Paper Title: Performance evaluation of medium voltage network (30/11KV)

Jamal. S.A.
Libyan Academy
Email:jabdulmalek@yahoo.com

Jamal. I.A.
General Electrical Company of Libya
Email:alhebhab@gmail.com

(Misurata center as a case study)

Article information

Key words

loadability, Misurata Central Loop, performance indicators, Load growth, NEPLAN program.

Abstract

This paper was devoted to a real practical case study, where the performance of the medium voltage network (11/30 kV) in the Misurata Central Loop, was studied, analyzed, and evaluated for an of five years so as to predict the network's performance and its ability to meet customer needs in the future. The aim of this research is to evaluate the performance of the medium voltage network in the Misurata Central Loop in terms of voltage drop, power losses, and loadability, estimate load growth for the next five years, resimulate the network, and make appropriate decisions to improve performance. The well-known NEPLAN program was used to evaluate performance indicators, based on data obtained from the General Electricity Company. The weaknesses found in the network were treated, and series conclusions are made. The results obtained from the program were tabulated and included, and these results were compared before and after treatment.

I. INTRODUCTION

The distribution system is one of the most important parts of the power system. Therefore, a study of performance for network (voltage drop, power losses and loadability) is necessary for the operators to manage how to control and operate network. This is to ensure the continuous supplying of electrical power to the consumers in the present and in the future (in case of increasing the loads because of the increase population and economic growth in the country). The main task of power distribution systems is to supply the required energy to the consumers. So, it is necessary to be well planned and well operated for system. Modeling and simulating the distribution networks is important to obtain data about their performance, which helps in knowing the status of the network as well as to estimate the future. The results obtained from the computer simulation are used to do any changes and developments in the current network to ensure the continuity of network functions. An excellent electrical control system should have a voltage value that does not exceed the tolerance limits and small power losses, the allowable tolerance for voltage drop is 5% of the nominal value and power losses cannot exceed 10% of the transmitted power [1]. It is important not to exceed these values, because voltage drops, and power losses are one of the benchmarks of the efficiency of a distribution network system. In practice, electricity distribution networks are designed to meet many technical and economic standards to achieve the best performance in both normal and abnormal operating conditions. Power losses, voltage drop, and loadability are some of the most important indicators to describe the electrical performance of a distribution network. [2]. Active power loss minimization plays a significant role in improving distribution system performances such as energy savings, voltage profiles and loadability. [3].

II. CENTRAL LOOP OF MISURATA MEDUIM VOLTAGE DISTRIBUTION NETWORK (30/11 KV)

The central loop of Misurata is feed from the main injection substation of Misurata center (220/30 KV) by three transformers of (100MVA) size each. The network includes nine transfer substations, each station has two transformers (30/11KV), except the ALtasweg station has one transformer, the capacity of each transformer is (20MVA) [8]. The obtained loads for all network stations were entered into the (NEPLAN) program, and a calculation of the power flow for the loads was made for all months of the year. It was noted that some problems appeared in the network in the month (8), which is considered the summer peak month in the Libyan electricity network. Data and load values for the stations within the central loop of Misurata for the year (2022) obtained from the General Electricity Company of Libya [7] as shown in Table I.

TABLE I. loads of stations (2022)

Substations	Transformer1 (MVA)	Transform2 (MVA)
misurata center	10.8	5.8
ALgoshi	4.5	12
ALadab	7.6	3.9
Aljazeera	9.5	4.6
AlShawahda	13	12.5
Yedr	10	13
ALseha ALmadrasiya	5.5	7.5
ALjamea ALaali	11	8.5
ALtasweg	0	7.7

A. THE NETWORK FOR THE YEAR OF STUDY (2022)

The network for the central loop of Misurata for the year (2022) is shown in Figure I:

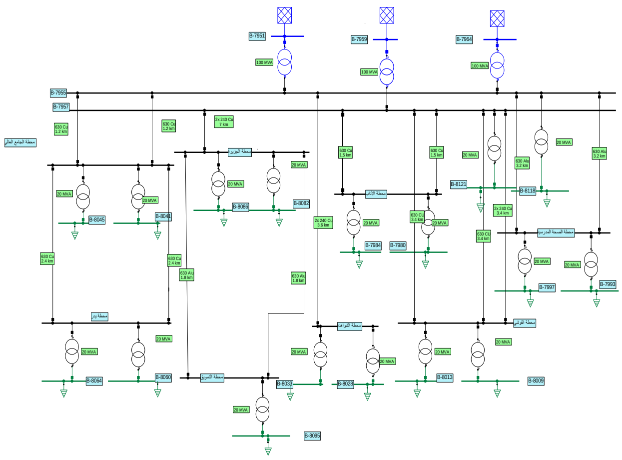

Figure I. The network for the year (2022)

III. NETWORK SIMIULATION

By using the NEPLAN program, the system's performance for the year (2022) was analyzed. The result was stable, with no voltage drop or significant power loss. But the network was suffering due to weak feeding sources for few stations, making the network's performance unsafe and unreliability. To improve network performance and increase its reliability, feeding sources must be enhanced so that we do not lose stations during the peak period.

A. HYBOTHESES USED IN THE SIMIULATION

- The system loads taken from GECOL are during august 2022 and considered as the yearly highest loads [8].
- Study the network performance at rated loading condition by using load flow analysis program (NEPLAN).
- The buses voltage limits in normal operating condition are ranged between (95% to 105%) [4].
- The load of transmission lines should not exceed 80% [4].
- The transformer load should not exceed 80% of its rated [4].

B. THE LOAD GROWTH AND LOAD GROWTH FACTOR

Load Forecast aims to study the future forecasts for the growth of demand for electric power during the coming years, with the aim of deciding the requirements for expansion of the existing electrical system (electricity production stations, transmission and distribution networks). In order to obtain accurate results for the study of load prediction, it is necessary to identify all the factors affecting it, and to have accurate data for these factors for a sufficient number of years, as well as economic, demographic and technical data to obtain accurate results linking the outputs of pregnancy prediction and the factors influencing it. In this research, using the exponential method, this method is depending on the existing power system load and the increase in past year and estimates the future load increase by exponential increase function and trend analyses. The procedures therefore cannot consider externally measured variable and are hardly suitable to supply reliable load and energy predictions [5]. The load forecast for the next five years will be calculated for the study network according to Equation (1):

$$P_n = P_0(1+m)^n \qquad (1)$$

where:
P_n (The load for the year of prediction)
P_0 (current load)
m (growth factor)
n (prediction year)

To calculate the load growth factor, we need the current year's (study year) loads as well as the previous year's loads. Table II shows the annual maximum load for the years (2016-2022):

TABLE II. Annual maximum loads of Libyan grid

Years	Largest Loads (MW)
2017	6922
2018	7158
2019	7315
2020	7350
2021	8150
2022	8865

Based on the annual largest loads for the years (2017-2022), the load growth factor (LGF) for this study will be determined using Equation (2):

$$\text{LGF } (\%) = \frac{Y_{new} - Y_{old}}{Y_{new}} \times 100 \quad (2)$$

where:

Y_{new}(current year)

Y_{old} (previous year)

By using equation (2), the load growth factor was determined to be (8%). This percentage will be used in this research as the load growth factor for Misurata Centre loop to (2027).

The forecasting loads after the next five years in (2027) as shown in Table III:

TABLE III. loads of stations (2027)

Substations	Transformer1 (MVA)	Transform2 (MVA)
misurata center	15.9	8.5
ALgoshi	6.7	19.7
ALadab	11.14	5.72
Aljazeera	13.95	6.75
AlShawahda	19.1	18.36
Yder	14.68	19.09
ALseha ALmadrasiya	8.08	11.02
ALjamea ALaali	16.15	12.47
ALtasweg	0	11.29

The maximum loads in the Misurata central loop for the years (2022–2027) are displayed in figure II:

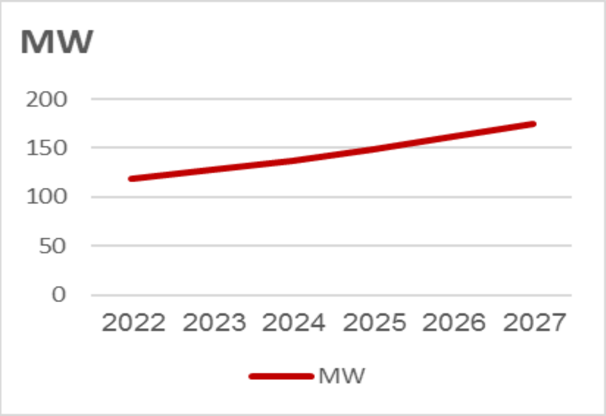

Figure II. Maximum loads in the Misurata central loop for the years (2022-2027).

The above values from the graph in the figure II shows a linear increase in the load of the power system due to the increasing demand for electrical energy as a result of population and economic growth in the country.

IV. RESULTS AND DISCUSSION

After simulating the network for the years 2022 and 2023 using NEPLAN software [6], the analysis shows that the network is suffering Due to a few stations' poor feeding sources, the network's performance is unstable and unreliable. The feeding sources need to be improved in order to avoid station loss during peak hours and improve network reliability and performance. Table (IV) lists the stations that need support their feeding sources:

TABLE IV. The treatment for years (2022-2023)

weak feeding sources			
Element	(station)	Type feeder	The treatment
L-9160	AlShawahda	(2x240$mm2$) (copper cable)	Add (630$mm2$) (copper cable)
L-8113	Aljazeera	(2x240$mm2$) (copper cable)	Add(630$mm2$) (copper cable)

The system's performance analysis showed stability, without any voltage drops or energy losses. The system's performance at actual load for the year 2022–2023 is shown in Tables (V) and (VI):

TABLE V. System actual load performance for the year (2022)

Area/Zone	P loss MW	Q loss MVAR	P Imp MW	Q Imp MVAR	P Gen MW	Q Gen MVAR	P load MW	Q load MVAR
Network	1.139	15.204	119.299	103.824	119.299	103.824	118.16	88.62
Area 1	1.139	15.204	0	0	119.299	103.824	118.16	88.62
Zone 1	1.139	15.204	0	0	119.299	103.824	118.16	88.62
Un	P Loss line	Q Loss line	P Loss Tran	Q Loss Tran				
KV	MW	MVAR	MW	MVAR				
30	0.459	-2.117	0.367	7.34				
220	0	0	0.313	9.982				

After simulating the network for the year 2022 using the NEPLAN program, the above values from the table (V) shows a voltage values do not exceed the tolerance limits and small power losses within the allowable limits.

TABLE VI. The system's actual load performance for the year 2023.

Area/Zone	P loss MW	Q loss MVAR	P Imp MW	Q Imp MVAR	P Gen MW	Q Gen MVAR	P load MW	Q load MVAR
Network	1.335	18.38	128.439	113.708	128.439	113.708	127.104	95.328
Area 1	1.335	18.38	0	0	128.439	113.708	127.104	95.328
Zone 1	1.335	18.38	0	0	128.439	113.708	127.104	95.328
Un	P Loss line	Q Loss line	P Loss Tran	Q Loss Tran				
KV	MW	MVAR	MW	MVAR				
30	0.535	-1.978	0.431	8.614				
220	0	0	0.368	11.744				

Through the results of the network simulation for the year 2023, the above values from the table (VI) shows a voltage values do not exceed the tolerance limits and small power losses within the allowable limits.

Using power flow calculations and the NEPLAN software, this network was studied for the years (2024–2027). The results of the analysis showed that the network is suffering from overloading in a few lines that feed it and in some transformers in some stations, as shown in Table (VII):

TABLE VII. Over loading values before and after treatment

Over loading					
Year	Element	Type	Station	Before Treatment %	After Treatment %
2024	(L-11476)	Line	Alshawahda	86.25	24.49
2025	TR2-(12132)	2WTran	main injection of misurata center	83.11	55.42
	TR1-(12196)	2WTran	AlShawahda	86.31	51.85
	(TR2-12198)	2WTran	AlShawahda	83.99	53.75
	TR2-(12230)	2WTran	Yder	86.62	71.85
2026	(TR1-13000)	2WTran	main injection of misurata center	81.78	76.45
	(TR3-13013)	2WTran	main injection of misurata center	81.78	76.45
	(TR2-13054)	2WTran	ALgoshi	97.23	63.81
	(TR2-13105)	2WTran	Yder	83.23	54.47
	TR1-(13103)	2WTran	Yder	81.9	55.74
	(L-13144):	Line	Aljazeera	82.81	23.44
2027	TR1-(13925)	2WTran	main injection of misurata center	80.02	77.15
	(TR3-13938)	2WTran	main injection of misurata center	80.02	77.15
	TR1-(14006)	2WTran	ALjamea ALaali	85.73	77.56
	TR1-(14069)	2WTran	main injection	83.92	67.35

The values from the table (VII) shows the network for the years (2024-2027) is suffering from overload on some of the lines feeding it and on some transformers. By increasing the capacity of some cables, distributing loads between transformers, and adding transformers to some stations, loadability problems were resolved and network performance was improved.

1. LOSSES FOR THE NETWORK

The system power losses in MW and Mvar for the years (2022-2027) as shown in Table (VIII):

TABLE VIII. The system power losses

LOSSES						
Year	P_{loss} MW	Q_{loss} Mvar	P_{Gen} MW	Q_{Gen} Mvar	P_{load} MW	Q_{load} Mvar
2022	1.139	15.204	119.299	103.824	118.160	88.620
2023	1.335	18.380	128.439	113.708	127.104	95.328
2024	1.565	21.881	138.557	124.625	136.992	102.744
2025	1.668	25.477	149.954	136.699	148.296	111.222
2026	1.939	30.081	163.905	151.556	161.966	121.475
2027	1.380	31.948	175.966	162.550	174.136	130.602

The above values from Table (VIII) show the system energy losses for the years (2022-2027), the energy loss results were within the allowable limits. In this work, the percentage of system losses in the year 2027 was decreased to 0.78% after treatment and improvement operations, in comparison to the system losses in the year 2022, where the losses were 0.95%. The system power loss in MW and Mvar is displayed in the following figures (III) and (IV):

Figure III. The system power losses in MW

The energy losses in active power (MW) of the system is shown by the above values in Figure (8). The year 2026 has the largest losses at 1.18%, while the year 2027 has the lowest losses at 0.78%.

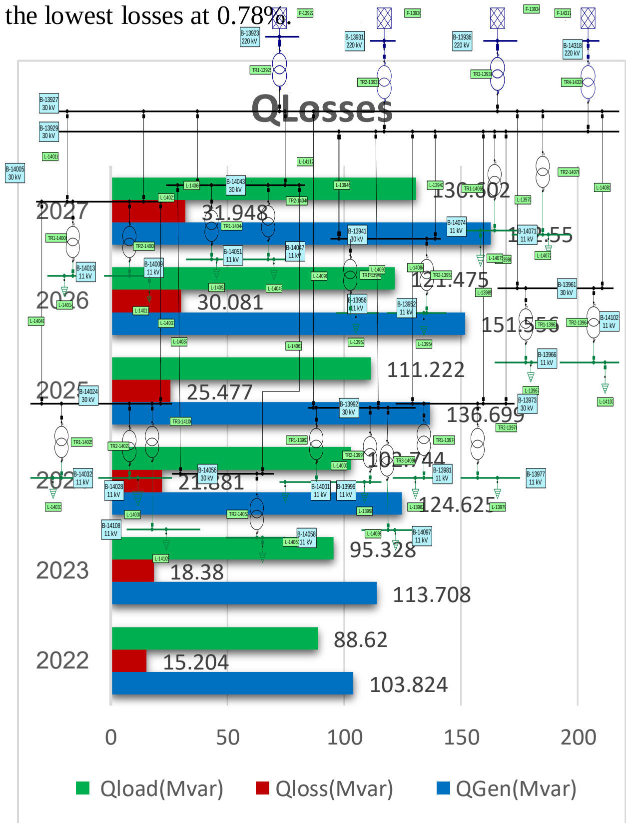

Figure IV. The system power losses in Mvar

The energy losses in reactive power (MVAR) of the system is shown by the above values in Figure (IV). The year 2027 witnessed the largest losses at 19.65%, while 2022 witnessed the smallest losses at 14.64%.

The network for the study's final year (2027) following treatment is displayed in figure (V):

Area/Zone	P loss MW	Q loss MVAR	P Imp MW	Q Imp MVAR	P Gen MW	Q Gen MVAR	P load MW	Q load MVAR
Network	1.139	15.204	119.299	103.824	119.299	103.824	118.16	88.62
Area 1	1.139	15.204	0	0	119.299	103.824	118.16	88.62
Zone 1	1.139	15.204	0	0	119.299	103.824	118.16	88.62
Un	P Loss line	Q Loss line	P Loss Tran	Q Loss Tran				
KV	MW	MVAR	MW	MVAR				
30	0.459	-2.117	0.367	7.34				
220	0	0	0.313	9.982				
Overload								
Element	%	Type						
TR1-140	85.37	2W Tran						
TR1-140	83.92	2W Tran						
TR1-139	80.02	2W Tran						
TR1-139	80.02	2W Tran						

Figure V. The network following treatment for the year 2027

Using power flow calculations and the NEPLAN programmer, this network's analysis for the year 2027 revealed that several transformers in the network are overloaded, as shown in Table (IX):

TABLE IX. System actual load performance for the year 2027.

By studying this network for the year (2027) using power flow calculations using the NEPLAN program, the analysis showed that the network is suffering from an overload in some of transformers overloading at the injection station and ALjamea ALaali station and center Misurata station and main injection substation of Misurata center.

The suggestions made were:

By installing a new transformer (TR4-14320) with a capacity of 100MVA and connecting it to the bus bar (B-13929), the loadability issue in the transformers at the main injection station in the city Centre will be resolved. The transformer (TR1-14006) in ALjamea ALaali station will have its loadability issue resolved by having its 2 MW transferred to the transformer (TR2-14008), which will lessen its load. The transformer (TR1-14069) will have its loadability issue resolved at the main injection station by having its 3MW transferred to the transformer (TR2-14070), which will lessen its load. The network treatment is displayed in Table (X) below:

TABLE X. Performance indexes of the system in 2027

Area/Zone	P loss MW	Q loss MVAR	P Imp MW	Q Imp MVAR	P Gen MW	Q Gen MVAR	P load MW	Q load MVAR
Network	1.806	28.526	175.942	159.128	175.942	159.128	174.136	130.602
Area 1	1.806	28.526	0	0	175.942	159.128	174.136	130.602
Zone 1	1.806	28.526	0	0	175.942	159.128	174.136	130.602
Un	P Loss line	Q Loss line	P Loss Tran	Q Loss Tran				
KV	MW	MVAR	MW	MVAR				
30	0.537	-2.76	0.676	13.499				
220	0	0	0.558	17.787				

The network simulation results for 2027 indicate that loadability problems were resolved and performance improved after treatment, as shown by the above values in table (X).

V. CONCLUSION

This paper presented the modeling and simulation of Misurata central loop medium voltage network. The results of the NEPLAN run were analyzed to check the performance indexes as voltage drop, power losses and loadability. The obtained results were tabulated and recorded. The simulation shows some weak indexes in the studied period and corrections and treatments are made to improve the indexes and the operation of the network. The results obtained were tabulated and recorded. Also, in this research, load forecasts for the next five years (2022-2027) were calculated for the study network. After simulating the network for the years 2022 and 2023 the analysis showed that the network is suffering due to weak feeding sources in some stations, which makes the network's performance unstable and unreliable. Feed sources must be optimized to avoid stations loss during peak hours and improve network reliability and performance. The results of the analysis after studying the network for the years 2024-2027 also showed that the network is suffering from overload on some of the lines feeding it and on some transformers. By increasing the capacity of some cables, distributing loads between transformers, and adding transformers to some stations, loadability problems were resolved and network performance was improved.

REFERENCES

[1] Ashari, M., & Syahputra, R., "Power loss reduction strategy of distribution network with distributed generator integration." The 1st International Conference on Information Technology, Computer, and Electrical Engineering (pp. 404-408). IEEE. (2014).

[2] Abeysinghe, S., Abeysekera, M., Sooriyabandara, M. "Electrical properties of medium voltage electricity distribution networks." CSEE Journal of Power and Energy Systems, 7(3), 497-509, (2020).

[3] Hung, D. Q., & Mithulananthan, N. "Loss reduction and loadability enhancement with DG: A dual-index analytical approach," Applied Energy, 115, 233-241, (2014).

[4] "Design Standards of Libyan network" General Electrical Company of Libya (GECOL).

[5] Kothari, D. P., & Nagrath, I. J,"Power system engineering." New Delhi, India: Tata McGraw-Hill. (2008).

[6] B. Dorin, C. Moldovan, M. Muj a Rotation and M. Muji "Power Engineering Education using NEPLAN software", Universities Power Engineering Conference, UPEC 2008, 43rd International.

[7] Central high voltage circuit, General Electricity Company of Libya.

[8] Central Medium Voltage Management, General Electricity Company of Libya.