Study and Analysis of The Kafr Rai Electricity Network

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***Abstract*—The importance of electricity in our daily lives cannot be overstated, and it has become an essential necessity. Continuous monitoring and analysis of electrical networks are crucial to stay abreast of network conditions, accommodate growing electrical demands, and prevent network issues that could lead to damage and power disruptions for consumers. In this project, we employ the ETAP program to study and analyze the electrical network in Kafr Rai, located in the West Bank of Palestine. Our objective is to identify network problems contributing to electrical losses and decreased reliability. Subsequently, we propose and implement solutions within the ETAP program to enhance network reliability and prevent potential penalties from the electrical supply company.**

Keywords— ETAP, AAUP, Network analysis.

I. INTRODUCTION

The electricity network serving Kafr Ra'i originally received power from the Israeli Electricity Company (IEC) via a 22 kV overhead transmission line. As the town's maximum demand reached 1.37 MVA, driven by population growth, there was a need for increased capacity to meet the rising electricity demands. To address this, a connection point with the Tubas Electricity Company was established in Fahma town, connected through a 22 kV overhead transmission line, accommodating a maximum demand of 5 MVA. Additionally, a 3 MVA solar power system was introduced from Aja town, and a recent solar power project with a capacity of 700 KWp was also incorporated, both operating at 22 kV voltage [1]–[10].

The southern region of the town is powered by the Israel Electric Company, supplemented by the solar power system from Aja town and the newly added solar power project. Conversely, the northern part of the town receives its electricity supply from the Tubas Electricity Company [11]–[17].

The problem that the town is currently facing is the inability to provide electricity demand during peak times, especially in the summer and winter seasons. This problem causes power outages in some areas supplied by the network.

In our study, a comprehensive study and analysis of the electricity network within the town of Kafr Rai was conducted. This analysis involved the collection of pertinent data related to the network, including transformer readings taken at regular intervals (half-hourly throughout the entire month), as well as information concerning the types of transmission lines employed within the network, among other relevant data, which are detailed in the third chapter of our study. Subsequently, ETAP program are used to perform the load flow analysis of the electrical network.

Using ETAP program, authors aim to achieve several objectives. Firstly, authors intended to identify the primary issues within the network. This analysis required to assess whether the existing transmission lines, in terms of their types and specifications, remain suitable to accommodate the continuous load growth. Additionally, the capacity of the transformers is sufficient or requires expansion are evaluated.

After analyzing of the electrical network, viable solutions to address the identified issues are proposed. Our goal is to mitigate electrical losses within the network, ultimately reducing penalties incurred within the municipality's total tariff. By doing so, authors aim to enhance the overall reliability of the network and optimize its performance.

Our project objectives are summarized as follows:

- Study and analyze of the Kafr Rai electricity network.
- Suggest a solution to the problem of power outages and the inability to provide it to all areas during peak times.
- Increasing the capability of the transformers whose load exceeds their capacity.

II. METHODOLOGY

In this section, the methodology employed to gather essential information and data required for our study of the Kafr Rai municipality's electrical network was outlined. Our approach involves the systematic collection of pertinent data related to the electrical network, followed by its representation within the ETAP program. Subsequently, authors conduct a comprehensive analysis of the network's performance under various scenarios. Based on the findings from these analyses, authors assess network performance, identify limitations, engage in in-depth discussions and analyses of drawbacks, and ultimately present suggestions for improvements.

This section provides an overview of the information obtained regarding the Kafr Rai electricity network, encompassing details about the network's components and their specific specifications. The data and information were sourced from the municipality of Kafr Rai and included:

- Lengths of transmission lines.
- Actual loads on transformers and power factors.
- The actual capacity of each transformer.

Our methodology also involves the process of converting the network into the AutoCAD program, enabling us to subsequently design a single-line network diagram within the ETAP program. This comprehensive approach allows us to conduct a thorough analysis of the network's performance and identify areas for potential enhancement.

The Kafr Rai electrical network receives power from two distinct sources, serving not only the town itself but also neighboring villages. These sources are as follows:

- The first electrical connection point is established in the town of Zeita and is supplied by the IEC through a 22 kV overhead transmission line. The network has reached its maximum demand, totaling 1.37 MVA.
- The second connection point is linked to the Tubas Electricity Company, and it is also connected via an overhead transmission line with a voltage of 22 kV. Similar to the first connection point, it has also reached its maximum demand, which amounts to 5 MVA.

In addition to these primary sources, the network is supplemented with power from solar power projects. An agreement between the municipalities of the villages, including the neighboring village of Ajja, has led to the inclusion of a 3 MWp solar power project shared among the Al-Anqoud area villages. This project operates at a voltage of 22 kV and contributes to Kafr Rai's electricity supply. Furthermore, a separate solar power project within the town of Kafr Rai itself provides an additional capacity of 700 kWP, also operating at 22 kV voltage.

The table below presents the specific amperage values allocated to each town. These amperage values correspond to the load borne by the primary circuit breaker located at the outset of each town's electricity network.

Kafr Ra'i network contains 11 distribution transformers. Table II shows local name, rated power and rated voltage of each transformer.

TABLE I. DISTRIBUTION OF AMPERES AMONG THE VILLAGES OF THE REGION.

Region	The number of amperes
Ellar	40
Saida	14.13
Kufr rai	36
Fahma	11.2
AL-Ramah	7
Al-Atarah	5

TABLE II. NUMBER & RATING POWER OF DISTRIBUTION TRANSFORMERS.

Trans. No.	Trans. Name	Rated Power kVA	Rated Voltage kV
1	Zakaria	400	22\0.4
2	Khalil	400	22\0.4
3	Ghazi	400	22\0.4
4	Abu Shukri	400	22\0.4
5	Shawkat	400	22\0.4
6	Jawad	250	22\0.4
7	Pump	250	22\0.4
8	Al-madaq	50	22\0.4
9	Kashkool	160	22\0.4
10	Al-Gharbi	400	22\0.4
11	Al-Fanon pv	1000	0.4\22

The overhead conductors used in the network are Aluminum Conductor Steel Reinforced (ACSR) type. The underground cables used in the network are (1x3x95) XLPE Al.

The load curve of all transformers is shown in the following figure.

Fig. 1. Load carve for all transformars in 26/12.

Our analysis focuses on the electrical network serving the town of Kafr Rai, considering the existing conditions. This network is divided into two distinct parts. In our study, authors summarize the apparent power for all loaded transformers throughout December 2022. Authors then construct a load curve for this summarized power, enabling us to identify the peak load day (worst case) and the minimum load day.

Part 1 of the network is supplied by the IEC through the Zeita feeder. It comprises seven electrical transformers, with six of them serving as step-down transformers of varying sizes to meet consumer electricity needs. The seventh transformer is a step-up transformer rated at 0.4/22 kV and 1000 KVA, connected to a solar power station with a capacity of 700 kWP. Additionally, Part 1 supplies electrical power to the town of Al-Rami, with a demand of 250 KVA.

Part 2 is connected to the Tubas electricity network and features four step-down transformers of varying KVA sizes. This part supplies electrical power to the town of Fahma, with a demand of 450 KVA.

After collecting transformer data for every half hour during December 2022 and analyzing it, authors obtained the electric load curve, highlighting the maximum load on December 26, 2022, and the minimum load on December 20, 2022. Authors proceeded to enter this network information and electrical transformer data into the simulation program, conducting hourly simulations for the worst day (maximum load) and the minimum load day. Six key outcomes for these network scenarios have been obtained:

- Simulation at maximum load at 6:30 pm for both parts not connected to each other.
- Simulation at minimum load at 11:00 am for both parts not connected to each other.
- Simulation at maximum load at 6:30 pm for both parts connected to other networks.
- Simulation at minimum load at 11:00 am for both parts connected to each other.
- Both parts of the electrical network connected to the Tubas electricity network.
- Both parts of the electrical network connected to the Zeita electricity network.

Our findings revealed specific issues in each scenario, including overvoltage on one of the transformers (Abu Shukri) in the part connected to the Tubas electricity network during maximum load and overvoltage at nearly all load buses in the network during minimum load. Connecting both parts to one main source of electrical energy resulted in undervoltage at almost all load buses and an overloaded distribution transformer.

Our simulation approach involved conducting simulations at hourly intervals. During these simulations, authors explored various scenarios, including the maximum and minimum load cases. Through this comprehensive simulation process, authors were able to identify and address all the issues that occurred in the network throughout the day. As a result, our study and tests focused on these two critical cases, which provided a thorough assessment of the network's performance.

III. Results

In this section, the results of our simulations are presented for various scenarios, including the maximum and minimum load cases, the opening and closing of the circuit breaker between two networks, and the analysis of power source failure in one network while relying on the other network to meet the demand. Each case is analyzed with data specific to the time of simulation, including photovoltaic energy input. These simulations were conducted using the ETAP program and compared the results with the data obtained from the municipality's meter readings.

Maximum case with the connection switch between two networks open. Simulation results for the maximum case indicate that almost all load buses in the network are experiencing undervoltage. Additionally, one of the distribution transformers, Abo Shokri, is overloaded.

For the minimum case when the switch between two networks was opened:

- Simulation results indicate that almost all load buses in the network are experiencing undervoltage.

For the minimum case when the connection switch between two networks was closed:

- Similarly, in the simulation of the minimum case with the switch closed, almost all load buses in the network are under voltage.

If the source of electric power in one of the two networks failed, the simulations produced similar results for both scenarios (Tubas Electricity Company failure and Israeli Electricity Company failure):

- Almost all load buses in the network experienced undervoltage.
- One of the distribution transformers was overloaded.
- No problems were observed in the transmission lines.

IV. Conclusions and Recommendations

This study of the Kafr Rai electrical network using the ETAP program has unveiled significant performance issues. These include voltage fluctuations, transformer overloads, and undervoltage conditions. Through comprehensive simulations across different scenarios, where the light shed on the challenges and the consequences. Our findings emphasize the urgent requirement to bolster network reliability and avert power interruptions. The study underscores the significance of prompt action to fine-tune network efficiency and guarantee a dependable electricity supply to Kafr Rai. Future research should prioritize sustainable solutions to accommodate the town's escalating electricity demands.

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