhil Gupta, and K. R. Niazi. "Optimal placement of fixed and switched shunt capacitors for large-scale distribution systems using genetic algorithms." Innovative Smart Grid Technologies Conference Europe (ISGT Europe), 2010 IEEE PES. IEEE, 2010.
[13] Jahnavi, W.V. "Reduction of losses in distribution system using HVDS with real time application." International Journal of Advanced Research in Electrical, Electronics and Instrumentation Engineering, vol.3, Issue 9, September 2014.
[14] Sarwar, Mehedi, et al. "Techno-economic feasibility of HVDS concept for distribution feeder power loss minimization." Power Electronics (IICPE), 2012 IEEE 5th India International Conference on. IEEE, 2012.
[15] Gupta, Ankita, Harmeet Singh Gill, and Isha Bansal. "Effectiveness of High Voltage in Distribution System: High Voltage Distribution System." (2012). IOSR Journal of Electrical and Electronics Engineering, Vol. 1,Issue 5, July-Aug 2012, pp. 34-38.
[16] Solanki, Arjun S., R. K. Pal, and Kulsum Aslam. "Rehabilitation of Electrical Power Losses by Implementing High Voltage Distribution System." International Journal of Engineering Technology, Management and Applied Sciences, vol.3, Issue 1, January 2015.
[17] Amit Dembra, A.K. Sharma. " High voltage distribution system for agricultural feeders in distribution system." International Journal of Engineering Research and Reviews, vol.2, Issue 3,pp 1-8, July-September 2014

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