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Analysis of 132/33 KVA Grid Sub-Transmission Line along Gombe to Yola Power System of Nigeria

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Abstract: In Nigeria, effective electric power transmission is a top priority. Power generating and the network of power distribution are connected via electric power transmission. A research project was conducted to determine the status of the networks in order to improve performance, which resulted in the performance evaluation of the 132KV Sub-transmission lines. Data from the Transmission Company of Nigeria (TCN) substations under investigation were utilized in the research work. The Gombe-Yola Sub-region's 132KV networks are divided into two 132KV active networks and 11 33KV active networks, with a total of 443.617MVA in active loads connected to the 33KV buses. The network was modeled and simulated using the Electrical Transient Analyzer Program (ETAP 12.6), and the bus voltages and network power losses were investigated using MATLAB and Simulink. It was discovered during simulation that the bulk of the network's equipment, including transformers, buses, and transmission lines, experience numerous disturbances that result in forced outages and a corresponding loss of load and productivity. All transformers were critically loaded based on the results of the base-case simulation, with several exceeding 100% loading. As bus voltage magnitudes went outside the +/- 5% nominal rated values, the percentage operational bus voltages were below threshold. Additionally, the systems had undesirable power factor levels. Threatening discoveries prompted an effort to strengthen the networks. In this study, three system enhancement algorithms—capacitor placement, transformer upgrade, and transformer load tap modifications—were applied. To get the best outcome, these algorithms were successively stacked. As a result of significant system improvements, both networks' performance in the final simulation result was within allowable bounds. System-wide apparent losses decreased to a 50% reduction enhancing the networks' efficiency in the process.
Keywords: Power System Network, Transmission line, 132/33KVA, Substation, Transformer.

I. INTRODUCTION

The power sector in Nigeria has been facing several challenges, including inadequate power supply, poor infrastructure, and lack of maintenance of existing facilities. Despite the numerous efforts made by the government to improve the situation, there is still a significant gap between the demand for electricity and the supply available. One of the major issues in the power sector is the transmission of electricity from the power generation stations to the distribution networks.

The transmission lines are an essential part of the power system, and any malfunction or failure can lead to power outages, loss of revenue, and damage to electrical equipment. This article, analyze the 132/33 kVA grid sub-transmission line along the Gombe to Yola power system of Nigeria. This power system plays a crucial role in delivering electricity to the region, contributing to the economic and social development of the area.

II. OVERVIEW OF THE GOMBE TO YOLA POWER SYSTEM

The Gombe to Yola power system is an essential part of Nigeria's electricity infrastructure. It encompasses a network of power generation, transmission, and distribution facilities that work together to ensure a reliable supply of electricity to consumers in the region. The 132/33 kV grid sub-transmission line is a critical component of this system, responsible for transmitting power from the generation stations to distribution centers.

The Gombe to Yola Power System is an electricity transmission network in Nigeria that connects the cities of Gombe and Yola. It plays a crucial role in supplying power to the northeastern region of the country, facilitating economic development, and meeting the energy needs of the population.

The power system consists of high-voltage transmission lines and associated infrastructure, including substations and transformers. These components work together to transmit electricity generated from various sources, such as power plants and renewable energy installations, to the consumers in Gombe and Yola.

The transmission lines are designed to carry electricity at high voltages, typically in the range of 132 kilovolts (kV) to 330 kV, to minimize power losses during transmission. These lines are supported by towers or poles and are strategically routed to ensure efficient and reliable power delivery.

Along the Gombe to Yola power system route, there may be intermediate substations that serve as connection points for transferring power between different transmission lines or adjusting voltage levels. These substations play a vital role in regulating and controlling the flow of electricity, ensuring its safe and reliable transmission.

The Gombe to Yola Power System contributes to the overall stability and reliability of the regional power grid. It enables the transfer of surplus power from areas with excess generation capacity to areas with high electricity demand. This helps in balancing the power supply and demand, reducing the likelihood of blackouts or voltage fluctuations.

The power system also supports the integration of renewable energy sources, such as solar and wind, into the grid. As Nigeria strives to diversify its energy mix and reduce dependence on fossil fuels, the Gombe to Yola Power System can accommodate the transmission of renewable energy-generated electricity, promoting sustainable and environmentally friendly power generation.

Efforts are continually made to improve the capacity, efficiency, and reliability of the Gombe to Yola Power System. Upgrades to the transmission infrastructure, such as the installation of advanced monitoring and control systems, are implemented to enhance grid performance, reduce downtime, and enable quicker response to faults or disruptions.

Overall, the Gombe to Yola Power System plays a vital role in ensuring the availability of electricity in the northeastern region of Nigeria. It serves as a backbone for power transmission, supporting economic growth, and improving the quality of life for the residents of Gombe and Yola.

III. IMPORTANCE OF THE 132/33 KV GRID SUB-TRANSMISSION LINE

The 132/33 kV grid sub-transmission line serves as a crucial link in the electricity supply chain. It facilitates the transfer of power from the generation stations, which produce electricity, to the distribution centers, which then deliver it to end consumers. This transmission line plays a vital role in ensuring efficient and reliable power transmission throughout the Gombe to Yola power system.

The 132/33 kV grid sub-transmission line holds significant importance in the power distribution network. It acts as a crucial link between the high-voltage transmission system and the distribution system, facilitating the efficient and reliable supply of electricity to consumers.

Voltage Transformation: The sub-transmission line plays a vital role in transforming the high-voltage electricity received from the transmission system (usually at 132 kV) into a lower voltage level suitable for distribution (commonly at 33 kV). This voltage transformation helps in reducing power losses during transmission and ensures that electricity is delivered to the distribution network at an optimal voltage level.

Power Distribution: The 132/33 kV sub-transmission line distributes electrical power from bulk supply points, such as power plants or primary substations, to various distribution substations. These distribution substations, in turn, further distribute electricity to residential, commercial, and industrial consumers. By efficiently transferring power from the transmission system to the distribution network, the sub-transmission line enables the widespread availability of electricity.

Load Balancing: The sub-transmission line allows for load balancing within the distribution system. It enables the transfer of power between different distribution substations to ensure an equitable distribution of electricity based on the varying demand from different areas. Load balancing helps in preventing overloading of specific substations, reducing the risk of equipment failures, and enhancing the overall stability of the distribution network.

System Reliability: The 132/33 kV sub-transmission line enhances the reliability of the power supply by providing alternative routes for electricity flow. In the event of a fault or maintenance work on a specific section of the line, the power can be rerouted through alternate paths, minimizing disruptions to consumers. This redundancy in the sub-transmission system helps in maintaining a reliable supply of electricity and reducing downtime.

Network Expansion: The sub-transmission line supports the expansion and growth of the distribution network. As new areas are developed or existing areas experience increased electricity demand, the sub-transmission line can be extended to connect new substations or feeders, enabling the provision of power to expanding communities and industries. This flexibility in network expansion ensures that electricity infrastructure keeps pace with the evolving needs of consumers.

In summary, the 132/33 kV grid sub-transmission line serves as a vital link between the high-voltage transmission system and the distribution system. It enables voltage transformation, efficient power distribution, load balancing, system reliability, and network expansion.

These factors collectively contribute to the overall effectiveness and reliability of the electricity supply, ensuring that consumers receive a consistent and uninterrupted power supply.

IV. DESIGN AND CONFIGURATION OF THE 132/33 KV GRID SUB-TRANSMISSION LINE

A. Load Analysis

Determine the load requirements for the sub-transmission line, including the expected power demand, peak loads, and load growth projections. This analysis helps determine the capacity and configuration of the sub-transmission line. To perform a load analysis of a 132/33 kV grid sub-transmission line, you would typically follow these steps:

1) *Gather data:* Collect information about the electrical load connected to the sub-transmission line. This includes data such as the types of loads (residential, commercial, industrial), their power ratings, operating schedules, and any anticipated future load growth.
2) *Load estimation:* Determine the total load demand connected to the sub-transmission line. This can be done by summing up the individual load demands or using statistical methods based on historical data.
3) *Load diversity:* Consider the diversity factor to account for the fact that not all loads are operating simultaneously at their peak. The diversity factor helps to reduce the total load demand estimation. Different types of loads have different diversity factors, and these can be obtained from electrical engineering handbooks or standards.

Diversity factor is defined as the ratio of the sum of the maximum demands of the various part of a system to the coincident maximum demand of the whole system. The maximum demands of the individual consumers of a group do not occur simultaneously. Thus, there is diversity in the occurrence of the load. Due to this diverse nature of the load, full load power supply to all the consumers at the same time is not required.

$$Diversity\ factor = \frac{(sum\ of\ individual\ maximum\ demands)}{(coincident\ maximum\ demand\ of\ the\ whole\ system)}$$

Mathematically, diversity factor is expressed as:

$$F_D = \frac{D_1 + D_2 \ldots\ldots\ldots\ldots\ldots + D_n}{D_g}$$

or

$$F_D = \frac{\sum_{i=1}^{n} D_i}{D_g}$$

Where,

F_D = Diversity factor

D_i = Maximum demand of the load I, irrespective of the time of occurrence.

D_g = D(1+2+3…….n) – maximum coincident demands of a group of n load.

Diversity factors can be defined for loads, substations, feeders, and generating stations. Usually, the maximum demands of the consumers do not occur at the same time. The diversity factor can be equal or greater than 1.

If the value of the diversity factor is greater than 1, then it is a good diversity factor, and 1.0 represents a poor diversity factor. A high diversity factor has the effect of reducing the maximum demand. It is obtained by using electrical energy at night load or light load periods.

4) *Load forecasting:* If future load growth is anticipated, perform load forecasting to estimate the expected load demand in the future. This can be based on factors such as population growth, economic development, and industrial expansion in the area.

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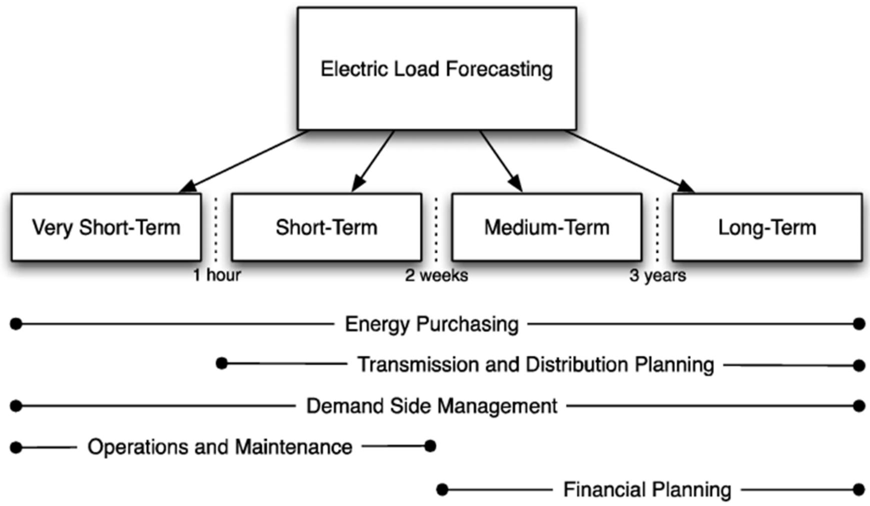
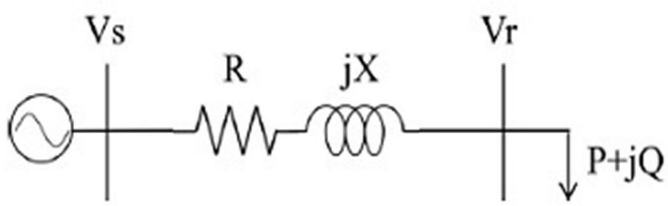


Fig. 1: Load Forecasting Application and Planning

Voltage drop analysis: Conduct a voltage drop analysis to determine the voltage profile along the sub-transmission line. This analysis ensures that the voltage levels are within acceptable limits at various points along the line, considering the load demand and the line's characteristics (resistance, reactance, length).



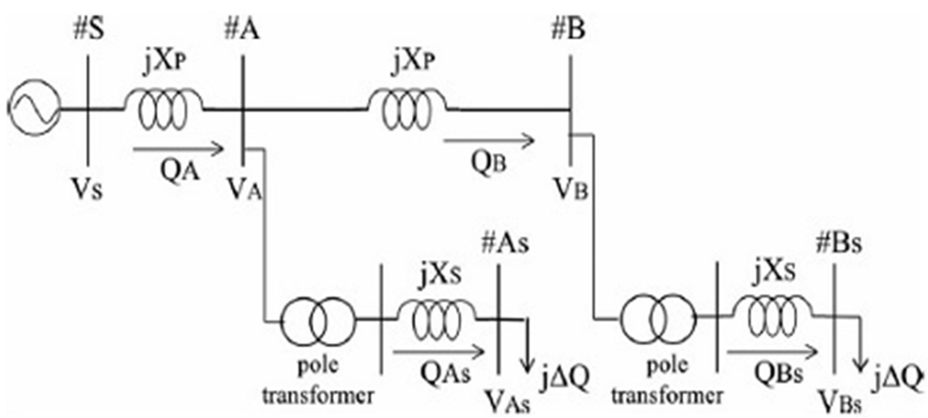


Fig.21: Voltage Drop Study and Analysis

5) *Transmission Line losses:* Calculate the losses in the sub-transmission line based on the load demand, line parameters, and operating conditions. This helps to assess the efficiency of the line and plan for any necessary compensation or mitigation measures.

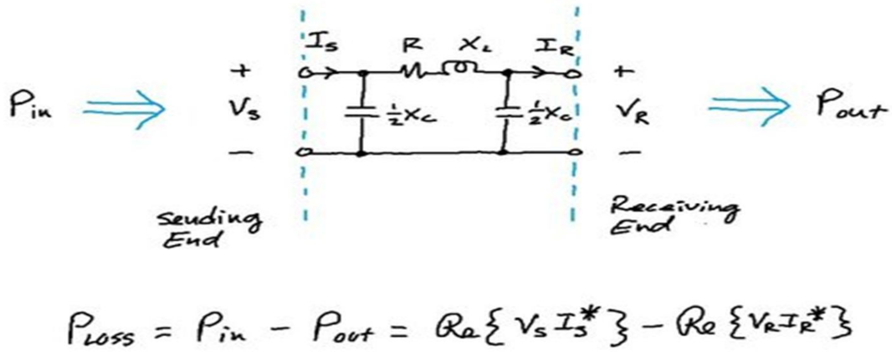


Fig.3: Transmission Line loses Analysis Equation

It's important to note that load analysis for a specific sub-transmission line requires detailed information about the line parameters, load characteristics, and the specific requirements and standards applicable to the grid in question. The above steps provide a general outline of the process involved in a load analysis, but the actual analysis may vary depending on the specific circumstances and available data.

Table 1: Sub-Transmission Network of Gombe –Yola Substation

S/N	Transmission Substation	Load (MW)	Transformer Size (MVA)
1.	Gombe	36	60
2.	Yola	41	60

Table 2: Substation With in Gombe –Yola Network

Sub-regions /Work Centers	330/132kV Substations	*Number of* Transformer	132/33kV Substations	*Number of* Substations
Gombe Sub-region	Gombe 330/132kV T/S	*1*	Gombe132/33kV S/S	*4*
			Potiskum 132/33kV S/S	
			Biu 132/33kV S/S	
			Makeri 132/33kV S/S	
			Pankshin 132/33kV S/S	
			Kafanchan 132/33kV S/S	
Yola Works Centre	Yola 330/132kV T/S	*1*	Yola 132/33kV S/S	*4*
			Savannah 132/33kV S/S	
			Mayo Belwa 132/33 kV S/S	
			Jalingo 132/33kV S/S	
			Damboa 132/33kV S/S	

V. FACTORS AFFECTING THE PERFORMANCE OF THE 132/33 KV GRID SUB-TRANSMISSION LINE

Several factors can affect the performance of a 132/33 kV grid sub-transmission line. Here are some key factors to consider:

1) *Line Length:* The length of the sub-transmission line plays a crucial role in its performance. Longer lines tend to have higher resistance, resulting in greater power losses and voltage drops. It is important to minimize line length where possible or use appropriate conductors to mitigate these losses. The distance between Gombe and Yola is about 240Kilometers, Though appropriate conductors were used, but they old enough to be replaced.
2) *Line Configuration:* The configuration of the sub-transmission line, such as the choice of conductors and the arrangement of phases, can impact its performance. Proper selection of conductors based on their electrical and thermal characteristics is crucial to minimize losses and ensure efficient power transfer.

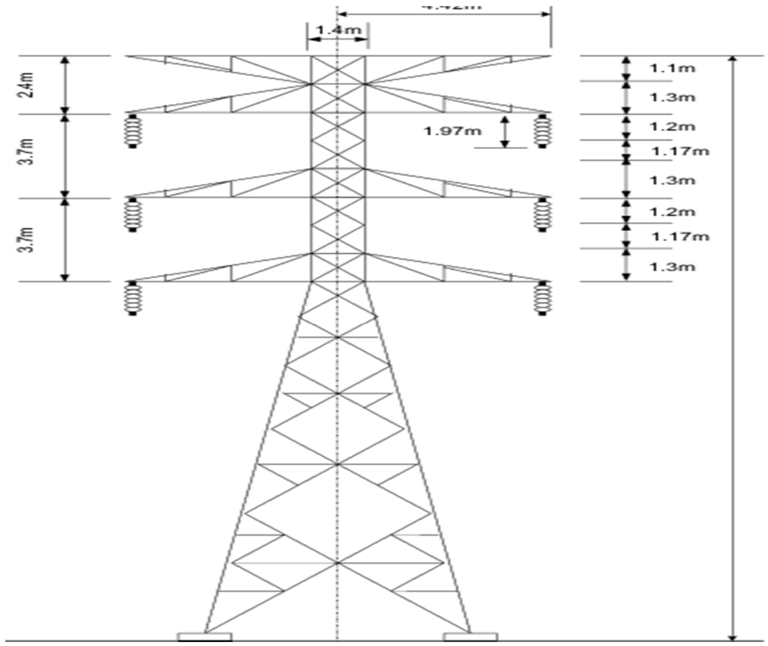
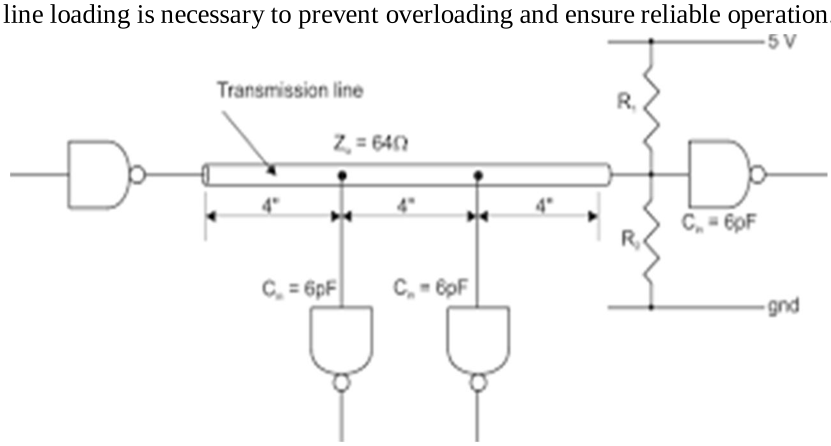


Fig. 4: 132KV Transmission Line Configurations

3) *Transmission Line Loading:* The amount of power carried by the sub-transmission line, referred to as line loading, affects its performance. Operating the line above its thermal limits can lead to increased losses, conductor sag, and potential overheating. Regular monitoring of line loading is necessary to prevent overloading and ensure reliable operation.



Transmission Line Loading

4) *Transmission Voltage Regulation:* Maintaining stable voltage levels along the sub-transmission line is essential. Voltage drops can occur due to line resistance and reactive power flow. Proper voltage regulation equipment, such as tap changers and voltage regulators, should be employed to ensure voltage stability and minimize power quality issues.

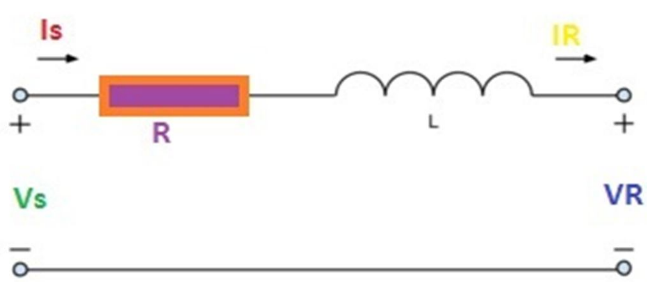


Fig. 5: Transmission Voltage Regulation

5) *Environmental Factors:* Environmental conditions can impact the performance of the sub-transmission line. Factors such as temperature, humidity, wind, and ice loading can affect conductor performance and clearance requirements. Adequate design considerations and maintenance practices should be implemented to withstand these environmental conditions. The physical presence of transmission lines can have an effect on wildlife. These potential effects include long-term changes to habitat, bird strikes, access issues, noise effects and associated avoidance behavior, and electric and magnetic fields.
6) *Transmission line Faults and Protection:* Faults, such as short circuits or line disturbances, can occur on the sub-transmission line. Proper protection schemes, such as relays and circuit breakers, are necessary to detect and isolate faults swiftly. Efficient fault clearance minimizes downtime and reduces the impact on system reliability.

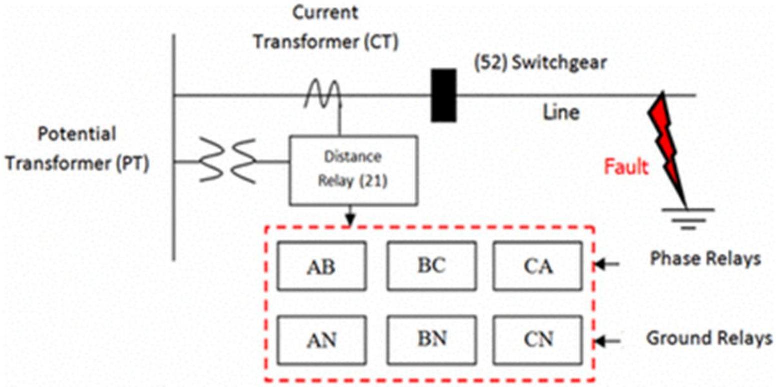


Fig. 6: Transmission line Faults and Protection

7) *Transmission line Maintenance and Inspection:* Regular maintenance and inspection of the sub-transmission line are vital to ensure optimal performance. This includes routine checks for loose connections, damaged insulators, vegetation encroachment, and other issues that can affect the line's reliability and efficiency.
8) *Transmission line System Planning and Expansion:* Effective system planning and expansion strategies are crucial for accommodating future load growth and ensuring the sub-transmission line's performance. Adequate capacity and redundancy should be considered to handle increasing demands and maintain system reliability.Transmission expansion planning (TEP) is a complex decision making process that requires comprehensive analysis to determine the time, location, and number of electric power transmission facilities that are needed in the future power grid.

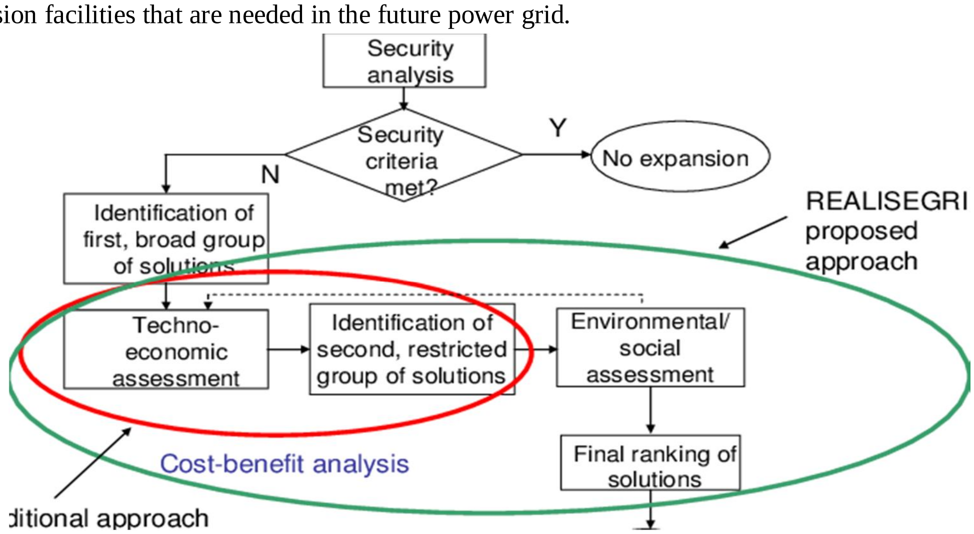


Fig. 7: Flow Diagram for Transmission line System Planning and Expansion

VI. CONCLUSION

The 132 kV lines covers a total distance of 240km with only one 132 / 33 kV with a substations at Savannah, Numan which makes it in sufficient as the line is radial and long. Another one will be require at Kaltungo to alleviate the demand of Federal Polytechnic Kaltungo and its environs.

The system may suffer a lot of disturbances leading to forced outages and concomitant loss of load and productivity. Upgrading the system will help in monitoring the system promptly.

The Transmission line may require a smart grid to make the system adequate to meet the demand and improve the economic wellbeing of the region.

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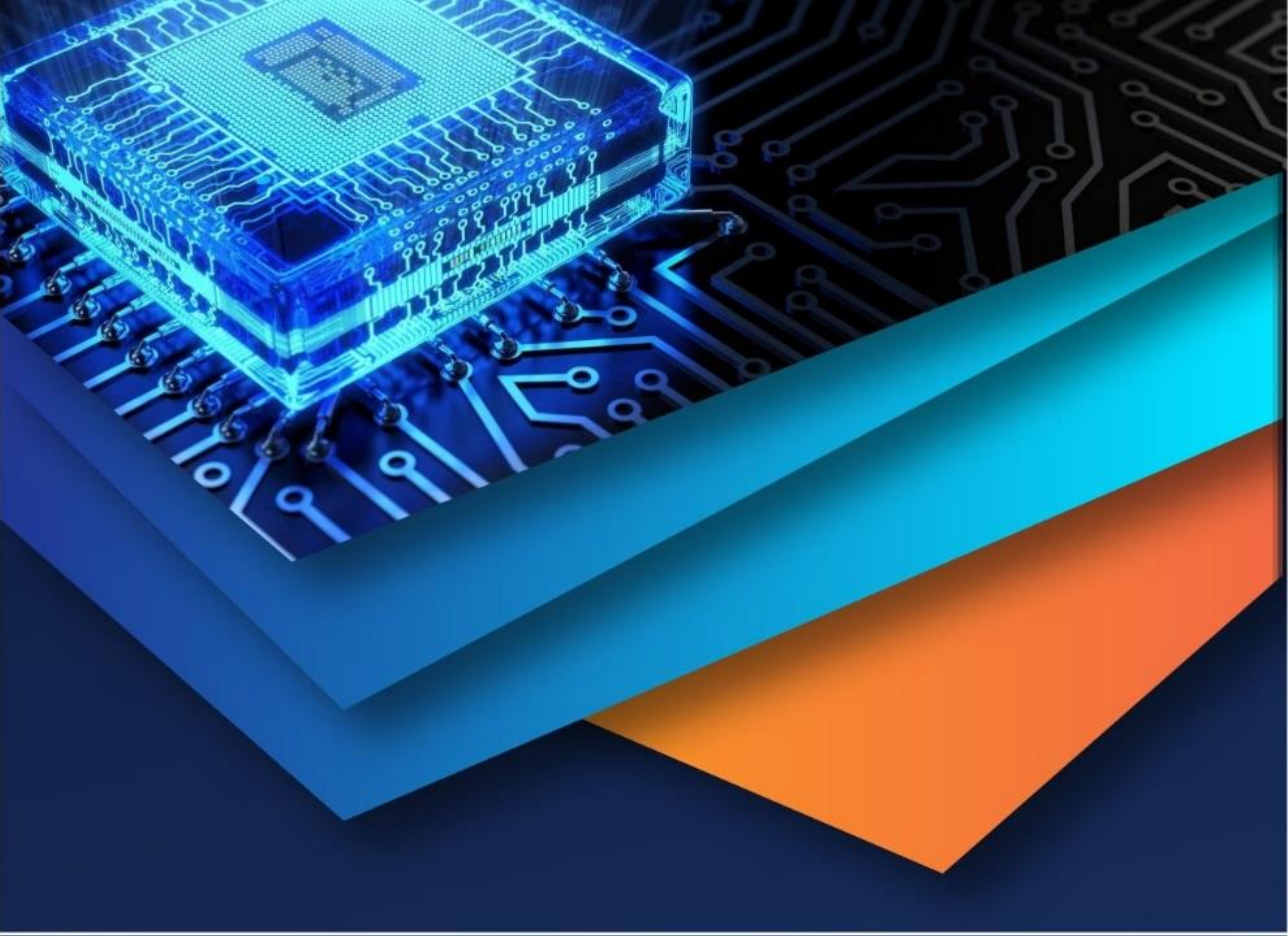

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