Analysis and Improvement of Anabta Distribution Network

Hothayfa Abu Sarees, Alaa Abu Ali, Obay Nedal Naffaa, Jafar Jallad, Samer Alsadi, Tareq Foqha, Basem Abu Izneid, and Mahmoud Odeh

Abstract Our project aims to analyze the Anabta town Electrical Network using ETAP software to identify areas for improvement in terms of power factor and reducing electrical losses. By doing so, we hope to minimize the penalties incurred by the municipality and increase the network's reliability. In addition, we will be designing a PV system to integrate renewable energy sources into the network, reducing reliance on traditional energy sources and promoting sustainable development in the community. Overall, our project will contribute to the long-term stability and sustainability of Anabta's electrical infrastructure.

Keywords Anabta · Etap · Load flow analysis

1 Introduction

The energy sector in Palestine has faced significant challenges due to the Israeli occupation, including financial and management obstacles, as well as severe restrictions on the import of materials needed to build and maintain energy infrastructure. This has resulted in Palestine's lack of a unified power system, with only local low voltage distribution networks currently in place. These networks are connected to the Israeli Electrical Corporation (IEC), which still supplies around 90% of the energy consumed in Palestine [1, 2]. The existing electricity situation is characterized in old

H. A. Sarees · A. A. Ali · O. N. Naffaa · J. Jallad · S. Alsadi (✉) · T. Foqha
Electrical Engineering Department, Faculty of Engineering and Technology, Palestine Technical University-Kadoorie, Tulkarm, Palestine
e-mail: s.alsadi@ptuk.edu.ps

B. A. Izneid
Department of Electrical Engineering, University of Business and Technology, Jeddah, Saudi Arabia

M. Odeh
Business Faculty, Zarqa University, Zarqa, Jordan
e-mail: modeh@zu.edu.jo

R. E. Khoury and N. Nasrallah (eds.), *Intelligent Systems, Business, and Innovation Research*, Studies in Systems, Decision and Control 489,
https://doi.org/10.1007/978-3-031-36895-0_54

fashion over loaded networks, high power losses (more than 20%), low power factor, poor system reliability, high prices of electricity supplied to the consumer due to high tariff determined by the IEC [3].

Due to all factors mentioned above, it becomes very important to design a national independent power system for the west bank of Palestine which will connect all the west bank areas by a reliable network to a national generating plant. The national power system should have the minimum annual cost and provide the consumer with a high quality of electric energy. This power system should also reduce the cost of KWH and be able to provide electricity to any area in the west bank [4, 5].

In order to get the desired results of the project has to be the work of a good action plan, and the most important goals we will work with them on this project as follows:

- Collecting data for network structure of all parameters and their specifications.
- Improving the voltage level and reducing the losses and correcting of power factor in the network; by modifying the current network model using ETAP program.
- Making the system more protected by increasing reliability and stability.
- Make required load calculation.
- Analyzing the network under maximum load condition using load flow analyses.
- Analyzing the effect of the PV system on the power system to get economic benefit when improving the performance of network.

One of the main goals will be achieved in a project to rehabilitate the Anabta network in the following points:

- Provide the electricity in good quality to the consumer.
- Reduce the losses of the kilowatt-hour.
- Minims the possibilities of interruption of Anabta network
- Give tips to change some of the place's transformers and Towers conductivity.
- Operational and planning reliability

2 Load Flow Analysis

Power flow analysis, also known as load-flow analysis, is a crucial tool in power engineering. It involves the use of numerical methods to analyze and model power systems. Unlike traditional circuit analysis, power flow analysis focuses on AC power, including reactive, real, and apparent power, rather than just voltage and current. Simplified notation, such as one-line diagrams and per-unit systems, are often used in power flow analysis [6].

The main purpose of power flow analysis is to provide information for planning and operating power systems. By determining the voltage and power flow at each bus and line, power flow analysis can help identify potential issues and optimize the operation of existing systems. This information is also essential for planning future expansion of power systems [7].

ETAP power station program is a software tool commonly used for power flow analysis. It can help engineers to conduct load flow studies and analyze the performance of power systems in normal steady-state operation. By using this program, engineers can obtain critical information about the system, including voltage magnitudes, phase angles, and power flows, which can be used to optimize the performance of the power system. Overall, power flow analysis is a crucial tool for power engineers and plays an important role in ensuring the reliable and efficient operation of power systems[8–10].

3 Electrical Networks Improvement

Improving the operating conditions in electrical networks is crucial for ensuring the reliable and efficient operation of power systems. There are several methods that can be used to improve the operating conditions of electrical networks, including [11]:

- Swing bus control: This method involves adjusting the voltage at the swing bus of the network to maintain system stability and balance.
- Transformer taps: Transformers can be equipped with taps that allow the voltage to be adjusted at the load end.
- Installation of capacitor banks (reactive power compensation): Capacitor banks can be installed in the network to improve the power factor and compensate for reactive power.
- Changing the configuration of distribution network: The configuration of the distribution network can be changed from radial to ring to improve the redundancy and reliability of the system.
- Addition of distributed generators, such as photovoltaic (PV) systems: By adding distributed generators to the network, it is possible to increase the local generation capacity, reduce the overall demand on the grid, and improve the stability and reliability of the system.

Overall, these methods can be used individually or in combination to improve the operating conditions of electrical networks, and ensure the reliable and efficient delivery of power to consumers.

4 Methodology

The project involves collecting data about the Anabta electrical distribution network and creating a single line diagram. Using software and real data, the medium voltage network will be analyzed to minimize technical loss and improve power factor. Network problems will be identified and solved to improve efficiency. The project will also add a PV station to support the grid and determine its impact on the network.

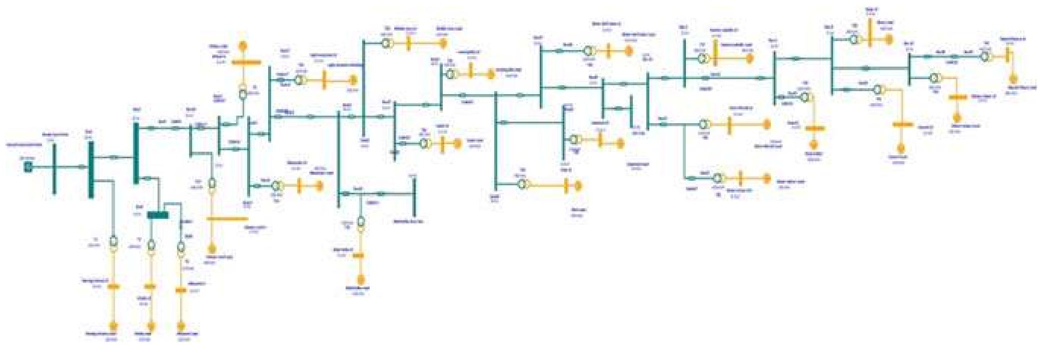

Fig. 1 Analysis net magnitude and direction force

4.1 Anabta Network Elements

The Anabta network consists of 23 distribution transformers with different ratings (1250, 630, 400, 250, and 160 kVA) to step down medium voltage (33 kV) power to low voltage (0.4 kV) power for distribution to consumers. The network has ACSR transmission lines with different sizes (120, 95, and 50 mm^2) for transmitting power from the source to the transformers, and XLPE underground cables with different sizes (300, 240, 150, and 95 mm^2) for distributing power from the transformers to consumers.

4.2 Single Line Diagram

In order to have the one-line diagram, we followed the network diagram from the network plans, and so we get this plan considered as an input to the ETAP program as shown in Fig. 1.

4.3 Case Study 1: Max Load Case

In this case study the network is analyzed under maximum load condition which is the rating of the transformer. This helps to ensure that the network is able to handle the maximum power demand without any issues. The results obtained from Etap for this case are transformers primary and secondary voltages, connection point PF, active power, reactive power, apparent power and apparent losses.

4.4 Case Study 2: Min Load Case

In the second case study the network is analyzed using Etap under minimum load condition, which is set to 60% of the transformer's rating. The results obtained from Etap for this case are transformers primary and secondary voltages, connection point PF, active power, reactive power, apparent power and apparent losses. However, it is important to note that analyzing the network under other load conditions is also necessary to fully understand its behavior and capabilities.

5 Results

The results from Etap software are represented as follows.

5.1 Case Study 1: Max Load Case

Table 1 presents the primary and secondary voltages for each transformer in the power system network being analyzed.

Table 2 presents the value of the connection point MWA, Mvar, MVA, apparent losses and PF.

Table 1 Software results: voltages at the medium voltage and low voltage sides

Transformer	Medium voltage kV	Low voltage kV	Transformer	Medium voltage kV	Low voltage kV
Tanning factory	32.95	0.384	Awartani	32.54	0.379
Alraby	32.93	0.384	Kufr Rman	32.54	0.379
Alkasarat	32.93	0.384	Water Well/ Jaber	32.54	0.379
Shawer land	32.78	0.382	Amer Ahmad	32.49	0.378
Alhejaz factory	32.78	0.382	Water indoor	32.47	0.378
Albawaten	32.76	0.382	Numan Jadallah	32.42	0.378
Light industries	32.7	0.381	Aziza indoor	32.32	0.376
Wadi Kalba	32.61	0.38	Bisan	32.31	0.376
Middle area	32.61	0.38	Council	32.31	0.376
South	32.57	0.38	Waher indoor	32.31	0.376
Municipality	32.56	0.38	Najeeb Mosa	32.31	0.376
Hilal	32.55	0.379			

Table 2 Connection point results

	MW	MVAR	MVA	P.F %
Swig buses	11.233	7	13.236	84.87
Total demand	1.233	7	13.236	84.87
Apparent losses	0.436	0.309	–	–

Based on the results of the analysis, it appears that there are several issues with the power system network being analyzed. Firstly, the power factor of the swing bus is 84.87 lag. A low power factor can result in high penalties and losses, which can impact the overall performance and efficiency of the power system. It is important to improve the power factor by adding power factor correction devices, such as capacitors, to the network. Secondly, the voltage of the buses is not within the acceptable range of 1.05 Vn $\leq$ V $\leq$ 1.1 Vn, where Vn is the nominal voltage level. A deviation from the nominal voltage level can lead to several issues, such as reduced equipment lifespan, increased losses, and decreased system stability. It is important to maintain the voltage level within the acceptable range by installing voltage regulation devices, such as tap changers, on the transformers.

5.1.1 Max Load Case Improvement

Increasing the voltage on the swing bus up to 5% from the original voltage of 33 kV can help to improve the performance of the power system network. The new value of the swing bus voltage would be 34.65 kV. After increasing the voltage on the swing bus, a load flow analysis is conducted to assess the impact of the voltage increase on the network. The results of the load flow analysis would provide valuable information about the new values of the network parameters, including the bus voltages, power flows, and power losses. Table 3 presents the secondary voltage for each transformer in the power system network being analyzed and Table 4 presents the value of the connection point MWA, Mvar, MVA, apparent losses and PF after improvement.

It is shown that increasing the voltage on the swing bus not be sufficient to fully optimize the network performance. Other measures, such as tap changers, on the transformers can help to maintain the voltage level within acceptable limits. Similarly, adding power factor correction devices, such as capacitors, to the network can help to improve the power factor and reduce penalties and losses.

Now the transformer's tap ratio is changed to 5%. Table 5 presents the secondary voltage for each transformer in the power system network being analyzed and Table 6 presents the value of the connection point MWA, Mvar, MVA, apparent losses and PF after the second improvement.

Adding shunt capacitor banks at the buses at both transmission and distribution levels can be an effective way to improve the power factor of the network. Shunt capacitors act as reactive power sources and can help to offset the reactive power demand of inductive loads in the network. By doing so, they can reduce the reactive

Table 3 Software results: voltages at low voltage sides of the transformers after the increasing the voltage on the swing bus

Transformers	Low voltage (actual) KV	Transformers	Low voltage (actual) KV
Tanning factory	0.405	Awartani	0.4
Alraby	0.405	Kufr Rman	0.4
Alkasarat	0.405	Water Well/Jaber	0.4
Shawer land	0.403	Amer Ahmad	0.399
Alhejaz factory	0.403	Water indoor	0.399
Albawaten	0.402	Numan Jadallah	0.399
Light industries	0.402	Aziza indoor	0.397
Wadi Kalba	0.401	Bisan	0.397
Middle area	0.401	Council	0.397
South	0.4	Waher indoor	0.397
Municipality	0.4	Najeeb Mosa	0.397
Hilal	0.4		

Table 4 Connection point results after improvement

	MW	MVAR	MVA	P.F %
Swig buses	11.427	7.072	13.439	85.03
Total demand	11.427	7.072	13.439	85.03
Apparent losses	0.409	0.243	–	–

Table 5 Software results: voltages at low voltage sides of the transformers after the increasing the voltage on the swing bus

Transformers	Low voltage (actual) KV	Transformers	Low voltage (actual) KV
Tanning factory	0.411	Awartani	0.405
Alraby	0.41	Kufr Rman	0.405
Alkasarat	0.41	Water Well/Jaber	0.405
Shawer land	0.408	Amer Ahmad	0.404
Alhejaz factory	0.408	Water indoor	0.404
Albawaten	0.408	Numan Jadallah	0.403
Light industries	0.407	Aziza indoor	0.402
Wadi Kalba	0.406	Bisan	0.402
Middle area	0.406	Council	0.402
South	0.405	Waher indoor	0.402
Municipality	0.405	Najeeb Mosa	0.402
Hilal	0.405		

Table 6 Connection point results after improvement

	MW	MVAR	MVA	P.F %
Swig buses	11.494	7.140	13.531	84.95
Total demand	11.494	7.140	13.531	84.95
Apparent losses	0.420	0.277	–	–

power flowing through the transmission and distribution lines and improve the power factor of the network. It is generally more effective to add shunt capacitor banks in the low-voltage distribution network, as this is where most of the inductive loads are located. Adding shunt capacitors at the distribution level can help to reduce the reactive power demand of these loads and improve the power factor of the network, which can in turn reduce penalties and losses. However, it is also important to ensure that the shunt capacitors are properly sized and coordinated to avoid overcompensation, which can lead to overvoltage and other issues. Table 7 presents the secondary voltage for each transformer in the power system network being analyzed with the value and location of the capacitors and Table 8 presents the value of the connection point MWA, Mvar, MVA, apparent losses and PF after the third improvement.

Table 7 Software results: voltage values at the low voltage sides of the transformers, along with the location and value of the capacitor banks, after the power factor (PF) was improved through the installation of shunt capacitor banks in the power system network

Transformers	Capacitor rating (kvar)	Low voltage (actual) KV	Transformers	Capacitor rating (kvar)	Low voltage (actual) KV
Tanning factory	500	0.411	Awartani	–	0.405
Alraby	–	0.41	Kufr Rman	–	0.405
Alkasarat	–	0.41	Water Well/ Jaber	–	0.405
Shawer land	–	0.408	Amer Ahmad	–	0.404
Alhejaz factory	–	0.408	Water indoor	–	0.404
Albawaten	–	0.408	Numan Jadallah	–	0.403
Light industries	–	0.407	Aziza Indoor	1000	0.402
Wadi Kalba	500	0.406	Bisan	–	0.402
Middle area	500	0.406	Council	–	0.402
South	500	0.405	Waher indoor	500	0.402
Municipality	–	0.405	Najeeb Mosa	–	0.402
Hilal	–	0.405			

Table 8 Connection point results after improvement

	MW	MVAR	MVA	P.F %
Swig buses	11.503	3.291	11.964	96.14 Lag
Total demand	11.503	3.291	11.964	96.14 Lag
Apparent losses	0.367	0.216	–	–

5.2 *Case Study 2: Min Load Case*

Table 9 presents the primary and secondary voltages for each transformer in the power system network being analyzed after decreasing the load to be 60% of the transformer rating.

Table 10 presents the value of the connection point MWA, Mvar, MVA, apparent losses and PF.

Table 9 Software results: voltages at the medium voltage and low voltage sides

Transformer	Medium voltage kV	Low voltage kV	Transformer	Medium voltage kV	Low voltage kV
Tanning factory	32.97	0.391	Awartani	32.73	0.388
Alraby	32.98	0.391	Kufr Rman	32.73	0.388
Alkasarat	32.98	0.391	Water Well/ Jaber	32.69	0.388
Shawer land	32.87	0.39	Amer Ahmad	32.69	0.387
Alhejaz factory	32.87	0.390	Water Indoor	32.73	0.387
Albawaten	32.86	0.389	Numan Jadallah	32.66	0.387
Light industries	32.82	0.389	Aziza Indoor	32.6	0.386
Wadi Kalba	32.77	0.388	Bisan	32.6	0.386
Middle area	32.77	0.388	Council	32.6	0.386
South	32.75	0.388	Waher Indoor	32.59	0.386
Municipality	32.74	0.388	Najeeb Mosa	32.59	0.386
Hilal	32.74	0.388			

Table 10 Connection point results

	MW	MVAR	MVA	P.F %
Swig buses	6.684	3.973	7.775	85.96
Total demand	6.684	3.973	7.775	85.96
Apparent losses	0.152	0.074	–	–

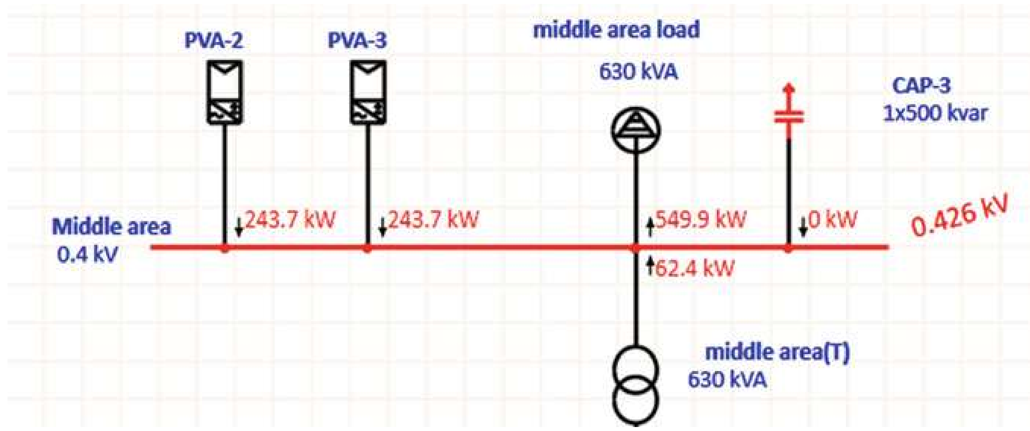

Fig. 2 The 400-kWp PV plant location

5.3 *Design PV System for Electrical Anabta Network*

The PV plant uses Jinkosolar modules with a total nominal power of 251 KWp, made up of 429 units with a unit nominal power of 585 Wp. The PV array consists of 16 modules per string and there are a total of 43 strings. The inverter used is made by KACO with a unit nominal power of 200 KWp and can handle a maximum PV power of 240 KW and a maximum PV current of 467 A. There are two inverters in total, and the operating voltage range is between 450 to 830 V. The location of the 400-kWp PV plant is shown in Fig. 2.

Table 11 presents the secondary voltage for each transformer in the power system network being analyzed with the value and location of the capacitors and Table 12 presents the value of the connection point MWA, Mvar, MVA, apparent losses and PF after the third improvement.

Table 11 Software results: Transformer low voltage side voltages after PV power plant installation

Transformers	Low voltage (actual) KV	Transformers	Low voltage (actual) KV
Tanning factory	0.411	Awartani	0.407
Alraby	0.41	Kufr Rman	0.407
Alkasarat	0.41	Water Well/Jaber	0.407
Shawer land	0.413	Amer Ahmad	0.407
Alhejaz factory	0.42	Water indoor	0.407
Albawaten	0.409	Numan Jadallah	0.407
Light industries	0.409	Aziza indoor	0.427
Wadi Kalba	0.419	Bisan	0.406

(continued)

Table 11 (continued)

Transformers	Low voltage (actual) KV	Transformers	Low voltage (actual) KV
Middle area	0.426	Council	0.406
South	0.424	Waher indoor	0.424
Municipality	0.408	Najeeb Mosa	0.406
Hilal	0.407		

Table 12 Connection point results after improvement

	MW	MVAR	MVA	P.F %
Swig buses	8.809	3.074	9.33	94.42
Total demand	8.809	3.074	9.33	94.42
Apparent losses	0.266	0.83	–	–

6 Conclusion

In conclusion, this paper presented an analysis of the Anabta power distribution network to identify and solve various problems in the grid. Different methods were implemented for different load conditions, including increasing the connection point voltage, changing the tap changer, and installing capacitor banks to improve the power factor. Furthermore, the paper introduced the addition of PV power plants into the grid to further enhance the performance of the network. The results showed significant improvements in the grid performance, including reduced electrical losses, increased power factor, and improve the voltage to be within acceptable limits. These improvements not only help to avoid penalties but also lead to a more efficient and reliable power distribution network.

References

1. Hamed, T.A., Peric, K.: The role of renewable energy resources in alleviating energy poverty in Palestine. Renew. Energy Focus **35**, 97–107 (2020)
2. Ibrik, I.: Energy profile and the potential of renewable energy sources in Palestine. In: Renewable Energy in the Middle East: Enhancing Security through Regional Cooperation, pp. 71–89 (2009)
3. Foqha, T., Alsadi, S., Refaat, S.S., Abdulmawjood, K.: Experimental validation of a mitigation method of Ferranti effect in transmission line. IEEE Access **11**, 15878–15895 (2023)
4. Nassar, Y.F.,Alsadi, S.Y., Miskeen, G.M., El-Khozondar, H.J., Abuhamoud, N.M.: Mapping of PV solar module technologies across Libyan territory. In: 2022 Iraqi International Conference on Communication and Information Technologies (IICCIT), pp. 227–232 (2022)
5. Nassar, Y.F., Alsadi, S.Y.: Assessment of solar energy potential in Gaza strip, Palestine. Sustain. Energy Technol. Assess. **31**, 318–328 (2019)

6. Melhorn, A.C.,Dimitrovski, A., Keane, A.: Probabilistic load flow: a business park analysis, utilizing real world meter data. In: 2016 International Conference on Probabilistic Methods Applied to Power Systems (PMAPS), pp. 1–6 (2016)
7. Balu, C., Maratukulam, D.: Power System Voltage Stability. McGraw-Hill, New York, NY, USA (1994)
8. Alsadi, S.Y., Nassar, Y.F.: A general expression for the shadow geometry for fixed mode horizontal, step-like structure and inclined solar fields. Sol. Energy **181**, 53–69 (2019)
9. Bam, L.,Jewell, W.: Power system analysis software tools. In: IEEE Power Engineering Society General Meeting 2005, pp. 139–144 (2005)
10. Ullah, M.A., Qaiser, A., Saeed, Q., Abbasi, A.R., Ahmed, I., Soomro, A.Q.: Powerflow & voltage stability analyses and remedies for a 340 MW nuclear power plant using ETAP. In: 2017 International Conference on Electrical Engineering (ICEE), pp. 1–6 (2017)
11. Nassar, Y., Alsadi, S., Ali, K.A., Yousef, A.H., Massoud, A.F.: Numerical Analysis and Optimization of Area Contribution of the PV Cells in the PV/T Flat-Plate Solar Air Heating Collector (2019)