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COMPREHENSIVE ENERGY LOSS ANALYSIS AND VOLTAGE PROFILE ENHANCEMENT FOR THE REHABILITATION OF 6-10 KV LOW VOLTAGE DISTRIBUTION NETWORKS

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Abstract: Over recent decades, electrical utilities have achieved remarkable advancements in Electrical Power Distribution Systems (EPDS). Nonetheless, energy losses within distribution networks—particularly in 6-10 kV systems—remain a persistent challenge. Modernizing power loss mitigation frameworks is increasingly crucial to ensure the reliable and economical delivery of electrical energy to end-users. Conventional Low Voltage Distribution Networks (LVDN) frequently suffer from substandard performance, causing pronounced voltage fluctuations and severe energy dissipation. This study addresses these critical inefficiencies by proposing targeted energy loss reduction strategies and voltage profile enhancements for 6-10 kV distribution networks. Through the application of advanced rehabilitation techniques, the research demonstrates significant improvements in overall LVDN operational efficiency and service quality.

Keywords: distribution networks, distributed generation, energy losses, financial saving, LVDN, power quality.

Introduction. With the deregulation of distribution companies, energy conserva tion has gained great importance as the conventional sources of bulk power generation are being depleted rapidly worldwide. Substantial amount of energy generated for transmission and distribution is wasted without reaching the end consumers, causing significant revenue loss [1]. The main problem in assigning energy loss in Low Voltage Distri bution Network(LVDN)isthenon-linearityamongtheenergylossesand power supplied by the electric utility [2]. From the previous few years, the electrical utilities have shown numerous progresses in developing their distribution network. On the other hand, during the operation of LVDN many challenges are being faced by the distribution companies. The ecological impacts, the effective utilization of the electrical energy generated and its supervision are the vital disputes [3]. The assessment and identification of high loss sections of the LVDN is a very complicated and difficult task owing to the complex nature of the distribution system [4]. The utilization of DG not only resolves the environmental issues but also helps to reduce the energy loss and voltage drop at the consumers end [5]. In developed countries, distribution engineers are planning to utilize the DC system for LVDN. Mostly, the DC generating units are much more effective for low voltage circuits having a span of not more than 2.4 kM [6]. In addition to that less conductor and insulating material is required for DC system that made the low voltage distribution system much cost effec tive. The energy loss reduction of LVDN is closely associated with the economic activities of the electrical utilities. The performance of the distribution system cannot be increased without improving its parame ters. It requires effective management of electrical load on the distri bution network and

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installation of highly sophisticated equipment for which considerable amount of revenue is needed [7]. In order to manage the electrical load of LVDN, exact field data is an essential prerequisite which is a cumbersome job. A set of variable data is needed for detailed investigation of the LVDN. Energy loss calculation mostly depends upon the segments length, resistance, reactance, voltage, current flowing in each segment, power factor, number of consumers and their load demands and many other factors related to the relevant distribution system. The most common problem encountered by the electrical utilities is the unavailability of the LVDN model [8]. The increasing demand of electrical energy forces the electric utili ties to increase the performance of EPDS. In the competitive environ ment, it has become essential for distribution and planning engineers to look for ways and means to upgrade the distribution networks in terms of improvedperformance.AliArefietal. proposesloss reduction method for performance improvement of distribution network using three pa rameters [7]. A statistical approach was applied for a particular type of feeder under special conditions. The prescribed method may not be applied for loss reduction of LVDN. Losses in EPDS are classified in two main categories: the technical and non-technical. The energy dissipated in electrical appliances and in the conductors of the EPDS comprises the technical losses. Theft of electrical energy, losses in the faulty energy meters, errors in the meter reading and wrong approximation of unmetered electrical energy supply constituted the non-technical losses. Configuration of EPDS, electrical load density and the pattern of energy employed are the main factors of such losses in LVDN [6]. Isha Bansal et al. recommended two stage methodologies for enhancing the voltage profile and controlling the energy theft. In step I, LVDN is to be con verted into a high voltage system and in step II, the yearly profit and payback duration is determined. However, the implementation of pro posed methodology is difficult because of two reasons; firstly, extra conduction insulation is required and secondly the consumer premises connections are challenging task. Mohammad Rasol Jannesar et al. has improved the efficiency of the LVDN by installing photovoltaic cells. The simulation has been executed in MATLAB. The authors claimed to improve the voltage profile, increase the reliability and minimize the energy losses [5]. The detailed analysis shows that implementation of proposed methodology reduces the energy losses but on the other hand creates the problem of power quality. No remedial measure has been taken to eliminate the issue of total harmonic distortion (THD), reverse power flow and voltage swell. Furthermore, the setting of different parameters value in DIGSILENT software is time consuming.

2. Studied system

2.1. Modeling of LVDN Power loss in three phase LVDN can bee numerated by:

$P_L = 3I^2R$ (1)

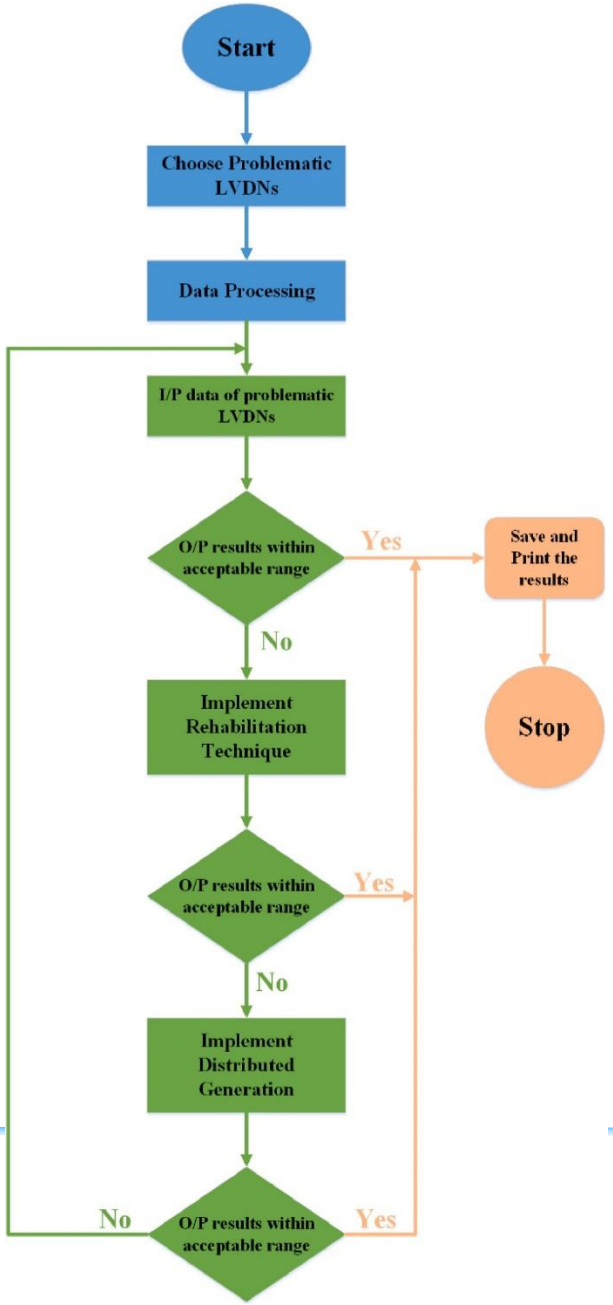
the performance of the distribution system suffers badly. Under such circumstances, the utilization of renewable energy resources considerably improves the efficiency of LVDN. Optimum sizing and location of distributed generation (DG) further enhances the effectiveness of the LVDN. In metropolitan areas, the rapid growth of population, the trade and commercial activities are responsible for snowballing demand of electrical power. In order to cope with the sit-uation, there is an intense need to enhance the power transfer capability of the existing low voltage AC distribution network. To manage the situation, electrical utilities are facing several constraints. The space restraint and financial resources are the most prominent ones. Under such circumstances, the electrical utilities are bound to initiate the prompt action for energy loss reduction and voltage profile enhance-ment of LVDN. The implementation of distributed energy resources (DERs) is another option to

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increase the performance of the LVDN. According to Ref, 13 % of the net energy produced is lost in LVDN. The majority of the existing distribution networks are of a radial nature. The unidirectional flow of the huge current in the laterals causes massive losses and voltage aberrations in the LVDN. In such networks, the increasing consumer's complaints compel the distribution engineers to

look for ways and means to increase the efficiency of LVDN. The most effective and the easiest ways are to refurbish the prevailing distribution system by applying advanced energy loss techniques.

Overloaded and old deteriorated single phase 11000/400V trans-formers are also causing substantial power and energy losses in the LVDN. The awareness among the investors about the energy loss can also play a key role. It will not only inform the shareholders about the occurrence of major events but will also share new ideas for the development of innovative technology. As a result, novel projects may be developed to eliminate energy losses. Most of the schemes are encountered with energy storage, heat recovery, network monitoring and automated control for flattening the load profiles. Intelligent fore-casting for upcoming energy demand and network modeling tools may help to curtail the energy loss in the LVDN. The balance between voltage and power flow is essential to control the energy loss. It can be achieved by distribution system voltage optimization, flexible power link and enhanced voltage assessment. During the field visit, it has been observed that portions of high voltage circuits run in parallel with the lower voltage networks.



improvement and energy loss calculation of LVDNs.

Under such conditions between the two levels of the circuit allows loads to be better balanced. The application of energy storage system may help to manage the energy loss in LVDN. The energy can be stored at the time of low load and dissipate the energy at the time of high load demand and accomplish the load on low voltage and high voltage circuits. More precise appli-cations include peak shaving, load shifting, transmission and distribu-tion support,

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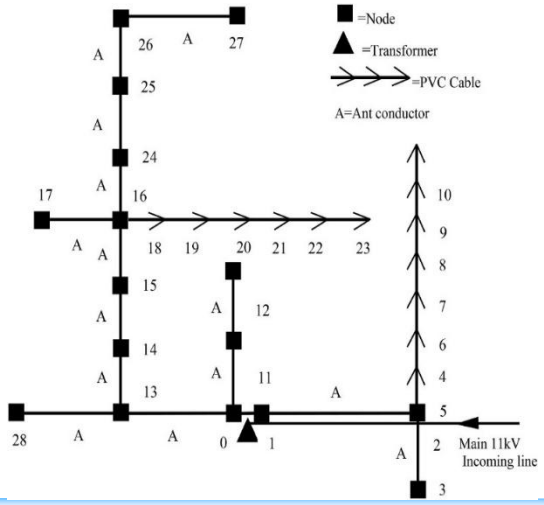
and islanding or emergency backup. The significance of eliminating energy losses in LVDN is escalating, as a result of the in-crease in intermitted distributed generation (DG) and high production prices.

Different consumers have diverse load demand owing to their re-quirements. Some consumers utilize single phase while others need two or three phase supply. Because of such varying load demand of the consumers, the occurrence of imbalance is common in the LVDN. In order to minimize the power loss, balance the accumulated load on each phase of the distribution transformer. Practically it has been observed that consumer consumption is difficult to predict and changes at different intervals of the day. Hence it is difficult to eliminate the imbalance using this method.

Generally, it has been noticed in the LVDN that power factor is less than unity. Under such circumstances, the current must be increased in the circuit in order to deliver the required amount of power that results in the increase in power loss. Therefore, low power factor also causes the substantial amount of power loss in LVDN. Majority of inductive loads causes harmonic in the circuit, causing increase in the I^2R losses in the distribution network.

The losses caused by the activities carried out outside to the electric power system are called non-technical losses. Such types of losses can be monitored by thorough investigations and coordination with concerned department. In Electric Power distribution System (EPDS), there are few loads like auxiliary services of the substation, street lights; traffic lights and roads signs are not metered. Demand for such loads is estimated rather than accurately measured. Such unmetered consumption is excluded from technical or non-technical losses. In order to control such losses, the distribution companies must work alongside consumers with unmetered supplies to improve the accuracy of inventories for precise billing. Detailed analysis of Electric Power System (EPS) delineates that distribution of electricity at LVDN causes most of the losses. The best way to minimize these losses is to identify and quantify these losses and then decide for the actions to be carried out.

Fig. 3. One line diagram of 50kVA transformer installed in the village New Kaliam IESCO, Pakistan.



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Result and discussion of case studies

In the last few decades, the deregulation of the power industry has forced the distribution companies to enhance their efficiencies in order to meet the energy crises. Under such circumstances, it is vital for electrical utilities to increase their financial resources by eliminating energy losses and the voltage drops from LVDN. To achieve the goal, distribution companies have the option to either utilize the conventional methods or implement artificial intelligence (AI) techniques. The application of traditional approaches is easy to implement but it is not cost effective. On the other hand, the adjustment of different parameters of LVDN in AI techniques is very complicated.

In this research work, two LVDNs of village New Kaliam (50kVA T/ F), and Upper Tharjial (100kVA T/F) Mandra Sub-Division, Islamabad electricity supply corporation (IESCO), Pakistan have been selected for detail investigation. The data of concerned LVDNs have been collected by actual field survey in coordination with the relevant staff. The data gathered has been used to develop the single line diagrams of LVDNs. Computer aided distribution planning

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and design (CADPAD) and Energy loss reduction (ELR) software has been used for detail analysis. The simulation results are verified and are within the allowable standard limits.

The purpose of this research work is to enhance the performance of electrical utilities by eliminating energy losses and improving the voltage profiles of LVDNs. Computer aided distribution planning and Design (CADPAD) and energy loss reduction (ELR) software programs are utilized for two actual LVDNs (worse cases) of IESCO Pakistan to eradicate the energy losses and voltage drop. Software is capable of producing database files from the input data. Input data comprises of Consumers reference number, percentage reading of the kWh meter of each consumer and its date of recording, the previous reading with date and the units consumed by individual consumer.

The other parameters of the low voltage circuit include node to node segment length, number of three phase and single-phase consumers, section kVA, cumulative kVA, type of conductor used for each segment, current flowing in each segment, percentage loading on each segment, percentage voltage drop, percentage losses, prevailing power factor and load factor. Various calculations including load flow analysis are carried out by the software applied for existing and proposed conditions of the LVDNs based on data provided as an input. The software has the capa-bility to adjust the circuit parameters as and when required. The soft-ware offers net current flowing in each segment, accumulative kVA load associated at each node of the circuit, percentage loading and voltage drop in different sections of the circuit, yearly energy losses as well as percentage energy losses. The software has the option to detect those sections of the LVDN for conductor replacement which have extreme energy losses and voltage drop and recommends the installation of ca-pacitors at optimum locations with their optimum kVAR ratings.

Conclusion. This research work presents the voltage profile improvement and the energy loss reduction of 6-10 kV low voltage distribution network of 50kVA transformer of village New Kalyam and 100kVA transformer of Upper Tharjial, Mandra Sub-Division IESCO of Pakistan. Elaborative analysis has been carried out with the help of CADPAD and ELR soft-ware. The actual field data of 6-10 kV networks has been collected by field visit in coordination with concerned department. 50kVA transformer of LVDN is situated in the village Mirishkor Sub-Division and is 1.043 km long with 28 nodes. 138 numbers of consumers are
connected with LVDN. After the application of rehabilitation techniques, all the node voltages have been brought within the permissible value as depicted and voltage profile curve of figure-2.

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