Design of Electrification for Housing Society

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I. Abstract

The rapid growth of the Gulshanabad cooperative society has led to an increasing demand for reliable and efficient electricity supply. Currently sourcing electricity from IESCO, the society faces challenges due to inconsistent information regarding the existing infrastructure and increasing population. With plans to develop a new sector (Sector IV), there exists an urgent need for a comprehensive electrification design tailored to the society's evolving needs. In collaboration with ABREEC Consultant Pvt Ltd, multiple site visits were conducted to gather essential data and assess the existing conditions. This project aims to formulate a detailed electrification design for the new sector, incorporating modern technologies and best practices to ensure a sustainable, resilient, and cost-effective electricity distribution system. The report presented herein outlines the findings, recommendations, and proposed a solution to address the electrification requirements of the Gulshanabad cooperative society, paving the way for future development and expansion while meeting the growing energy demands of its residents. The solution includes Load assessment,mounting plan, cost estimation,Load flow analysis via ETAP software, H.T/L.T drawings and implementation of Machine Learning.

II. Introduction

The "Electrification Design of a Housing Society" project focuses on addressing the increasing electricity demands of the Gulshanabad cooperative society, which currently relies on the IESCO connection. As the society's population grows and plans for a new sector (Sector IV) are underway, there is an evident need for a structured and efficient electrification design. The primary objective of this project is to develop a comprehensive electrification design tailored specifically for the new sector, considering the evolving needs and future growth of the society. To achieve this, the project collaborates with ABREEC Consultant Pvt Ltd, conducting multiple site visits to gather essential data, assess the existing infrastructure, and understand the unique challenges faced by the society. Key components of the project include:

- **Data Collection and Assessment:**
  Gathering detailed information about the existing electricity infrastructure, population distribution, and energy consumption patterns within the society.
- **Design Formulation:**
  Developing a customized electrification design for Sector IV, incorporating modern technologies, and adhering to industry standards and best practices.
- **Recommendations and Solutions:**
  Identifying potential challenges, proposing innovative solutions, and recommending suitable options to optimize the electricity distribution system's efficiency, reliability, and sustainability.
- **Report Compilation:**
  Documenting the findings, design proposals, and recommendations in a comprehensive report to guide the society's decision-making process and future electrification projects.

Delved into various systems and techniques in electrical engineering to enhance efficiency and reliability. For instance, conducted load flow analysis of single line diagrams using E-tap, employing modeling, simulating, and bifurcation techniques on these diagrams. The primary goal here is to eliminate power and line losses within the distribution system, thereby enhancing network reliability and resilience. However, this process isn't without challenges, as the computational complexity can be significant, especially for complex networks. Additionally, explored high tension analysis using Energy Loss Reduction (ELR) software, focusing on reconducting and bifurcation techniques. This aims to improve overall efficiency in load flow analysis. While this facilitates seamless integration, it may lack the versatility needed to analyze power systems in different organizational contexts.

Beyond these specific systems, engaged with load forecasting models, cost estimation models, power system simulation tools, and HT/LT drawings. Techniques like load balancing and life-cycle cost analysis are crucial for accurately predicting electricity demand and ensuring budget-friendly electrification systems. Demand-side management and cable sizing further contribute to maintaining steady power flow and precise system layouts. The positive outcomes of these efforts include improved power distribution and compliance with safety standards. However, adapting to sudden changes in consumption and unforeseen cost fluctuations remain challenges, as does the dependency on software for precise planning. Overall, these experiences underscore the intricate balance between achieving technological advancements and navigating the complexities inherent in power systems.

III. Design Challenges and Solutions

- **Scalability:**
  Designing for scalability involves anticipating future growth and ensuring the infrastructure can accommodate increased demand without extensive modifications. This requires a modular approach in the initial design phases, where components such as substations and distribution panels are configured to allow for easy expansion.
- **Load Management:**
  Effective load management is critical in areas experiencing rapid population growth. Techniques such as demand response, load forecasting, and peak load management can be employed to optimize the distribution system's performance and reliability.
- **Case Studies and Applications:**
  Exploring case studies of electrical distribution systems in similar urban settings provides practical insights into successful implementations and common pitfalls. For instance, the deployment of smart grid or other technologies in a neighboring city demonstrated a 30% reduction in energy losses and improved grid stability.
- **Technological Innovations:** The advent of smart grids or other technological innovations has significantly impacted the design and operation of modern electrical distribution systems. Smart grids enable real-time monitoring and control of the grid, which enhances both efficiency and reliability.

IV. Case Specific: Gulshanabad Cooperative Society

A. Load Assessment of Residential Area for Sector IV In this section, we present the load assessment for the residential area in Sector IV. The assessment takes into account various factors such as population density, energy consumption patterns, and infrastructure requirements to ensure the provision of adequate services to the residents.

LOAD ASSESSMENT (Residential) External Electrification of Abad Cooperative Housing Society				
Sr.No	**Size of plot**	**No. of plots**	**WAPDA/IESCO Criteria (kW) per plot**	**Assessed load (kW)**
1	25x60 (6 Marla)	37	5.7	211
2	30x60 (7 Marla)	30	5.7	171
3	35x72 (10 Marla)	1003	6.60	6620
4	42x60 (10 Marla)	110	6.60	726
5	60x90 (1 kanal)	207	10.61	2196
6	25x50 (5 Marla)	302	5	1510
7	50x90 (18 Marla)	44	10.61	467
Total	-	1733	-	11901

Fig. 1. Load Assessment of Residential Area for Sector IV

The table provides a detailed breakdown of the electrical load assessment for different residential plot sizes within a development project, presumably for the Gulshanabad Cooperative Society's expansion in Sector IV. Here's a summary of the key data from the table:

- The table lists seven different sizes of residential plots, ranging from 5 Marla (25x50 feet) to 1 Kanal (60x90 feet).
- The number of plots for each size is specified, totaling 1733 plots.
- The WAPDA/IESCO criteria provide a specified load in kilowatts (kW) per plot, which varies according to the size of the plot. The smallest plot size (5 Marla, 25x50 feet) has a designated load of 5 kW per plot, while the largest (1 Kanal, 60x90 feet) carries a higher load of 10.61 kW per plot.
- The assessed load for each plot size is calculated by multiplying the number of plots by the respective kW per plot, providing specific electrical load figures for each plot category. For example, the largest contribution to the total load comes from the 35x72 feet plots, which, with 1003 plots at 6.60 kW each, contribute 6620 kW.
- The total assessed load for all the plots combined is 11901 kW. This assessment is crucial for planning the electrical infrastructure required to adequately supply power to all the plots in the new sector, ensuring that the electrical demand is met based on the predicted usage patterns.

V. Implementation Plan

Residential Transformer Loading

- **Transformer Capacity:** Each transformer's capacity is listed, with most rated at 200kVA, and one at 100kVA.
- **Plot Size Distribution:** Plots are categorized by size from 5 marla to 1 kanal, and their corresponding kW load per plot size is based on assumed WAPDA/IESCO criteria.
- **Number of Plots per Size:** Each entry details the number of residential plots per size that are serviced by the respective transformer.
- **Total Plots:** The cumulative number of plots serviced by each transformer.
- **Total Load (kW):** This is the sum of the loads from all plots connected to a particular transformer, calculated by multiplying the number of plots by the kW per plot for each category.
- **Ultimate Demand (kW):** This appears to be the expected peak load taking into account factors like diversity and simultaneous maximum usage, which might be lower than the simple sum of individual maximums due to diversity factors.
- **Ultimate Demand (kVA):** Converted from kW using an assumed or standard power factor (not explicitly stated but typically around 0.8 to 0.9 in residential settings).
- **% Loading:** Represents the load on the transformer as a percentage of its rated capacity, important for assessing whether transformers are under-loaded or nearing their capacity, which impacts their efficiency and lifespan.

Commercial Transformer Loading

- **Specific Uses:** Includes transformers serving the commercial plot, mosque, and sports complex.
- **Area Sft:** The area of each facility in square feet.
- **Assessed Load (kW):** The electrical load calculated based on the area and specific usage criteria.
- **Total Load (kW):** Sum of the assessed loads for facilities connected to each transformer.
- **Ultimate Demand (kW and kVA):** Calculated peak demand in kW and the corresponding kVA.
- **% Loading:** Percentage loading for these transformers.

Financial Summary:

- **Sub Total (A):** Rs. 29,338,643, covering all material costs.
- **Sub Total (B):** Rs. 16,900, associated with civil works.
- **Total A+B:** Rs. 35,223,271, combining the costs of materials and civil works, giving a comprehensive total necessary for budgeting and financial planning of the substation setup.

This detailed breakdown helps ensure transparency and effective financial management, providing clear visibility into the costs involved in establishing the substation infrastructure.

VI. Load Flow Analysis in Electrical System Design

Load flow analysis is a fundamental computational technique used to predict how electrical loads and power will be distributed across a network under steady-state conditions. It plays a crucial role in planning and designing electrical distribution systems, especially in growing communities like the Gulshanabad Cooperative Society.

Purpose in Sector IV Development

In the context of developing Sector IV, performing a load flow analysis allows for understanding and anticipation of how electricity will travel through the network. This ensures that all areas receive adequate power without overloading any part of the system. The analysis is conducted using E-tap software, which provides a detailed simulation based on projected loads, generation capacities, and the physical layout of the network.

Significance in Housing Society Electrification Design

Load flow analysis serves several purposes in the design of electrification for a housing society:

1) **Capacity Planning:** It helps determine the capacity requirements for power transformers and conductors to ensure they meet expected demands adequately.
2) **Voltage Stability:** Ensures that voltage levels are maintained within safe and efficient operating limits across the entire network, crucial for safety and reliability.
3) **Optimal Power Flow:** Allows optimization of the network configuration for efficient electricity distribution, minimizing losses and balancing generation and load economically.
4) **Fault Analysis:** By understanding normal operating conditions, potential issues can be predicted and mitigated, improving system reliability and stability.
5) **Future Expansion:** Provides a framework for accommodating future expansions or modifications as the needs of the society evolve.

Essentially, load flow analysis is integral to designing an electrical system that is robust, efficient, and scalable, ensuring that as Sector IV of the Gulshanabad Cooperative Society develops, its electrical infrastructure can support its growth without compromise.

VII. Electrical Transient Analyzer Program(E-TAP)

ETAP (Electrical Transient Analyzer Program) is a comprehensive platform used extensively for the design, simulation, and analysis of electrical power systems across various industries, including power generation, industrial facilities, and critical infrastructure. It enables engineers to model, simulate, and analyze electrical components under different conditions to enhance system efficiency and safety. Key features include a digital twin model for real-time predictive simulations and decision support, extensive network analysis tools like load flow and short circuit analysis, and protective device optimization through its Star Protection Coordination™ system. ETAP also supports the integration of renewable energy sources into the grid, offering advanced solutions for smart grids and microgrids, complete with IoT integration for enhanced operational capabilities. Additionally, its project collaboration tools facilitate multi-user engagement across various project phases, ensuring accuracy and consistency. The software's capabilities in arc flash analysis and cable system management further ensure compliance with safety and industry standards, making ETAP an essential tool for modern electrical engineering and efficient power system management.

Load Flow Analysis Report/Single Line Diagram

Attached in the appendix is the load flow analysis performed using ETAP software for the existing 11KV electrical distribution system in Sector IV. The Bifurcation Method was used in this analysis, a technique used to simplify the complexity of network calculations by dividing the network into manageable sections and analyzing each section independently before integrating the results.

Overview of Load Flow Analysis Report

This report provides detailed metrics such as branch losses, bus voltage levels, and power flows (in MW, Mvar, kW, kvar) across various components of the network, which include transformers (denoted as 'T'), lines (denoted as 'Line'), and lumps (possibly aggregating load points or minor distribution nodes).

Key Elements from the Report:

1) **Transformers and Load Points (Lumps):**
   - Transformers of various capacities (e.g., 100 kVA, 200 kVA) are listed with their respective power flows and losses. For example, Transformer T61 and T62 each show a power flow of about 2.59 kW and 3.88 kvar.
   - Lump points, possibly representing aggregated load areas or specific distribution points, are also noted with similar data detailing power consumption and reactive power.
2) **Bus Voltages:**
   - Different bus voltages are listed at various nodes throughout the network. For instance, Bus33 at 11 kV has a voltage percentage of 95.69%, indicating the voltage level relative to a base or nominal voltage, useful for assessing voltage stability across the network.
3) **Branch ID and Flow Directions:**
   - The data indicates the direction of power flow between buses, specifying losses and efficiency at different segments of the network. For example, significant power flows are noted at major transformers with considerable kW and kvar figures, reflecting substantial energy handling and transformation capabilities.

Application of the Bifurcation Method:

The Bifurcation Method helped in analyzing this complex network by breaking down the flow into sections, each calculated individually for parameters like voltage drops, load distributions, and power losses. This method is particularly useful in large-scale distribution networks to pinpoint areas of inefficiencies and potential upgrades.

Importance of This Analysis for Sector IV:

Given the expanding infrastructure and increasing population in Sector IV, this detailed analysis aids in ensuring that the electrical distribution is both efficient and capable of handling future load increases. It helps in identifying critical points where upgrades may be necessary, ensuring voltage stability, and optimizing the overall network design to prevent overloads and enhance reliability.

This load flow analysis is crucial for strategic planning and operational adjustments in the electrical network of Sector IV. By identifying key parameters and potential bottlenecks, the analysis supports informed decision-making for future developments, maintenance schedules, and resilience improvements in the electrical supply system.

Analysis After Bifurcation

When we performed the "After Bifurcation" analysis, it signified a successful reconfiguration of the electrical network to optimize its performance and efficiency. The load flow analysis post-bifurcation provides a clear picture of the operational improvements and sets a robust foundation for ongoing management and future planning of the sector's electrical infrastructure. This strategic approach ensures that the network remains sustainable, reliable, and capable of supporting the community's needs as it grows.
The single line diagram is attached in the appendix.

Improved Load Management

Each transformer is handling a well-distributed load, which is essential for preventing overload conditions and ensuring each area of Sector IV receives adequate power supply.

Enhanced System Reliability

The bifurcation has enhanced reliability, as shown by stable voltage readings and balanced load across the transformers. This setup reduces the risk of failures and enhances the overall reliability of the power distribution system.

Future Scalability

With the current distribution setup, the network is better positioned to accommodate future expansions or increases in load without significant reconfiguration or upgrades. This scalability is vital for a growing sector like Sector IV.

VIII. Role of H.T. and L.T. Drawings in Electrification

In the context of the electrification project for Sector IV of the Gulshanabad Cooperative Society, the High Tension (H.T.) and Low Tension (L.T.) drawings play a crucial role. These drawings, created using AutoCAD, serve as detailed blueprints for the layout and installation of electrical infrastructure within the housing society. Here's a detailed explanation of these drawings and their purpose for inclusion in a thesis:

H.T. and L.T. Drawings Explained

H.T. Drawings: High Tension (H.T.) drawings detail the layout and placement of high voltage equipment and lines that transmit electricity at high voltages from the power source to the distribution points or substations within the society. These drawings include the location of H.T. poles and any associated high voltage transmission lines. High tension lines are crucial because they transport electricity over long distances with minimal loss of energy.

L.T. Drawings: Low Tension (L.T.) drawings focus on the distribution of electricity at lower voltages suitable for end-user consumption within the housing society. These drawings map out the installation of L.T. poles, pad-mounted transformers, and low tension cables that distribute electricity from local transformers to individual homes and other buildings. Low tension lines are essential for the final delivery of electrical power at safe, usable voltage levels.

Purpose of H.T. and L.T. Drawings in Electrification

1. Systematic Planning and Layout: The H.T. and L.T. drawings provide a systematic and precise layout for the installation of the electrical distribution system. This planned approach helps in ensuring that all areas of the housing society are adequately and safely powered, addressing both current and future energy needs.

2. Efficient Power Distribution: These drawings are designed to optimize the efficiency of power distribution. By carefully planning the routes and connections of both high and low tension lines, the system minimizes energy loss and ensures reliable power supply across different sectors of the community.

3. Safety and Compliance: H.T. and L.T. drawings are critical in ensuring that the electrification of the housing society adheres to national safety standards and local building codes. These drawings help in identifying safe pathways for electrical lines, appropriate placements for transformers and poles, and ensure that the electrical infrastructure does not pose a hazard to residents.

4. Facilitate Construction and Maintenance: With detailed H.T. and L.T. drawings, the construction and subsequent maintenance of electrical infrastructure become more manageable. Contractors have clear guidelines on where and how to install components, which speeds up the construction process and reduces the likelihood of errors. Maintenance teams can also refer to these detailed maps for routine checks and during troubleshooting of electrical issues.

5. Scalability and Upgrades: As the Gulshanabad Cooperative Society grows, the electrical system may require upgrades or expansion. H.T. and L.T. drawings allow planners and engineers to foresee potential expansion challenges and plan accordingly, ensuring that the system can be scaled up efficiently to meet increased demands without extensive overhauls.

In conclusion, H.T. and L.T. drawings are fundamental components of the electrical design and planning process in the development of new sectors like Sector IV of the Gulshanabad Cooperative Society. They ensure that the electrification project is executed efficiently, safely, and in compliance with regulatory standards, providing a reliable power supply to meet the needs of the community. These drawings represent a critical step in the documentation and implementation phases of the electrification project, serving as a blueprint for current installations and future expansions.

IX. Implementation of Machine Learning for Future Energy Prediction in Housing Society Electrification Design

Energy consumption forecasting is critical for efficient energy management, planning, and sustainability efforts. Accurate predictions can help mitigate energy shortages, optimize power generation, and reduce operational costs. Leveraging deep learning techniques, specifically recurrent neural networks (RNNs) and long short-term memory networks (LSTMs), can significantly enhance the accuracy of these forecasts by capturing complex patterns and trends in historical data. This study aims to develop a predictive model to forecast future energy consumption based on historical data from 2020 to 2024, utilizing these advanced machine learning algorithms.

Data Preparation

The dataset comprises historical energy consumption records for the years 2020 to 2024. Key attributes include:

- *Year*: Indicates the specific year within the dataset.
- *Time*: Represents the time of day, potentially divided into hourly intervals.
- *Energy Consumption (in kW)*: Quantifies the energy consumed during each time interval.

The dataset is divided into two subsets: one for training the predictive model and another for testing its performance. This separation ensures that the model can learn from past data while its predictive accuracy is evaluated on unseen data.

Data Visualization

Visualization of the historical energy consumption data reveals underlying trends and patterns over time. Plotting these data points helps in understanding the temporal dynamics of energy usage, which is crucial for effective model training.

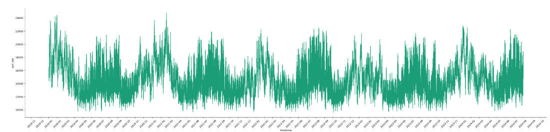

Fig. 2. Data Visualization

Model Training

Deep learning algorithms, particularly RNNs and LSTMs, are employed to train the predictive model. These algorithms are adept at handling sequential data and can learn temporal dependencies from the historical energy consumption records. The training process involves feeding the model with the training dataset, allowing it to learn the relationship between the input attributes (year and time) and the output (energy consumption).

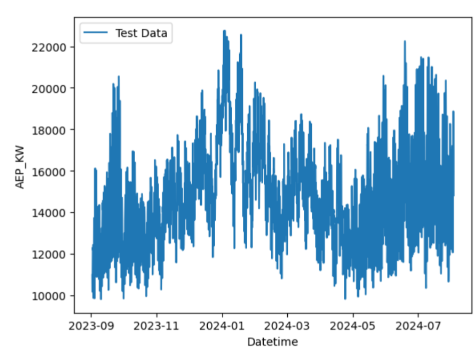

Fig. 3. Model Training

Model Evaluation

The performance of the trained model is evaluated using the testing dataset. Predicted energy consumption values are compared with actual values to assess the model's accuracy. Key metrics such as Mean Absolute Error (MAE) and Root Mean Squared Error (RMSE) are used to quantify the model's predictive performance.

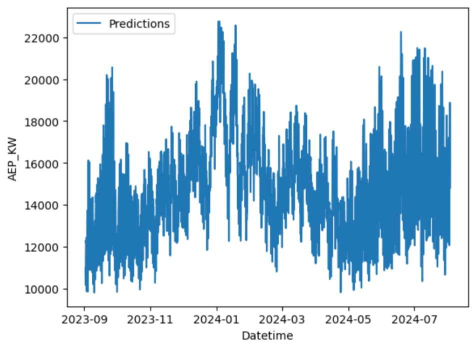

Fig. 4. Model Evaluation

Future Prediction

Upon satisfactory evaluation, the model is used to forecast energy consumption for the years 2025 to 2029. The relevant attributes (year and time) are input into the model to generate predictions for each specified year.

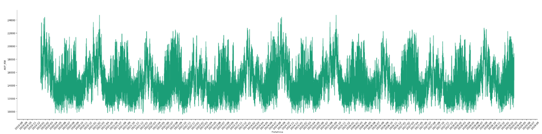

Fig. 5. Future Prediction

Comparison

Predicted energy consumption values for 2025 to 2029 are compared with actual values, if available. This comparison helps determine the accuracy of the predictions and identify any discrepancies, providing insights into the model's reliability and areas for improvement.

By following these steps and utilizing deep learning techniques, a robust predictive model for future energy consumption can be developed. This model not only enhances the accuracy of energy forecasts but also contributes to better energy management and planning strategies.

The integration of machine learning into the electrification design for Gulshanabad Cooperative Society represents a forward-thinking approach to urban energy management. By leveraging historical data and predictive analytics, the project not only meets current needs but also proactively prepares for future challenges. This model exemplifies how traditional engineering and modern data science can combine to create smarter, more sustainable urban environments.

X. Conclusion

The electrification project for Sector IV of the Gulshanabad Cooperative Society exemplifies a meticulous and collaborative approach to addressing the growing community's electrical needs. Partnering with ABREEC Consultant Pvt Ltd, the project began with comprehensive town planning using AutoCAD, seamlessly integrating the electrical infrastructure into the sector's layout. Detailed load assessments for residential and commercial areas ensured the power supply system was adequately designed, while transformer loading calculations optimized power distribution. Utilizing E-tap software for load flow analysis and creating single line diagrams enhanced network efficiency and stability. AutoCAD drawings provided precise installation guidelines, ensuring compliance with safety standards. Additionally, machine learning techniques predicted future energy demands, enabling proactive planning. This systematic approach, from planning to implementation, has not only met Sector IV's current needs but also established a sustainable foundation for future growth, serving as a model for other expanding communities.

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