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Energy Management and Loss Reduction in HT Sides Using ETAP

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ABSTRACT: Effective management of energy is essential to enhance the reliability of the network, reduce losses, and regulate the voltage. This study aims to delve into the modelling and analysis of a High-Tension (HT) network distribution using the ETAP software. This software simulates a power distribution network. This study aims to create a comprehensive single-line model of an institutional power distribution network. This model will include the grid supply, the step-down transformer, the high-tension bus, the feeders, the load, and the devices providing reactive power support. This study will perform a load-flow analysis to scrutinise the pattern of the voltage, the distribution of the load on the feeders, and the losses incurred on the high-tension network. This study will also perform a short-circuit analysis to assess the level of the fault current. This analysis will help to verify the proper functioning of the protective gear provided on the network, such as the circuit breakers. This study will also assess the impact of the shunt capacitor banks on the network to enhance the power factor and reduce the losses incurred on the network. The results of the simulation have shown a significant improvement in the stability of the voltage on the network. The addition of the capacitor banks reduces the currents flowing on the lines and the losses incurred on the network. This study provides a comprehensive framework to enhance the efficiency of the high-tension network distribution.

KEYWORDS: ETAP simulation, energy management, high-tension distribution systems, load flow analysis, reactive power compensation, and power loss reduction.

I INTRODUCTION

The need to efficiently manage energy has increased rapidly with the increasing demand for electric power supply and the extension of electric power distribution networks. The high voltage electric distribution network is an essential part of the electric power supply system that helps to transmit electric power to large institutions, commercial establishments, and industries from the electric supply substations. The inefficient management of reactive power supply and uneven loading of the network can lead to an increased risk of power loss. The effects of such inefficient management not only affect the efficiency of electric energy distribution but also have a significant effect on the performance of the electric power supply system. Therefore, it is now an essential task for today's electric power engineers to efficiently evaluate the performance of the high voltage electric distribution networks and develop an efficient loss reduction strategy. The modern electric power supply system can be efficiently analyzed using an electric power system simulator like ETAP.

The main sources of power losses in a high voltage distribution system are the poor power factor, excessive reactive power requirements, and line resistance. The common solution for these problems is the use of reactive power compensation systems, which are usually achieved with the use of capacitor banks. The use of capacitor banks for reactive power compensation reduces the reactive power drawn from the source, thereby increasing the power factor. This, in turn, minimizes the line current, hence minimizing the losses. However, with the use of modern technology, optimization techniques have been developed to locate the reactive power compensation devices, aside from the use of the traditional capacitor bank technique.

Various methods of increasing energy efficiency and reducing power loss in electrical distribution systems have been explored. To cite an example, a bi-level Volt-VAR optimization framework was proposed by K. Jha et al. (2019) for optimizing reactive power components, including voltage regulators and capacitor banks, in an electrical distribution system. The authors proposed a hybrid approach that incorporates conventional distribution system devices and smart inverter control technology for optimizing voltage regulation in an electrical system. The proposed method was

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validated through a power flow analysis of standard electrical distribution systems of 13-bus and 123-bus topologies. The study established that effective reactive power management of an electrical system through high voltage termination (HT) side optimization can significantly increase energy efficiency, thereby reducing overall system loss.

Despite these developments, many power distribution systems within institutions still function without improved compensation for reactive power or thorough system analysis. Consequently, relatively high levels of energy loss are experienced, and voltage regulation problems may occur under varying load conditions. Hence, a study aimed at researching actual power distribution systems and proposing techniques for energy management based on simulation results is necessary. This paper is focused on using the ETAP software for modelling and analysis of the electrical distribution network within an institutional power system. An in-depth diagram of a power distribution network, as implemented in the ETAP environment, includes utility supplies, transformers, buses, feeders, and loads. In addition, a load-flow analysis is performed for assessing power losses, loading conditions, and voltage levels within the network. Furthermore, a short-circuit analysis is carried out for assessing protection schemes and fault current levels.

Furthermore, the study investigates how reactive power compensation by capacitor banks affects the performance of the HT distribution system. The study compares scenarios that do and do not include capacitor compensation in order to identify improvements in voltage stability, reduction in line currents, and minimization of overall losses. The results obtained from the ETAP simulation offer useful insights for effective energy management in institutional distribution networks. The study results can help planners and electrical engineers optimize the performance of HT power distribution systems.

II METHODOLOGY

The effective control of electrical energy in high-tension distribution networks relies on the accurate modelling of the system and the comprehensive analysis of the system's performance. In this study, the electrical distribution system of an institutional network is modelled and analysed using the power system simulator ETAP. The purpose of the modelling is to investigate the response of the system to normal conditions as well as to fault conditions, including the effects of the compensation of reactive power on the system's voltages and losses.

2.1 System Configuration

The study considers the electrical distribution system, which includes the supplies of the utility grid, the step-down transformers, the high-tension buses, the feeders, the loads, and the devices used to compensate the power. The electricity supply to the distribution network comes from the utility grid at 11 kV. This electricity is stepped down to a suitable level to distribute the institutional loads. This is achieved by a primary transformer. From the transformer, the high-tension bus is the distribution point. This bus supplies power to the various feeders.

The electrical supply is transmitted to a group of feeders that serve different parts of the campus. The feeders are designed to serve different parts of the campus, including academic buildings, administrative buildings, laboratories, etc. The feeders are also provided with safety devices like circuit breakers and isolators to ensure safe operation.

The ETAP model shows that the electrical load is represented as an aggregated static load. The load consists of lighting, air conditioning, laboratory equipment, elevator load, etc.The high-tension bus is also provided with a capacitor bank to supply reactive power to the system. The reactive power is locally supplied to the system to minimize the reactive power demand from the grid supply. The reactive power demand is reduced to minimize system loss, line currents, etc., to improve the power factor.

2.2 Development of the Single-Line Diagram

When using ETAP, you first create a detailed single line diagram (SLD) of your entire electrical system. The SLD is a simplified view of your system that helps you visualize how everything is connected. To begin, you create a utility source that represents your grid input. To this, you add a two-winding transformer that you size to bring your voltage level down into a range that is suitable for your system's distribution. The next step is to create your main node for your power distribution system by creating a central high tension (HT) bus. This bus is then connected to several feeders that distribute your power throughout your system.

The electrical load profile of various buildings and facilities is represented by summing up the static loads. The power rating of each of these loads is given a practical value, along with a suitable value of the power factor under practical conditions. To ensure proper coordination of faults, protective devices are also included in this model, represented by

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air circuit breakers (ACBs). To study the impact of reactive power compensation on system performance, a capacitor bank is also connected to the HT bus.

2.3 Load Flow Analysis

A major approach toward understanding the steady state of an electrical power system is through load flow analysis. In this analysis, ETAP is employed for carrying out load flow analysis, which helps in understanding the voltage levels, power flow, and loss in the system's distribution network. In this analysis, for each component of the system, bus voltage levels, line currents, active power (kW), and reactive power (kVAR) are obtained. The purpose of this analysis is to identify problems that may exist in the system, including voltage drops, overloaded feeders, and loss in the system. This analysis is carried out under two operating conditions: one where no reactive compensation is provided, and another where a shunt capacitor is employed for compensation. By comparing these two sets of data, we can understand how effective the system is when a capacitor is employed for compensation.

The information obtained through load flow analysis is critical in understanding feeder loading, actual power loss in transmission lines and transformers, and voltage levels in different parts of the system, which are important in understanding the reliability of the system's performance.

2.4 Fault Analysis

The analysis of faults helps in complementing the load flow analysis by identifying the behaviour of the electrical power system during abnormal states. There are different kinds of faults that include three-phase faults, line-to-line faults, and line-to-ground faults. These kinds of faults are caused by equipment failures or insulation problems. If not controlled properly, these faults may cause high fault currents that may be harmful to electrical equipment.

In ETAP analysis software, fault analysis is used for identifying the magnitudes of fault currents at different points in the electrical power system. This helps in ensuring that the circuit breakers are capable of clearing the fault current.

2.5 Reactive Power Compensation Strategy

The key to improving the efficiency at which an electric distribution network operates is linked to improvements in how efficiently reactive power is utilized. In this study, reactive power is supplied at the point of need at the high tension bus via a capacitor bank. The capacitor bank improves the overall power factor and reduces the reactive power taken from the utility company's grid.

The study examines the performance of the distribution network in the presence and absence of capacitor compensation. The key performance indicators in this study are voltage profiles and currents in the distribution network. The results show that capacitor banks help in energy efficiency and voltage stability in high tension distribution networks.

The study offers a comprehensive framework for assessing and improving the performance of an electric distribution network by incorporating system modelling, load flow analysis, and fault analysis using ETAP.

III. FUNCTIONS

In the study of an electric power system, load flow study is one of the most important studies carried out. The high tension network's steady-state operating characteristics were determined in this project by carrying out a load flow study using ETAP software. Electrical characteristics such as voltages at each bus, active power supplied (kW), reactive power supplied (kVAR), currents, and power losses in the system are calculated using the load flow study. The characteristics are illustrated in a graphical format in the single-line diagram of the high tension network in the load flow study screenshot, as obtained from the ETAP software. Voltage drops, overloads, and inefficient power supply in the system can be determined by the engineer. It is possible to determine the performance of the system and whether the electric network is performing within acceptable and safe limits by analysing the results obtained.

The comparison of the system performance under different operating conditions, with and without capacitor bank compensation, is done through a load flow solution. The areas where reactive power compensation is required and optimization can reduce power losses and improve voltage stability are emphasized. In conclusion, the load flow solution is critical for efficient energy management, smooth power flow, and reliability of the electrical distribution network.

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IV MATHEMATICAL MODEL

In order to understand the management of energy and the places where power is being wasted in the network, the system is represented by a set of equations. The objective of the proposed model is to reduce power loss, keeping the voltage within appropriate limits, and managing the reactive power in an efficient manner.

The total power loss in the distribution network is given by:

$$\text{Ploss}=\sum_{i=1}^{n} I_i^2 R_i$$

In this equation, $I$is the current passing through the network, R_i is the resistance in the network, and n is the total number of network feeders. This equation indicates that power loss is proportional to the square of the current passing through the network and the resistance in the network.

In the case of HT systems with three phases, the real power transmitted by the system can be calculated by using the following equation:

$$p = \sqrt{3}\, v_L I_L \cos\Phi$$

Poor power factor conditions result in increased reactive power requirements, which cause increased current flows and ultimately result in increased transmission losses.

The reactive power compensation by using capacitor banks is introduced to achieve better power factor correction and reduce power losses. The required capacitor reactive power is given by:

$$Q_c = P\,(tan\,\phi_1 - tan\,\phi_2)$$

In addition, the model should comply with the operating constraints of the system, such as voltage:

$$v_{min} \le v_i \le v_{max}$$

and power balance:

$$P_{gen} = P_{load} - P_{loss}$$

V. EXPERIMENTAL RESULTS

The performance of the high tension (HT) distribution system was analyzed by carrying out load flow and fault studies on the system with the help of the ETAP software. The simulation model of the electrical network was created by including transformers, buses, feeders, loads, and capacitor banks. The results obtained from the load flow and fault studies give a clear idea about the voltage profile, power loss, and stability of the electrical network.

Firstly, load flow study results were obtained without considering the reactive power compensation. The voltage drop in the electrical network was found to be significant across some of the buses, especially the far-end bus of the electrical network. The voltage level of the electrical network was found to deviate from the nominal voltage level, indicating poor voltage regulation. In addition, the current level of the electrical network was found to be high due to low power factor conditions, resulting in high real power loss in the electrical network. The electrical network was found to operate close to the thermal limit of the electrical network.

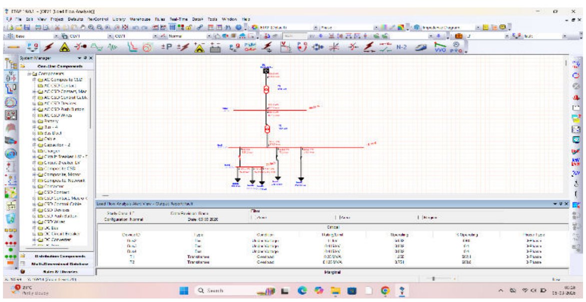

Fig 4.1 Load Sharing network system

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The comparison between the two cases has revealed that the inclusion of capacitor banks reduces the total real power loss, thus improving the efficiency of the system. This has validated the effectiveness of reactive power compensation in the HT distribution system. Apart from this, the results of the fault analysis revealed that the fault current was within permissible limits, thus ensuring the proper operation of the circuit breaker. This has validated the effectiveness of the system in protecting itself from faults.

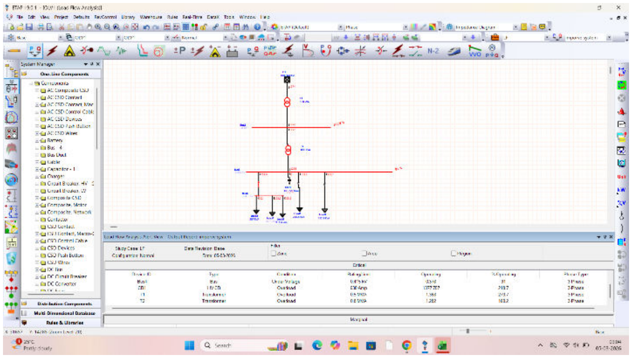

Fig 4.2 Installion capacitor bank

The results obtained from the ETAP software were further supported by the MATLAB simulation tool, which indicated similar trends in the improvement of the voltage level, power factor, and reduction of loss. The similarity between the simulation tools validates the accuracy and reliability of the proposed method.

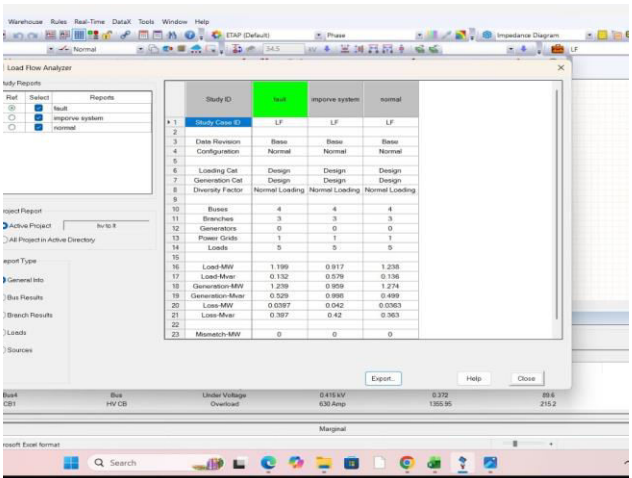

Fig 4.3 Analysis of the power factor

It can be concluded from the results that the energy management system plays an essential role in improving the performance of the HT distribution system with the help of reactive power compensation. The study validates the fact that the addition of the capacitor banks can reduce the power loss in the electrical system.

Parameter	Before Compensation	After Compensation
Reactive Power (kVAR)	800	500
Power Factor	0.85	0.97
Voltage Stability	Poor	Stable
System Efficiency (%)	85 %	95 %

VI. CONCLUSION

Analysis of the HT distribution system by using the ETAP program shows that the addition of the reactive compensation has a major effect on the improvement of the overall performance of the system. The addition of the capacitor banks improves the voltage profile, reduces the current, and minimizes the energy losses in the system. The load flow and fault analysis indicate that the system is operating well within the safe limits

VII. DECLARATIONS

Conflict of interest
The authors declare that they have no conflict of interest to declare in relation to the research, authorship, and publication of this article.

Ethical Approval
This content represents original work done by the author that has not been published elsewhere. It is not under consideration for publication elsewhere. This paper represents a true and accurate account of the author's research.
Human and Animal Rights
The authors at this moment declare that the research in this paper has no subjects.

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